I. del: PREGLED HIDROLOŠKIH RAZMER V LETU 2002

Part I: A REVIEW OF HYDROLOGICAL CONDITIONS IN THE YEAR 2002

A. POVRŠINSKE VODE

VODOSTAJI IN PRETOKI REK

Igor Strojan

V celoti je leta 2002 preteklo okoli dvajset odstotkov manj vode kot v dolgoletnem primerjalnem obdobju 1971-2000. Bolj so bila vodnata povodja južne, manj pa vzhodne in severovzhodne Slovenije. V južnem delu Slovenije so pretoki le malo odstopali od dolgoletnih povprečij, v severovzhodni Sloveniji pa so bili tudi do šestdeset odstotkov manjši (v.p. Ledava Polana). Sušne razmere so bile preko celega leta najbolj izrazite v severovzhodni Sloveniji (karta 1). Podobno kot v letu 2001 so tudi leta 2002 izostale običajne spomladanske visoke vode.

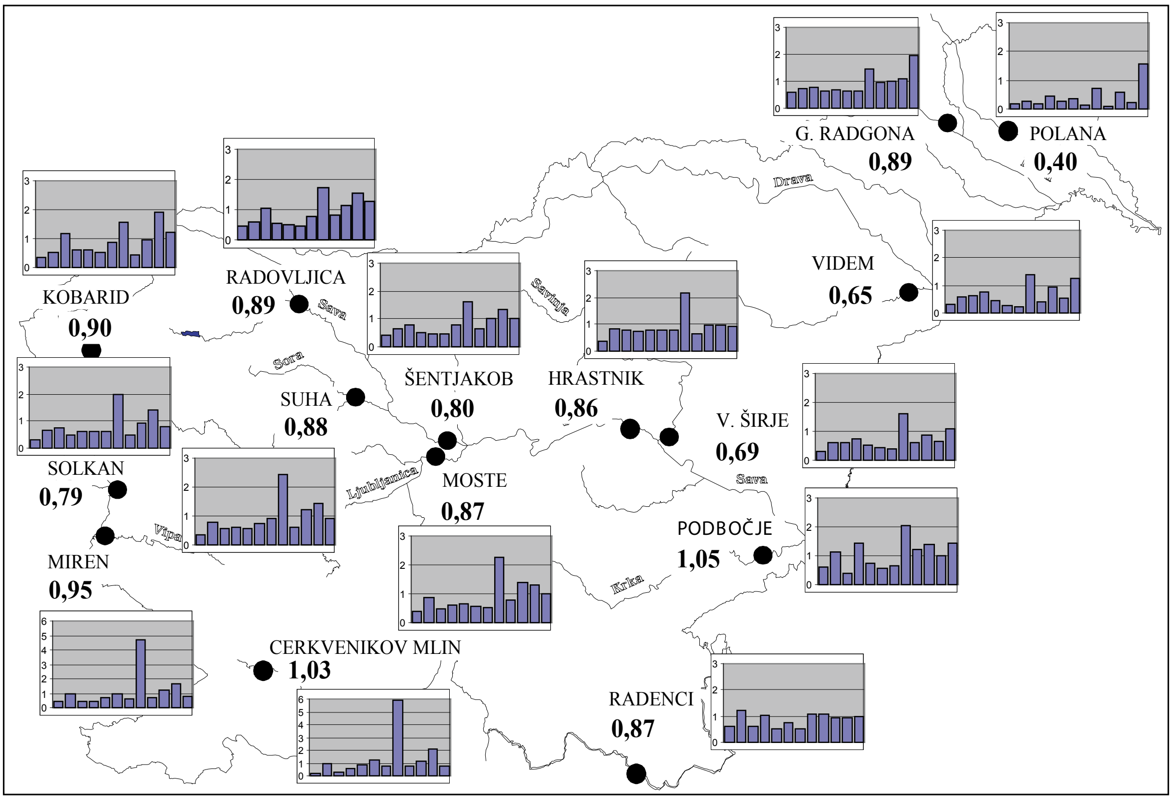
Značilno za leto 2002 je bilo hidrološko suho obdobje, ki je na večini rek trajalo vse od začetka leta do avgusta. Avgusta so bili pretoki rek tudi do šestkrat večji (vodomerna postaja Cerkve-

A. SURFACE WATERS

WATER LEVEL AND RIVER DISCHARGE

Igor Strojan

The annual river discharge of 2002 in Slovenia was around twenty percent lower than the annual flow of the multi-annual comparative period of 1971-2000. Water was more abundant in the catchments of southern Slovenia, while there was less water in the catchments of eastern and north-eastern Slovenia. Discharges in the southern part of Slovenia did not differ much from the multi-annual means, while they were also up to sixty percent lower in the north-eastern part of Slovenia (g.s. Ledava Polana). During the year, drought conditions were most registered in the north-eastern part of Slovenia (Map 1). Like in 2001, the usual high waters in spring again failed to appear in 2002.



Karta 1: Razmerja med srednjimi letnimi pretoki leta 2002 in obdobja 1971-2000 ter grafični prikaz razmerij med srednjimi mesečnimi pretoki leta 2002 in obdobja 1971-2000. Vrednost razmerja 1 pomeni enak pretok leta 2002 kot v povprečju dolgoletnega obdobja.

Map 1: Ratios between the mean annual discharges in 2002 and the period 1971-2000, and a graphic presentation of ratios between the mean monthly discharges in 2002 and the period 1971-2000. The ratio of 1 means that discharge in the year 2002 was the same as the multi-annual mean.

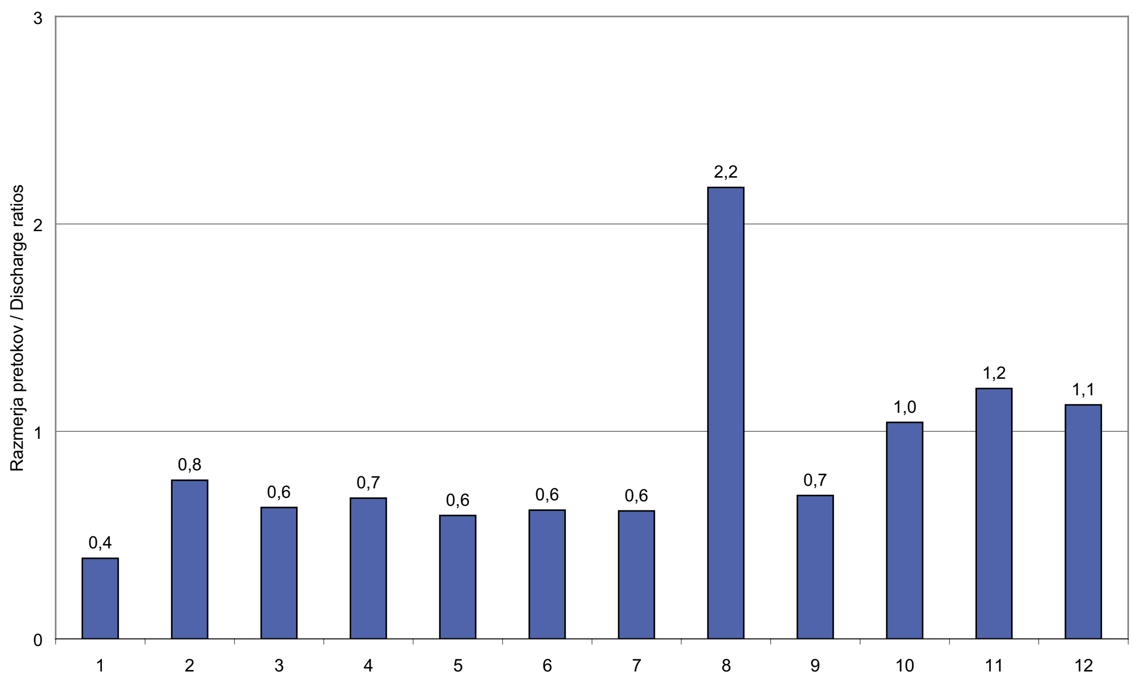
nikov mlin na Reki) kot običajno v tem mesecu. V povprečju so bili pretoki v prvih sedmih mesecih v celoti 40 odstotkov manjši kot v dolgoletnem obdobju. Občasne padavine so hidrološko sušo omilile. Od avgusta dalje je bila vodnatost rek v celoti večinoma višja od dolgoletnih povprečij v posameznih mesecih.

Deleži mesečnih pretokov glede na celoletno količino pretokov, ki sicer na posameznih rekah predstavljajo standardne režime, so bili v celoti v prvih sedmih mesecih leta ter tudi septembra manjši kot v dolgoletnem obdobju 1971-2000 (graf 2). Do celoletne izravnave je prišlo ob povečanih pretokih avgusta, oktobra, novembra in decembra. Odstopanja od ustaljenih režimov rek se kažejo v zelo majhnem deležu pretokov v prvih sedmih mesecih in septembru ter povečanih deležih pretokov v avgustu in zadnjih treh mesecih leta. Najbolj izrazita odstopanja od povprečnih razmer so bila v januarju in avgustu. Januar je imel najmanjši delež v letu in največje negativno odstopanje, avgust pa največje pozitivno odstopanje. V primerjalnem obdobju je bil v avgustu delež pretokov najmanjši.

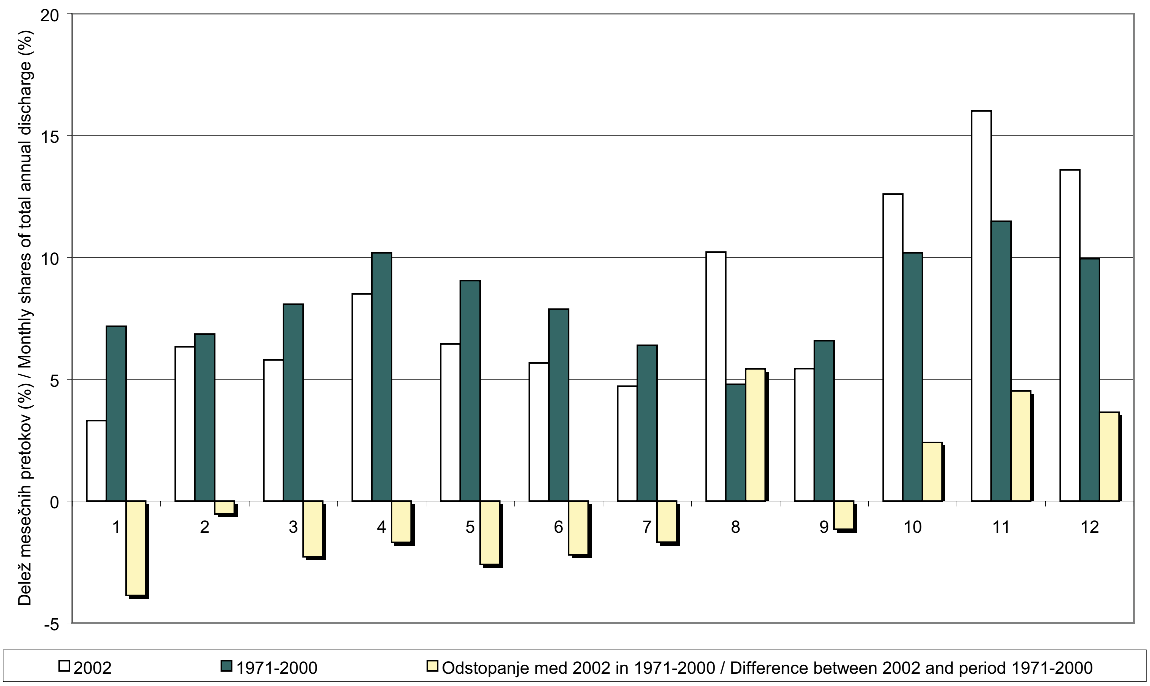
Letni potek pretokov v letu 2002 je najmanj odstopal od ustaljenega režima (obdobje 1971-2000) na Kolpi v Radencih in Savi v Hrastniku. Največje posebnosti v letu 2002 v primerjavi z opazovanim obdobjem so:
- vodomerna postaja Podbočje izstopa po pretokih v aprilu,

Characteristic for the year 2002 was the hydrological dry period, which on most of the rivers lasted from the beginning of the year until August. In August the river discharges were also up to six times greater than is usual for that month (the water gauging station Cerkvenikov mlin on the Reka River). On average, the discharges in the first seven months were 40 percent lower in total than in the multi-annual period. Occasional rainfall mitigated the hydrological drought somewhat. From August onwards, the river discharges were, in total, mostly higher than the multi-annual means in the individual months.

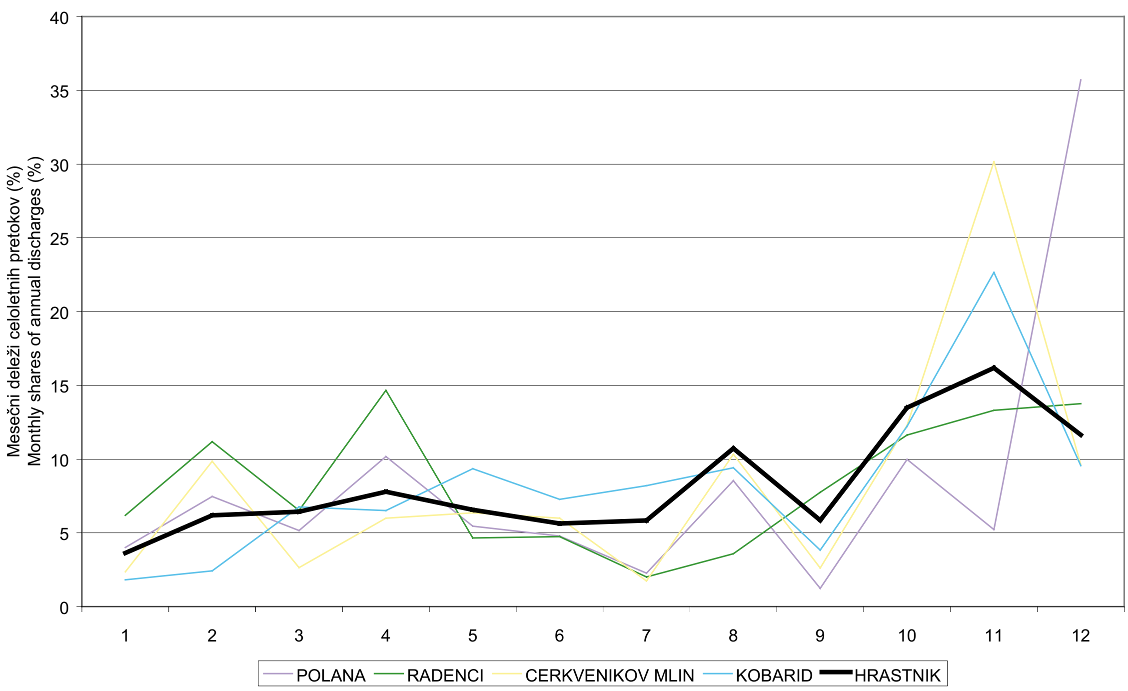
Shares of the monthly discharges according to the yearly amount of discharges, which otherwise represent the standard regimes on the individual rivers were, in the first seven months of the year as well as in September, lower in total than in the multi-annual period 1971-2000 (Graph 2). The yearly balance was accomplished by the increased discharges in August, October, November and December. Differences from the norms are shown by the very small share of discharges in the first seven months and in September, as well as in the increased shares of discharges in August and the last three months of the year. The most significant deviations from the average conditions occurred in January and August. January had the smallest share in the year and the largest negative deviation, while August had the largest positive deviation. In the comparative period, the



Graf 1: Razmerja med srednjimi mesečnimi pretoki v letu 2002 in obdobnimi srednjimi mesečnimi pretoki. Razmerja so izračunana kot povprečja razmerij na izbranih postajah (glej karto1).
Graph 1: Ratios between the mean monthly discharges in 2002 and the comparative period's mean monthly discharges. Ratios are calculated as the mean values of ratios at the chosen stations (see Map 1).



Graf 2: Delež mesečnih pretokov v odstotkih glede na celotno količino pretokov v letu 2002 in obdobju 1971-2000. Na grafu je podano tudi odstopanje deležev mesečnih pretokov v letu 2002 od deležev v 1971-2000.
Graph 2: The share of the monthly discharges in percentages of to the total amount of discharges in the year 2002 and in the period 1971-2000. The graph also shows the deviation of shares in the year 2002 compared with the shares in 1971-2000.



Graf 3: Raztros deležev v posameznih mesecih je največji v zadnjih treh mesecih.
Graph 3: The scattering of shares in individual months was greatest in the last three months.

- pretoki vodomerne postaje Radenci so za razliko od vseh ostalih v avgustu povprečni,
- nadpovprečno visoki pretoki novembra v zahodni Sloveniji
- nadpovprečno visoki pretoki v vzhodni Sloveniji decembra, posebej na vodomerni postaji Polana na Ledavi.

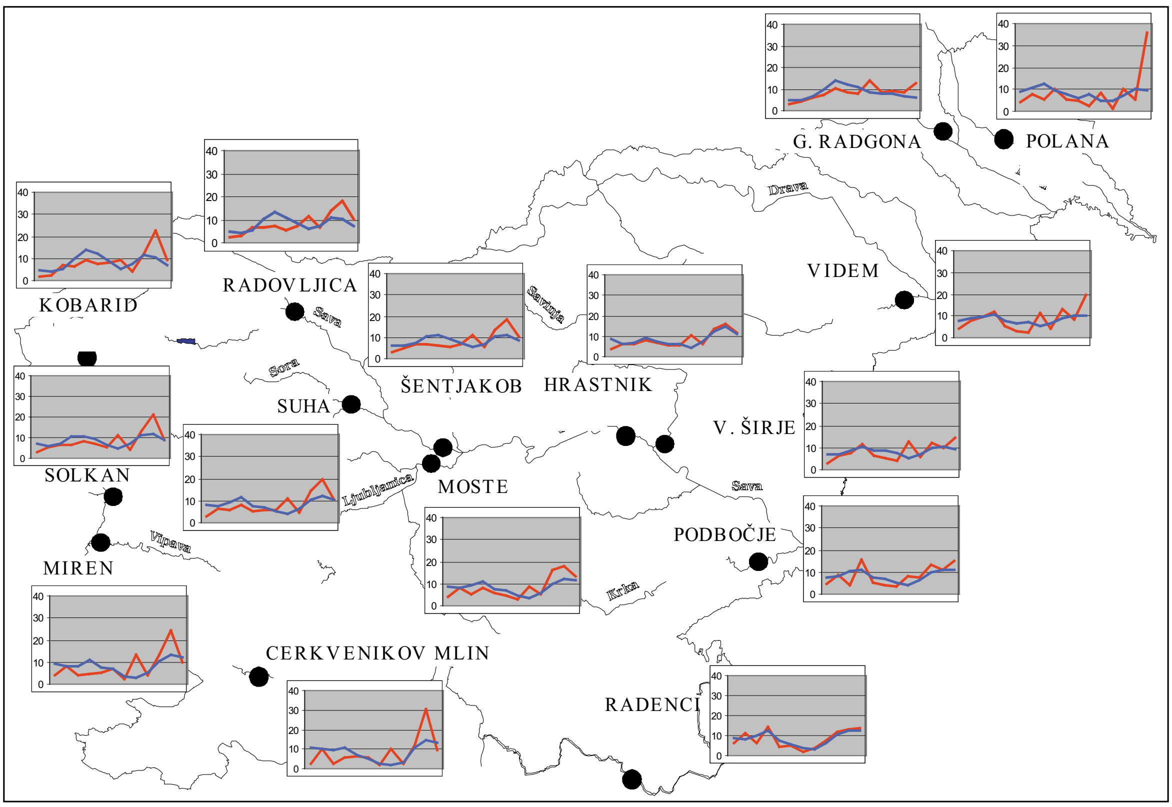
V mesecih avgustu, oktobru, novembru in decembru so bili pretoki rek v povprečju višji kot v dolgoletnem primerjalnem obdobju (graf 2). Tedaj so bile visokovodne konice najvišje in reke so poplavljale, večinoma v območju vsakoletnih poplavnih območjih. V redkih primerih so imele visokovodne konice 5-letno povratno dobo. Dokaj pogosto so poplavljali manjši hudourniki.

Leto 2002 je bilo tretje leto zapored, ko so bile sušne razmere bolj izrazite kot navadno. Najnižji pretoki so dosegali dve- do petletne povratne dobe. Najbolj je bil ogrožen severovzhodni del Slovenije. Sušne razmere so se pričele že v začetku leta oz. so se nadaljevale od konca leta 2001. Prvič so padavine prekinile poglabljanje sušnih razmer februarja, kasneje je bilo sušno stanje prekinjeno aprila. Kratkotrajne padavine maja, junija in julija so nekoliko omilile sušne razmere.

share of discharges in August was the smallest.

The annual course of discharges in the year 2002 had the smallest deviations from the normal regime (the period 1971-2000) on the Kolpa River at Radenci and on the Sava River at Hrastnik. The most distinctive features in the year 2002 compared to the comparative period were:
- the water gauging station Podbočje was exceptional due to the discharges in April,
- the discharges at the water gauging station at Radenci were on average contrary to all the others in August,
- the discharges in western Slovenia in November were above average,
- the discharges in eastern Slovenia in December, especially at the water gauging station Polana on the Ledava River, were above average.

In the months of August, October, November and December the river discharges were, on average, higher than in the multi-annual comparative period (Graph 2). At that time, high-water peaks were highest and rivers overflowed, mostly in the annual flooding areas. In rare cases, the high-water peaks had a 5-year return period with torrents overflowing quite often.



Karta 2: Delež mesečnih pretokov v letu 2002 (rdeče linije) in v obdobju 1971-2000 (modra linija) kot ponazoritev odstopanj v letu 2002.
Map 2: The share of monthly discharges in the year 2002 (red lines) and in the period 1971-2000 (blue line) as an illustration of the deviations in the year 2002.

Časovni pregled hidroloških razmer na rekah v posameznih mesecih leta

Januarja se je na slovenskih rekah nadaljevalo hidrološko sušno obdobje, ki je bilo značilno že za zadnje tri mesece v preteklem letu. Večji del meseca so bili pretoki mali. V povprečju so dosegli 42 odstotkov običajnih pretokov v tem mesecu (karta 2).

Februarja se je po nekajkratnih padavinah hidrološka suša nekoliko omilila. Večji del meseca so bili pretoki med malimi in srednjimi. Pretoki rek so v povprečju dosegli 72 odstotkov običajnih pretokov v tem mesecu.

Marec je bil hidrološko suh mesec, pretoki so se večinoma ves mesec zmanjševali. V povprečju so bili 41 odstotkov manjši kot navadno. Nekoliko ugodnejše so bile razmere na Muri in Dravi, kjer sta bila pretoka le 21 oz. 25 odstotkov manjša kot navadno.

Hidrološka suša se je nadaljevala do konca meseca julija. Občasno so jo prekinile kratkotrajne padavine. V povprečju se je po slovenskih rekah pretakala le polovica običajne količine vode.

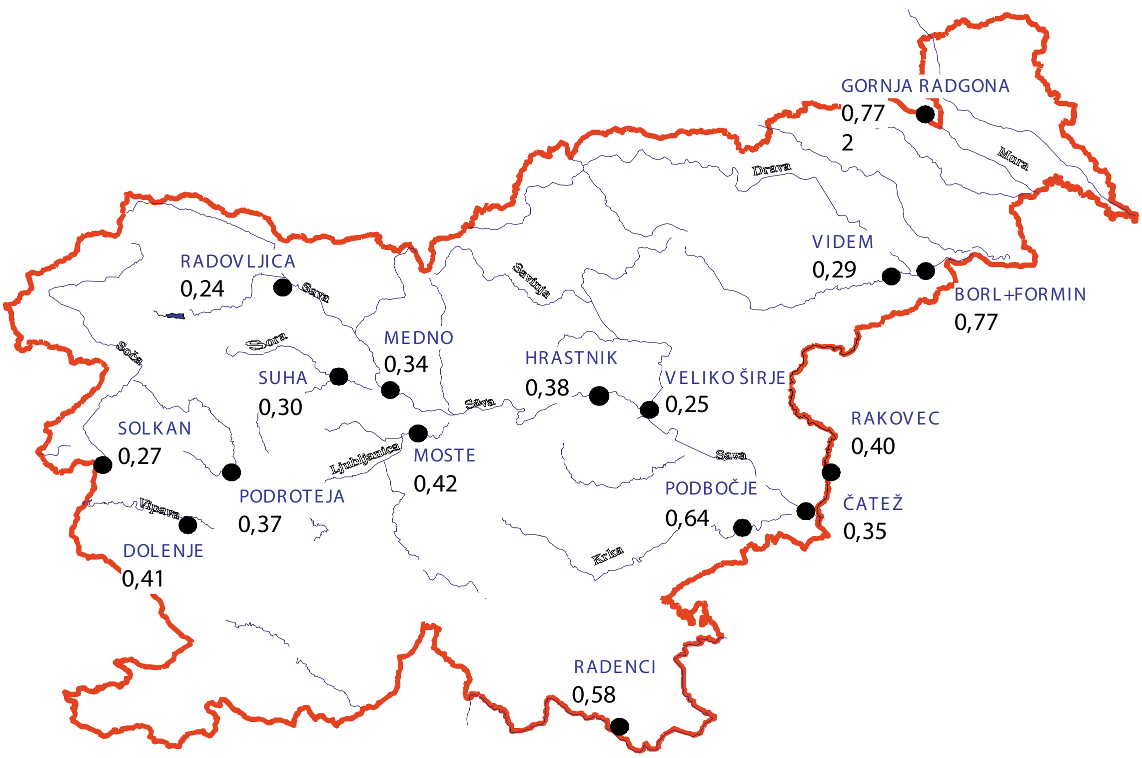
Po večmesečnem hidrološko sušnem obdobju so bili pretoki rek v avgustu nadpovprečni. Večji so bili v prvi polovici meseca, ko so se v dveh

The year 2002 was the third year in a row with more significant drought conditions than usual. The lowest discharges reached two- to five-year return periods. The north-eastern part of Slovenia was under the greatest threat. Drought conditions had already begun at the beginning of the year, i.e. continuing from the end of 2001. For the first time, rainfall brought the deepening of drought conditions to an end in February. The drought situation was interrupted again in April. The short-lasting rainfall in May, June and July also mitigated the drought conditions to some extent.

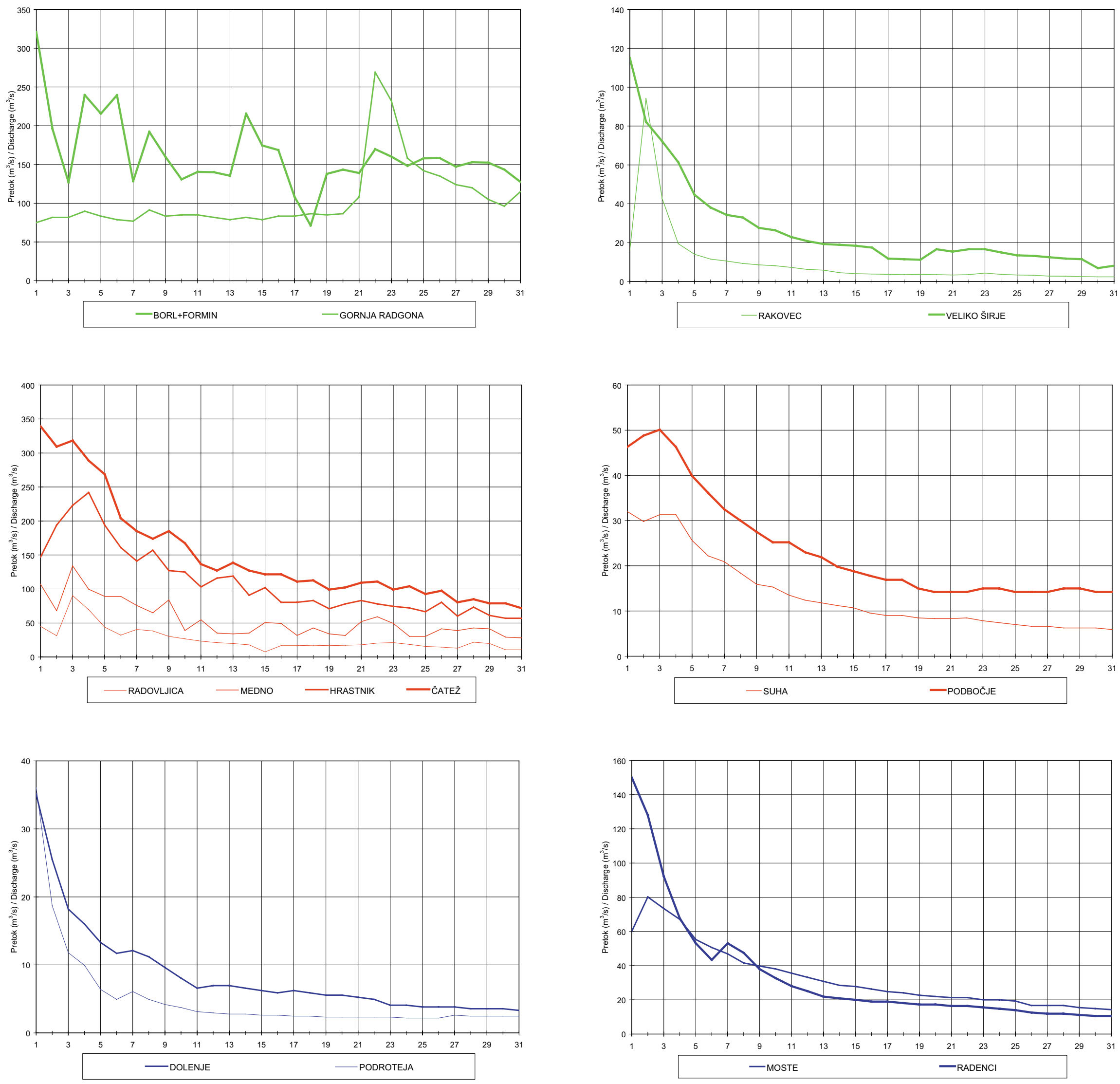
A Timeline of the Hydrological Conditions on Rivers in the Individual Months of the Year

In January, the hydrological dry period on Slovenian rivers, which had been characteristic for the last three months of the previous year, continued. For the majority of the month, discharges remained low. On average, they reached 42 percent of the usual discharges for that month (Map 2).

In February, the hydrological drought was mitigated to some extent after several occurrences of rainfall. For the majority of the month, the discharges were between low and mean levels. River discharges, on average, reached 72 percent of the usual discharges for that month.



Karta 3: Razmerja med srednjimi pretoki januarja 2002 in povprečnimi srednjimi januarskimi pretoki v obdobju 1961-1990 na slovenskih rekah.
Map 3: The ratios between the mean discharges in January 2002 and the average mean discharges on Slovenian rivers in January in the period 1961-1990.



Graf 4: Pretoki izbranih rek marca 2002.
Graph 4: The discharges of selected rivers in March 2002.

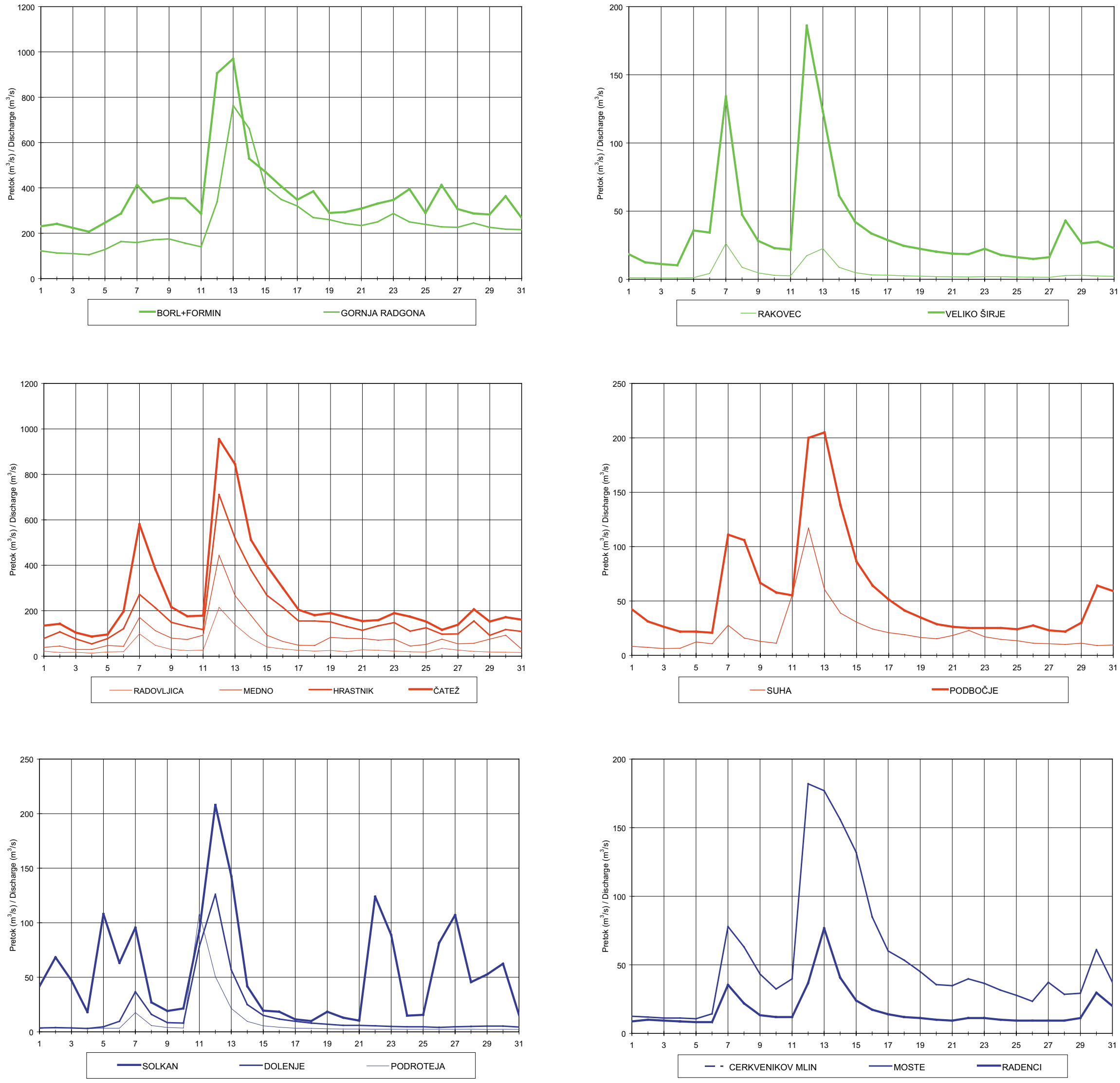
nekajdnevnih padavinskih obdobjih povečali tudi do velikih vrednosti. V drugi polovici meseca so se pretoki večinoma zmanjševali. Manjši porasti v tem obdobju so bili posledica občasnih ploh in neviht. V celoti so bili pretoki 50 odstotkov večji kot navadno.

Septembra so bili pretoki rek v večjem delu države manjši kot običajno, z izjemo rek v južni Sloveniji in Mure, ki se večinoma napaja v sosednji Avstriji. Krajevne padavine v prvem delu meseca so le malo spreminjale male do srednje pretoke rek. Ti so se večinoma zmanjševali vse do 21. septembra, ko se je pričelo nekajdnevno obdobje obilnih padavin. Tedaj so se ponekod pretoki povečali tudi do velikih vrednosti in se do konca meseca zmanjšali na raven obdobja pred padavinami.

March was a hydrologically dry month, since discharges mostly decreased throughout the month. On average, they were 41 percent lower than usual. The conditions on the Mura and Drava Rivers were somewhat more favourable however, where the discharges were only 21 and 25 percent lower than usual.

The hydrological drought continued until the end of July, occasionally interrupted by short-term rainfall. On average, only half of the usual amount of water was flowing in the rivers of Slovenia.

After several months of the hydrological dry period, the river discharges in August were above average. They were greater in the first half of the month, increasing to very high values during two periods of rainfall lasting several days. In the second half of the month, discharges mainly decreased. The



Graf 5: Pretoki izbranih rek avgusta 2002
Graph 5: The discharges of selected rivers in August 2002.

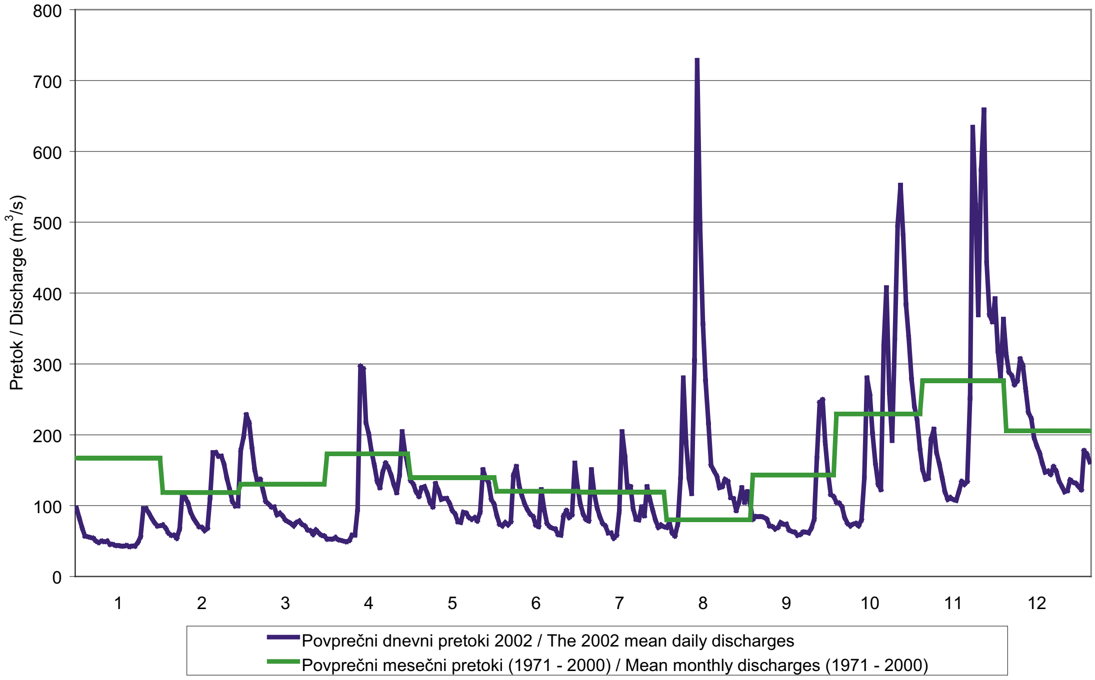
Do četrtega oktobra se je hidrološko suho obdobje nadaljevalo še iz septembra. Pretoki so se postopoma zmanjševali. V naslednjih dneh so padavine le malo povečale pretoke. Ti so se kasneje izraziteje povečali v treh visokovodnih obdobjih do konca meseca. V prvem porastu rek, od 11. do 13. oktobra, se je najbolj povečal pretok Krke, v drugem, od 18. do 19. oktobra, so bili pretoki največji na Savi v zgornjem toku, Muri, Soči in Kolpi. Pri tretjem porastu rek, ob tridnevnih padavinah, od 22. do 25. oktobra, je bilo povečanje pretokov najbolj obširno, obilno in dolgotrajno. V splošnem so bili pretoki rek oktobra večji kot navadno.

Tudi v novembru so bili pretoki večji od povprečja, predvsem zaradi visokih voda v drugi polovici meseca. Daljša padavinska obdobja so do velikih vrednosti povečevala predvsem pretoke večjih rek Drave, Save, Ljubljanice in Krke.

small increases during this period were caused by occasional rain showers and storms. In total, the discharges were 50 percent greater than usual.

In September, river discharges in the majority of the country were lower than usual, with the exception of rivers in southern Slovenia and of the Mura River, which has headwaters in the neighbouring Austria. Local rainfall in the first part of the month had only slight influence on the low to mean discharges of the rivers. These mainly decreased until the 21st September, when a period of several days of abundant rainfall began. At that time, the discharges in some areas increased to great values, later decreasing until the level of the period before the rainfall by the end of the month.

The hydrological dry period in September continued until the 4th October. The discharges were gradually decreasing and the rainfall in the follow-



Graf 6: Srednji dnevni pretoki v letu 2002 in srednji mesečni pretoki v dolgoletnem obdobju 1961-1990 na Savi v Hrastniku.
Graph 6: The mean daily discharges in the year 2002 and the mean monthly discharges in the multi-annual period 1961-1990 on the Sava River at Hrastnik.

Pretoki so bili decembra v povprečju večji kot navadno. Večina povprečnih decembrskih pretokov rek je le malo odstopala od dolgoletnih povprečij. Pretoki so bili decembra v celoti nadpovprečni zaradi velikih pretokov Mure, Drave, Sotle in Krke. Večji kot navadno so bili predvsem pretoki rek v severovzhodni Sloveniji. Posebej je izstopala Ledava, ki je imela za tretjino večji pretok od povprečnega.

Selška Sora pri vodomerni postaji Vešter 1. oktrobra 2002. (foto: Vinko Bogataj)
The Selška Sora river at the gauging station Vešter on the 1st October 2002.
(photo: Vinko Bogataj)

ing days increased the discharges only by little. These were later increased more significantly during the three high-water periods occurring before the end of the month. During the first rise of the rivers, from the 11th to the 13th October, the discharge of the Krka River increased most significantly, while during the second, from the 18th to the 19th October, the discharges were greatest in the upper stream of the Sava River, as well as on the Mura, Soča and Kolpa Rivers. During the third rise from 22nd to the 25th October, following a three-day rainfall, the increase of discharges was the most extensive, abundant and long-lasting. Generally, the river discharges in October were greater than usual.

Discharges were also higher than average in November, especially due to the high waters in the second half of the month. Longer periods of rainfall increased the discharges of large rivers such as the Drava, Sava, Ljubljanica and Krka to great values.

On average, the discharges in December were higher than usual, however, the majority of river discharges in December varied only slightly from the multi-annual means. Discharges in December were above average in total due to the great discharges of the Mura, Drava, Sotla and Krka Rivers. The discharges of rivers in north-eastern Slovenia were especially higher than usual. The Ledava River especially was exceptional, since it had a discharge one-third higher than average.

Primerjava značilnih pretokov

Najmanjši pretoki v letu 2002 so bili v povprečju devet odstotkov manjši kot v primerjalnem dolgoletnem obdobju. Pretoki rek so bili najmanjši v več različnih nekajdnevnih obdobjih vse do sredine septembra (preglednica 1). Že v januarju so bili doseženi najmanjši pretoki leta na Muri v Gornji Radgoni, Savi v Šentjakobu in Hrastniku ter na Soči v Kobaridu in Solkanu, kot nadaljevanje sušnega obdobja iz konca leta 2001. Glede na dolgoletno primerjalno obdobje so bili ti pretoki okoli dvajset odstotkov manjši kot navadno. Na Savi v Radovljici je bil najmanjši pretok petega februarja, na Sori v Suhi pa osmega aprila. Na Savinji v Velikem Širju je bil letni minimum 24. junija. Na koncu hidrološko sušnega obdobja so bili pretoki najmanjši v letu na Dravinji v Vidmu (11. julija), Krki v Podbočju (13. julija) ter Vipavi v Mirnu (31. julija). Najmanjši od omenjenih treh pretokov je bil pretok na Dravinji, ki je bil kar 55 odstotkov manjši kot navadno. Ljubljanica v Mostah je imela najmanjši pretok 3. avgusta. Ledava v Polani, Kolpa v Radencih in Reka pri Cerkvenikovem mlinu so imele najmanjše pretoke septembra. Na omenjenih rekah so bili porasti pretokov v avgustu manj izraziti. Na Ledavi je bil najmanjši pretok 55 odstotkov manjši kot v dolgoletnem primerjalnem obdobju. Najdaljše in najbolj izrazito sušno obdobje leta 2002 je bilo na Dravinji in Ledavi.

Srednji letni pretoki rek so bili v povprečju okoli dvajset odstotkov manjši kot v dolgoletnem primerjalnem obdobju. Pretoki v severovzhodni Sloveniji so bili med najmanjšimi v primerjalnem obdobju. Srednji letni pretok Ledave v Polani je bil 60 odstotkov manjši kot v dolgoletnem primerjalnem obdobju.

Tudi **največji pretoki** so bili okoli 20 odstotkov manjši kot v dolgoletnem obdobju. Nekoliko večje kot navadno so bile le visokovodne konice na Muri v Gornji Radgoni, Vipavi v Mirnu ter na Krki v Podbočju. Vsi ostali največji pretoki v letu so bili manjši od dolgoletnega povprečja največjih letnih pretokov. Ti so bili v veliki večini največji v zadnjih treh mesecih leta. Najbolj izrazite visokovodne konice so bile od 19. do 22. novembra. Na Savinji v Velikem Širju ter na Muri v Gornji Radgoni so bili pretoki avgusta največji v letu.

A Comparison of Characteristic Discharges

The lowest discharges in the year 2002 were on average nine percent lower than in the comparative multi-annual period. River discharges were lowest on a number of different multi-day periods lasting until the middle of September (Table 1). Already in January, the lowest discharges were reached on the Mura River at Gornja Radgona, on the Sava River at Šentjakob and Hrastnik, and on the Soča River at Kobarid and Solkan, a continuation of the dry period from the end of the year 2001. Compared to the multi-annual comparative period, these discharges were around twenty percent lower than usual. The lowest discharge was registered on the Sava River at Radovljica on the 5th February, while on the Sora River at Suha it occurred on the 8th April. On the Savinja River at Veliko Širje the annual minimum was registered on the 24th June. At the end of the hydrological dry period, the lowest discharges of the year were reached on the Dravinja River at Videm (11th July), the Krka River at Podbočje (13th July) and the Vipava River at Miren (31st July). The lowest of these three discharges was the discharge on the Dravinja River, which was as much as 55 percent lower than usual. The Ljubljanica River at Moste had the lowest discharge on the 3rd August and the Ledava River at Polana, the Kolpa River at Radenci and the Reka River at Cerkvenikov mlin all had the lowest discharges in September. On these rivers, the discharge increases in August were less significant. On the Ledava River, the lowest discharge was 55 percent lower than in the multi-annual comparative period. The longest and most significant dry period in the year 2002 was on the Dravinja and Ledava Rivers.

The mean annual discharges were on average around twenty percent lower than in the multi-annual comparative period. Discharges in north-eastern Slovenia were among the lowest in the comparative period. The mean annual discharge of the Ledava River at Polana was 60 percent lower than in the multi-annual comparative period.

Also the **maximum discharges** were around 20 percent lower than in the multi-annual period. Only the high-water peaks on the Mura River at Gornja Radgona, the Vipava River at Miren and the Krka River at Podbočje were somewhat greater than usual. All the year's other maximum discharges were lower than the multi-annual mean. The great majority of these were highest in the last three months of the year. The most significant high-water peaks occurred during the 19th to the 22nd November. On the Savinja River at Veliko Širje and on the Mura River at Gornja Radgona, the discharges in August were the highest for the year.

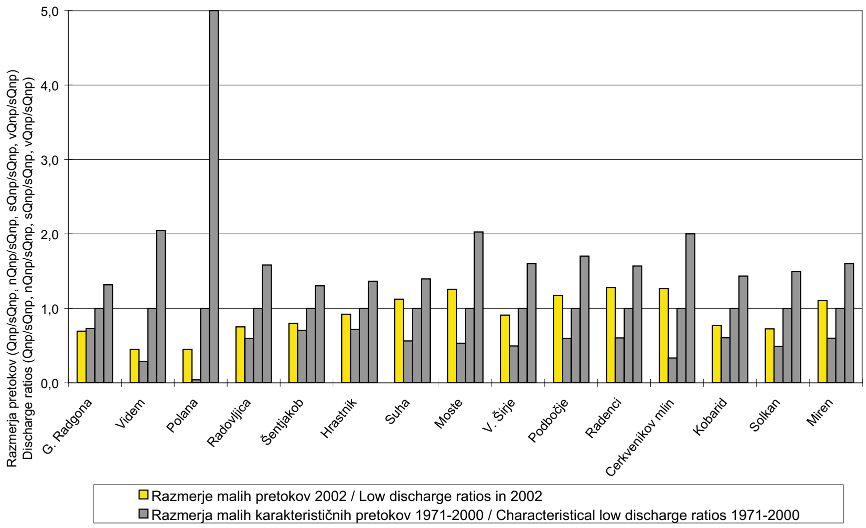
Preglednica 1: Značilni pretoki v letu 2002 in v obdobju 1971-2000.
Table 1: Characteristic discharges in the year 2002 and in the period 1971-2000.

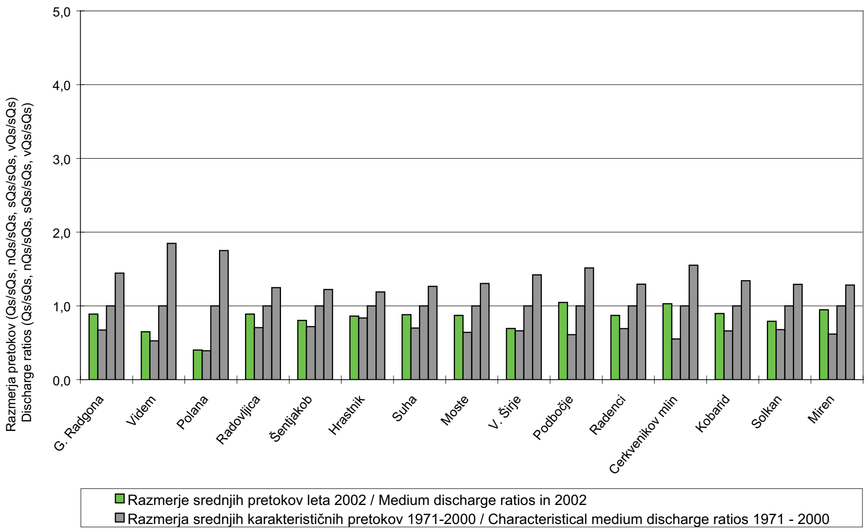
VODOTOK STREAM	POSTAJA GAUGING STATION	**Qnp**		nQnp	sQnp	vQnp
		2002		1971-2000		
		m3/s	dan/day	m3/s	m3/s	m3/s
MURA	GORNJA RADGONA	43,1	10.01.	45,3	62,1	81,7
DRAVINJA	VIDEM	0,9	13.07.	0,6	2,1	4,3
LEDAVA	POLANA	0,05	12.09.	0,004	0,1	0,5
SAVA	RADOVLJICA	6,3	05.02.	5,0	8,4	13,3
SAVA	ŠENTJAKOB	21,7	08.01.	19,1	27,1	35,3
SAVA	HRASTNIK	42,0	20.01.	32,8	45,6	62,2
SORA	SUHA	4,3	08.04.	2,1	3,8	5,3
LJUBLJANICA	MOSTE	9,7	03.08.	4,1	7,7	15,6
SAVINJA	VELIKO ŠIRJE	8,7	24.06.	4,7	9,5	15,2
KRKA	PODBOČJE	12,2	11.07.	6,2	10,4	17,7
KOLPA	RADENCI	7,4	18.09.	3,5	5,8	9,1
REKA	CERKVENIKOV MLIN	0,8	19.09.	0,2	0,6	1,2
SOČA	KOBARID	5,8	13.01.	4,6	7,6	10,9
SOČA	SOLKAN	14,2	16.01.	9,6	19,6	29,3
VIPAVA	MIREN	2,2	31.07.	1,2	2	3,2

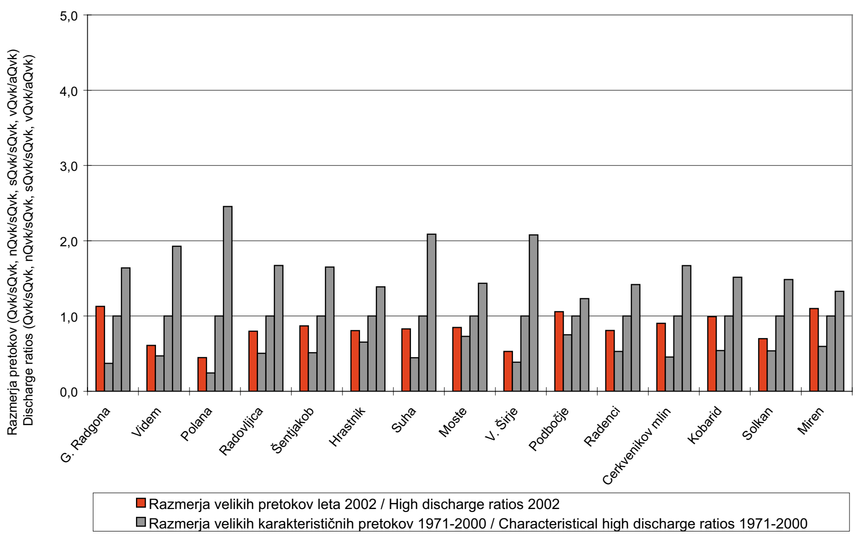
VODOTOK STREAM	POSTAJA GAUGING STATION	**Qs**	nQs	sQs	vQs
		2002	1971-2000		
		m3/s	m3/s	m3/s	m3/s
MURA	GORNJA RADGONA	136	103	153	221
DRAVINJA	VIDEM	7,3	5,9	11,2	20,7
LEDAVA	POLANA	0,54	0,47	1,2	2,1
SAVA	RADOVLJICA	38,3	30,4	43,1	53,8
SAVA	ŠENTJAKOB	68,4	61,2	85,1	104
SAVA	HRASTNIK	136	132	158	188
SORA	SUHA	17,0	13,5	19,3	24,4
LJUBLJANICA	MOSTE	48,4	35,7	55,6	72,5
SAVINJA	VELIKO ŠIRJE	30,5	29,2	44	62,5
KRKA	PODBOČJE	54,3	31,7	51,9	78,6
KOLPA	RADENCI	44,2	35,1	50,7	65,6
REKA	CERKVENIKOV MLIN	8,0	4,3	7,8	12,1
SOČA	KOBARID	29,7	21,9	33,1	44,4
SOČA	SOLKAN	71,1	60,9	89,8	116
VIPAVA	MIREN	16,4	10,7	17,3	22,2

VODOTOK STREAM	POSTAJA GAUGING STATION	**Qvk**		nQvk	sQvk	vQvk
		2002		1971-2000		
		m3/s	dan/day	m3/s	m3/s	m3/s
MURA	GORNJA RADGONA	829	14.08.	273	735	1205
DRAVINJA	VIDEM	92,0	06.12.	71,1	151	291
LEDAVA	POLANA	14,7	06.12.	8	32,8	80,5
SAVA	RADOVLJICA	328	19.11.	208	411	687
SAVA	ŠENTJAKOB	749	22.11.	442	861	1422
SAVA	HRASTNIK	969	22.11.	786	1202	1668
SORA	SUHA	273	22.11.	147	329	687
LJUBLJANICA	MOSTE	239	24.10.	206	282	405
SAVINJA	VELIKO ŠIRJE	380	11.08.	278	717	1490
KRKA	PODBOČJE	306	07.12.	217	289	356
SOČA	KOBARID	541	13.04.	355	669	949
KOLPA	RADENCI	165	19.11.	83,3	182	305
REKA	CERKVENIKOV MLIN	434	18.10.	237	438	664
SOČA	SOLKAN	973	19.11.	747	1391	2066
VIPAVA	MIREN	264	22.11.	143	240	319

Qnp	**najmanjši pretok v letu - dnevno povp.**	**Qnp**	**the minimum discharge in the year – daily average**
nQnp	najmanjši mali pretok v obdobju	nQnp	the minimum low discharge in the period
sQnp	srednji mali pretok v obdobju	sQnp	the mean low discharge in the period
vQnp	največji mali pretok v obdobju	vQnp	the maximum low discharge in the period
Qs	**srednji pretok v letu - dnevno povprečje**	**Qs**	**the mean discharge in the year – daily average**
nQs	najmanjši srednji pretok v obdobju	nQs	the minimum mean discharge in the period
sQs	srednji pretok v obdobju	sQs	the mean discharge in the period
vQs	največji srednji pretok v obdobju	vQs	the maximum mean discharge in the period
Qvk	**največji pretok v letu - konica**	**Qvk**	**the maximum discharge in the year – peak**
nQvk	najmanjši veliki pretok v obdobju	nQvk	the minimum high discharge in the period
sQvk	srednje veliki pretok v obdobju	sQvk	the mean high discharge in the period
vQvk	največji veliki pretok v obdobju	vQvk	the maximum high discharge in the period







Graf 7: Razmerja malih, srednjih in velikih pretokov v letu 2002 ter razmerja karakterističnih pretokov obdobja 1971-2000. Vrednosti so relativne glede na srednje vrednosti malih, srednjih in velikih obdobnih pretokov.
Graph 7: The ratios of minimum, mean and maximum discharges in the year 2002, as well as the ratios of characteristic discharges in the period 1971-2000. The values are relative according to the mean values of the low, medium and high discharges for the period.

TEMPERATURE REK IN JEZER

Barbara Vodenik

Leta 2002 je bila povprečna temperatura Mure, Save, Kamniške Bistrice, Ljubljanice, Krke in Soče pol stopinje Celzija (°C) višja, povprečna temperatura Blejskega in Bohinjskega jezera pa 0.9 °C višja kot v večletnem primerjalnem obdobju. Odstopanje od večletnega povprečja je bilo posebej izrazito v juniju, ko je povprečna temperatura rek presegla dolgoletno povprečje za 1.7 °C, povprečna temperatura jezer pa za 3.0 °C.

Časovno spreminjanje temperatur rek

Temperaturna nihanja so bila najbolj izrazita na Krki in Muri (graf 8), pri katerih temperatura vode zaradi dolgega in relativno počasnega toka najbolj sledi spremembam temperature zraka. Obe reki sta bili v poletnih mesecih v povprečju tudi najtoplejši. Drugačne so bile razmere na Kamniški Bistrici, ki je med najhladnejšimi slovenskimi rekami, temperaturna nihanja pa so najmanj izrazita.

Temperature rek so nekoliko narasle ob koncu januarja, v februarju pa so bile razmeroma ustaljene. V drugi polovici marca in v začetku aprila je mogoče opaziti dve kratkotrajni povišanji temperature, sicer pa so se reke znatno ogrele šele v maju. V drugi polovici junija so dosegle najvišje vrednosti, ki so se z večjimi ali manjšimi nihanji ponavljale vse do sredine poletja. V prvem tednu avgusta je mogoče opaziti hiter padec in nato proti koncu meseca ponoven porast temperature vode. Znatna ohladitev je sledila šele v drugi polovici septembra, nakar je do konca leta sledil padajoči trend temperatur.

Časovno spreminjanje temperatur jezer

Letni potek temperatur Blejskega in Bohinjskega jezera je bil zelo podoben rekam, le da so bila kratkotrajna nihanja manj izrazita, kar velja še posebej za Blejsko jezero (graf 9). Bohinjsko jezero je bilo vse leto hladnejše in sicer v celoletnem povprečju za 3.4 °C.

Jezeri sta se od januarja do junija segrevali, ko sta na začetku poletja dosegli letni maksimum, potem sta se do konca leta ohlajali.

Primerjava značilnih temperatur rek in jezer z večletnim obdobjem

Januarja 2002 so bile povprečne temperature rek nižje kot navadno. Povprečna temperatura je bila 3.8 °C, kar je za 0.9 °C manj kot v primerjalnem obdobju. Februarja in marca je bila povprečna

THE TEMPERATURES OF RIVERS AND LAKES

Barbara Vodenik

In 2002 the mean temperature of the Mura, Sava, Kamniška Bistrica, Ljubljanica, Krka and Soča rivers were half a degree (°C) higher, and the mean temperature of Bled and Bohinj lakes was 0.9 °C higher than in the multi-annual comparative period. Deviation from the multi-annual mean was especially large in June, when the mean temperature of the rivers exceeded the multi-annual mean by 1.7 °C, while the mean temperature of the lakes exceeded it by 3.0 °C.

Timeline of River Temperature Changes

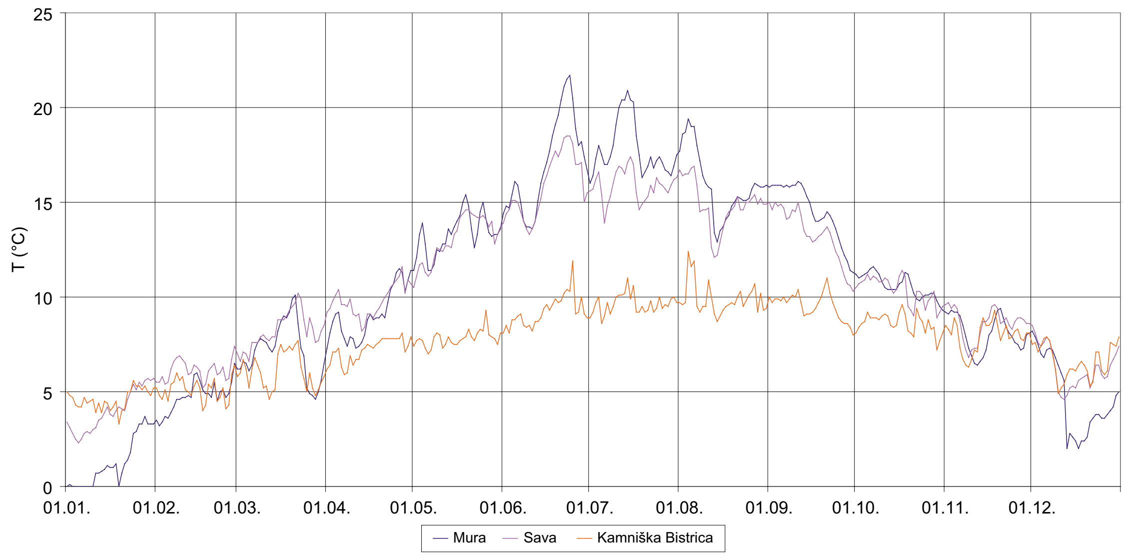
The temperature fluctuations were most significant on the Krka and Mura rivers (Graph 8), where the temperature of the water closely follows the changes of air temperature due to the long and relatively slow current. During the summer months both rivers were also the warmest on average. Conditions proved different on the Kamniška Bistrica, which is among the coldest Slovenian rivers and where temperature fluctuations are the least extreme.

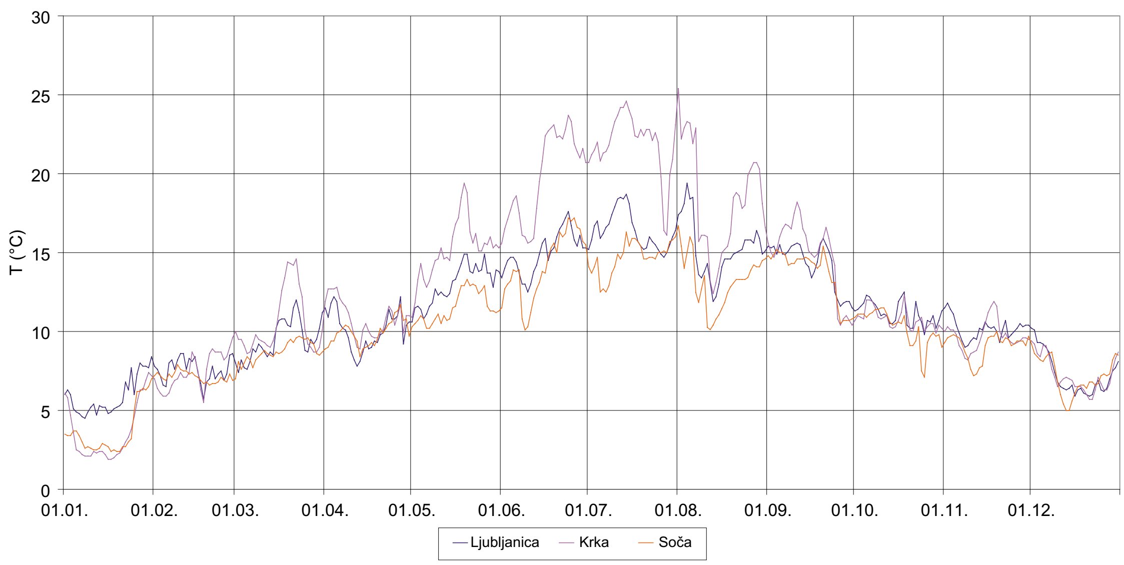
The temperatures of the rivers increased to some extent at the end of January, while the conditions in February were relatively stable. In the second half of March and the beginning of April, two brief rises of temperature can be seen, with the rivers otherwise only becoming substantially warmer in May. In the second half of June they reached the highest values, which reoccurred with greater or lesser fluctuations until the middle of summer. In the first week of August a rapid drop can be seen and then a repeated rising of water temperatures towards the end of the month. A substantial cooling followed only in the second half of September, followed by a trend of falling temperatures until the end of the year.

A Timeline of Lake Temperature Changes

The annual course of temperatures for Bled and Bohinj lakes is very similar to that of the rivers; only that the short-lasting fluctuations were less explicit. This is especially true for Lake Bled (Graph 9). Lake Bohinj was colder throughout the year, resulting in a 3.4 °C lower annual mean.

The lakes warmed from January through to June, reaching the annual maximum temperature at the beginning of the summer and afterwards cooling until the end of the year.



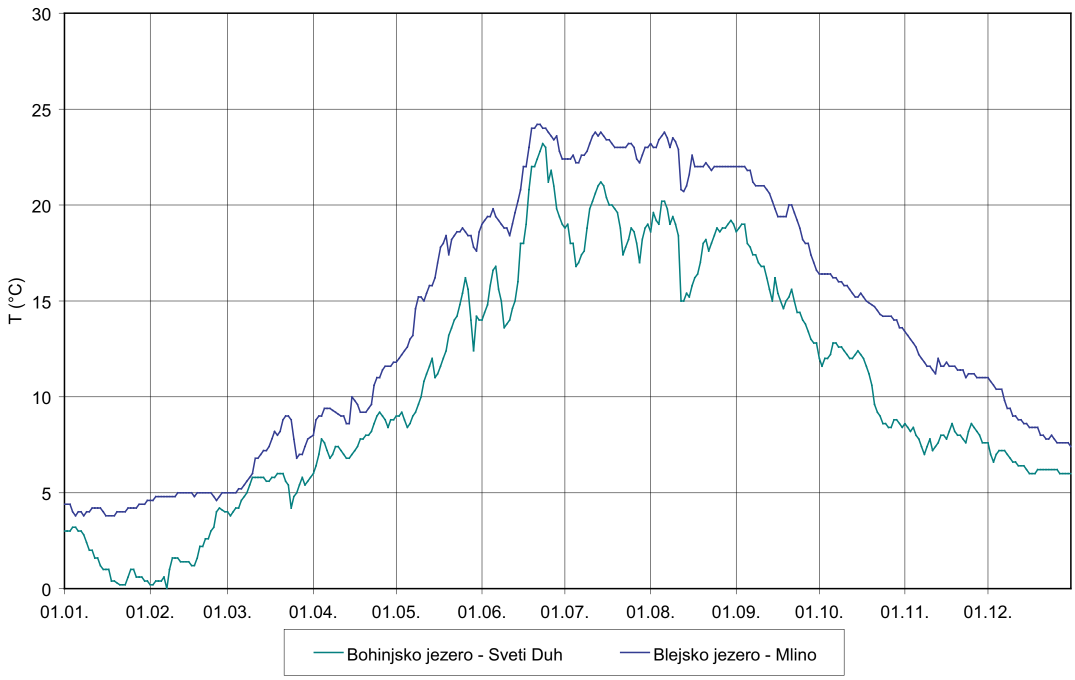


Graf 8: Temperaturna nihanja slovenskih rek leta 2002: Mura v Gornji Radgoni, Sava v Šentjakobu, Kamniška Bistrica v Kamniku, Ljubljanica v Mostah, Krka v Podbočju in Soča v Solkanu.
Graph 8: The temperature fluctuations of Slovenian rivers in 2002: the Mura River at Gornja Radgona, the Sava River at Šentjakob, the Kamniška Bistrica at Kamnik, the Ljubljanica River at Moste, the Krka River at Podbočje and the Soča River at Solkan.

temperatura rek 6.4 oz. 8.3 °C in so bile 1.1 oz. 1.3 °C toplejše kot v večletnem primerjalnem obdobju. Tudi v aprilu in maju so bile povprečne temperature višje kot navadno. Največje odstopanje od dolgoletnega povprečja je bilo v juniju, ko so bile povprečne mesečne temperature kar za 1.7 °C višje kot v primerjalnem obdobju. Povprečne temperature rek so dosegle najvišje vrednosti v juliju, ko so imele temperaturo 16.1 °C. Avgusta so se temperature izrazito znižale. Reke so se ohladile pod povprečno avgustovsko vrednost za 1.1 °C. Povprečna temperatura je znašala 14.6 °C. September je bil temperaturno podoben obdobnemu povprečju, oktobra pa so se temperature povprečno znižale za 0.4 °C pod obdo-

Comparison of the Characteristic Temperatures of Rivers and Lakes with the Multi-Annual Period

In January 2002 the mean temperature of the rivers were lower than usual. The mean temperature was 3.8 °C, which is 0.9 °C less than in the multi-annual comparative period. In February and March the mean temperature of rivers was 6.4 °C and 8.3 °C, being 1.1 °C and 1.3 °C warmer than in the comparative period. Also in April and May, the mean temperatures were higher than usual. The largest deviation from the multi-annual mean was in June, when the mean monthly temperatures were as much as 1.7



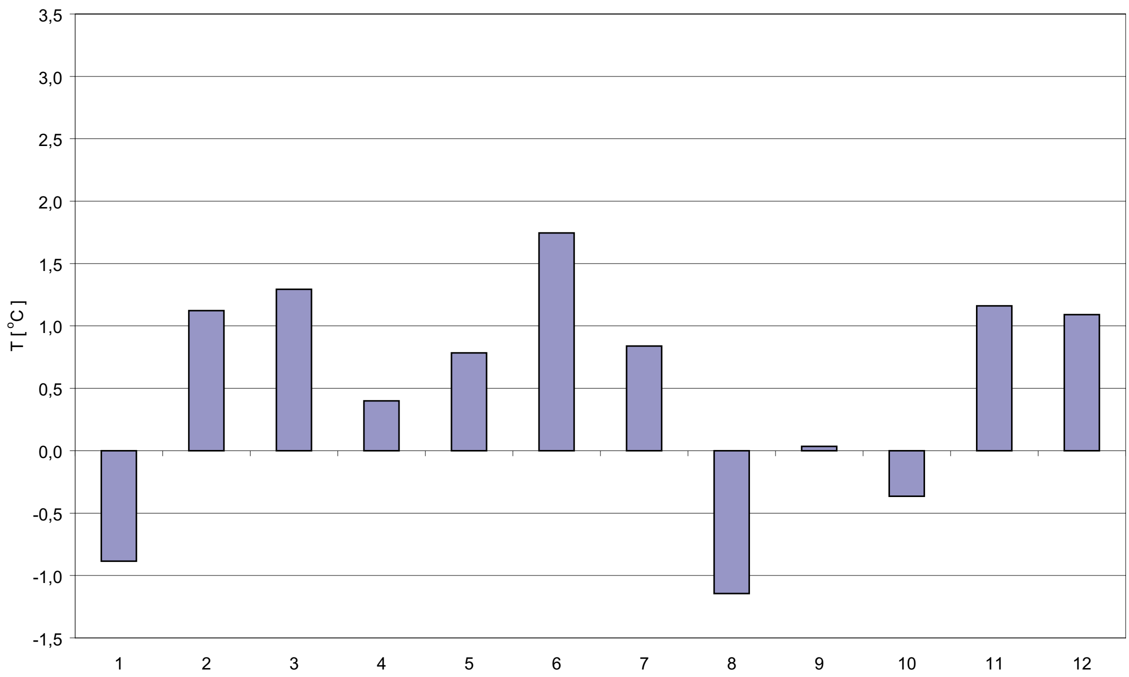
Graf 9: Temperaturna nihanja Blejskega in Bohinjskega jezera leta 2002.
Graph 9: The temperature fluctuations of Bled and Bohinj lakes in 2002.

bno povprečje. Novembra in decembra so bile reke občutno toplejše kot navadno. Obdobno povprečje so presegle za 1.2 oz. 1.1 °C (graf 8 in graf 10).

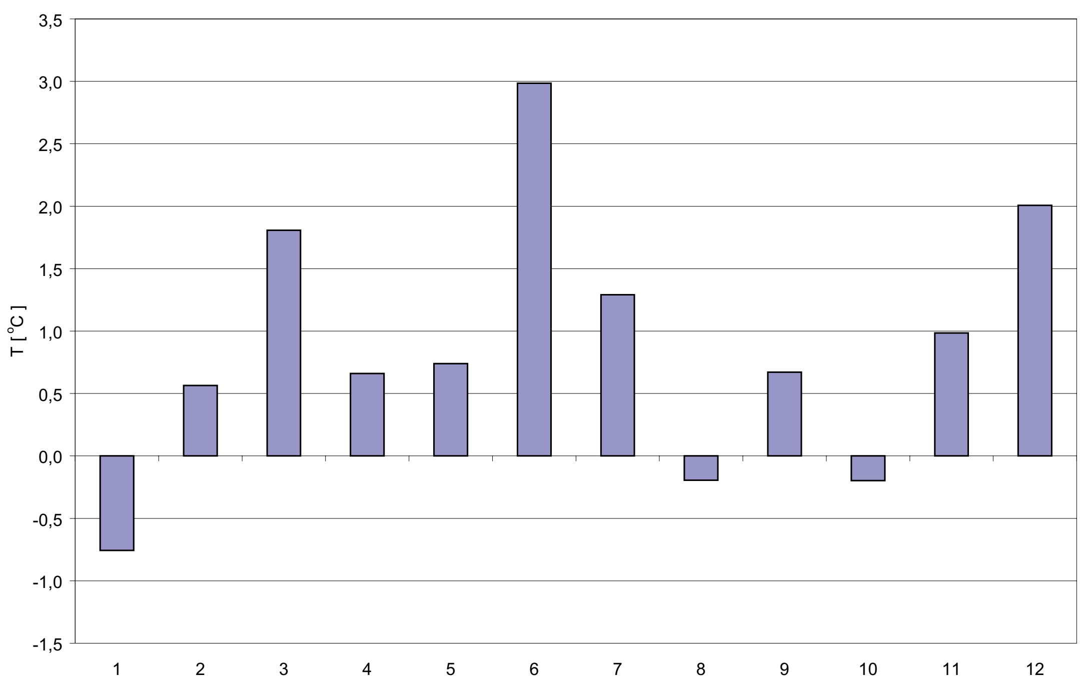
Januarja 2002 so bile temperature obeh največjih slovenskih jezer nižje kot navadno. Povprečna temperatura je bila 2.8 °C, kar je za 0.7 °C manj kot v primerjalnem obdobju. Na mestu meritev temperature Bohinjskega jezera je bil od 8. do 29. januarja led. Februarja je bila povprečna temperatura jezer 3.4 °C in sta bili jezeri v povprečju 0.6 °C toplejši kot v večletnem primerjalnem obdobju. Marca so bile temperature jezer nadpovprečno visoke. Povprečna temperatura Blejskega jezera je bila 6.9 °C, Bohinjskega pa 5.3 °C, kar je za 1.3 °C oziroma 2.4 °C več, kot znaša dolgoletno povprečje. Tudi v aprilu in maju so bile temperature višje kot navadno. Zaradi nadpovprečnega sončnega obsevanja v juniju, je tudi povprečna temperatura jezer presegla dolgoletno povprečje. Znašala je 19.8 °C, kar je za 3 °C več kot navadno. Najvišje zabeležene temperature jezer v letu 2002 so bile v drugi polovici junija in sicer je bila temperatura Blejskega jezera 24.2 °C, Bohinjskega pa 23.2 °C . Temperature v juliju so bile nadpovprečno visoke in so za 1.3 °C presegle obdobne vrednosti. Avgust in oktober sta bila temperaturno enaka obdobnemu povprečju, septembra pa je bila povprečna temperatura za 0.7 °C višja kot navadno. Tudi novembra in decembra so bile temperature obeh jezer višje kot v primerjalnem obdobju. V novembru je bila povprečna temperatura višja od obdobne vrednosti za 1 °C, v decembru pa za 2 °C.

°C higher than in the comparative period. The mean temperature of the rivers reached the highest values of all in July, when their temperature was 16.1 °C. In August however, the temperatures dropped considerably. The rivers cooled to 1.1 °C below the August mean value to a mean temperature of 14.6 °C. Temperatures in September were similar to the period mean, while in October, temperatures dropped by 0.4°C below the period mean. In November and December, the rivers were substantially warmer than usual. They exceeded the period mean by 1.2 °C and 1.1 °C (Graphs 8 and 10) respectively.

In January 2002 the mean temperatures of both the largest Slovenian lakes were lower than usual. The mean temperature was 2.8 °C, which is 0.7 °C less than in the comparative mean. At the location of the temperature measurement for Lake Bohinj, there was ice from the 8th to the 29th January. In February, the mean temperature of the lakes was 3.4 °C and the lakes were on average for 0.6 °C warmer than in the multi-annual period. In March, the temperatures of the lakes were significantly above average. The mean temperature of Lake Bled was 6.9 °C and that of Lake Bohinj was 5.3 °C, which is 1.3 °C and 2.4 °C higher respectively than the multi-annual period. The temperatures were also higher than usual in April and May, and also in June, due to the above-average insolation. The mean temperature in June exceeded the multi-annual mean as well reaching 19.8 °C, which is 3 °C higher than usual. The highest registered temperatures of the lakes in 2002



Graf 10: Temperaturna odstopanja srednjih mesečnih temperatur v letu 2002 od srednjih mesečnih temperatur primerjalnega obdobja. Odstopanja so izračunana kot povprečja odstopanj na šestih rečnih merilnih postajah (graf 8).
Graph 10: The deviations of the mean monthly temperatures in 2002 from the mean monthly temperatures of the comparative period. The deviations are calculated as mean values of the deviations at six gauging stations on the rivers (Graph 8).



Graf 11: Temperaturna odstopanja srednjih mesečnih temperatur v letu 2002 od srednjih mesečnih temperatur primerjalnega obdobja na Bohinjskem in Blejskem jezeru.
Graph 11: The deviations of the mean monthly temperatures in 2002 from the mean monthly temperatures of the comparative period on Lake Bohinj and Lake Bled.

Najnižje temperature rečnih voda v letu 2002 so bile večinoma nekoliko nižje kot v primerjalnem obdobju. Najnižji temperaturi obeh jezer, Blejskega 3.8 °C v januarju in Bohinjskega 0 °C v februarju, pa sta bili v povprečju 1.2 °C višji od dolgoletnega povprečja za januar in februar.

Srednja letna temperatura izbranih rek je bila 0.5 °C višja od povprečja, srednja letna temperatura obeh jezer pa 0.9 °C. Srednja letna temperatura rek na izbranih postajah je bila 10.4 °C, jezer pa 12 °C. Srednje mesečne temperature rek so bile glede na primerjalno obdobje višje februarja, marca, junija, novembra in decembra, nižje pa januarja in avgusta (graf 10). Srednje mesečne temperature jezer so bile glede na primerjalno obdobje višje marca, junija, julija, novembra in decembra, nižje pa januarja.

Najvišje temperature rek in obeh jezer so bile v splošnem nadpovprečne. Povprečna mesečna temperatura voda je bila najvišja junija, vendar je pri nekaterih rekah opaziti temperaturne konice v avgustu. Prvega avgusta je izstopala temperatura Krke v Podbočju s 25.4 °C. Le 1.2 °C hladnejše je bilo Blejsko jezero v Mlinem 21. junija. Visoki sta bili tudi temperaturi Bohinjskega jezera pri Svetem Duhu in sicer 23.2 °C ter Mure v Gornji Radgoni z 21.7 °C.

were in the second half of June; specifically, the temperature of Lake Bled was 24.2 °C, and that of Lake Bohinj was 23.2 °C. Temperatures in July were high above average and exceeded the period values by 1.3 °C. Temperatures in August and October were equal to the period mean, while in September the mean temperature was 0.7 °C higher than usual. Also in November and December, the temperatures of both lakes were higher than in the comparative period. In November, the mean temperature was 1 °C higher than the comparative period values, while in December, it was 2 °C higher.

In most cases the lowest temperatures of river water in 2002 were somewhat lower than in the comparative period. The lowest temperatures of both lakes however, 3.8 °C for Lake Bled in January and 0 °C for Lake Bohinj in February, were on average, 1.2 °C higher than the multi-annual mean for January and February.

The mean annual temperature of the selected rivers was 0.5 °C higher than the mean, while the mean annual temperature of both lakes was higher by 0.9 °C. The mean annual temperature of the rivers at selected stations was 10.4 °C, with 12 °C for the lakes. The mean monthly temperatures of the rivers were higher, compared to the comparative period, in

Preglednica 2: Najnižje (Tnk) in navišje (Tvk) temperature izbranih rek in jezer v letu 2002.
Table 2: The lowest (Tnk) and highest (Tvk) temperatures of selected rivers and lakes in 2002.

Vodotok Stream	Postaja gauging station	Tnk	datum date	Tvk	datum date
Mura	Gornja Radgona	0	01.01.2002	21,7	24.06.2002
Sava	Šentjakob	2,3	05.01.2002	18,5	23.06.2002
Kamniška Bistrica	Kamnik	3,3	19.01.2002	12,4	04.08.2002
Ljubljanica	Moste	4,5	08.01.2002	19,4	04.08.2002
Krka	Podbočje	1,9	16.01.2002	25,4	01.08.2002
Soča	Solkan	2,4	17.01.2002	17,2	24.06.2002
Blejsko jezero	Mlino	3,8	05.01.2002	24,2	21.06.2002
Bohinjsko jezero	Sveti duh	0	07.02.2002	23,2	23.06.2002

Preglednica 3: Srednje mesečne in letne temperature izbranih rek v letu 2002.
Table 3: The mean monthly and yearly temperatures of selected rivers in 2002.

Ts 2002	jan Jan	feb Feb	mar Mar	apr Apr	maj May	jun Jun	jul Jul	avg Aug	sep Sep	okt Oct	nov Nov	dec Dec	letna Ts annual Ts
Mura	1,2	4,7	7,1	9,1	13,3	17	17,8	15,9	14,5	10,6	8,1	4,7	10,3
Sava	4	6,1	8,2	9,8	13	15,9	15,9	14,9	13,3	10,3	8,6	6,3	10,5
Kamn. Bistrica	4,6	5,1	6,1	7,2	7,8	9,2	9,6	9,9	9,6	8,6	8	6,6	7,7
Ljubljanica	5,9	7,6	9,4	10,1	13	15	16,4	15,3	14,3	11,1	10,2	7,3	11,3
Krka	3,6	7,5	10,5	10,9	15,2	19,8	21,9	18,3	14,9	10,8	9,7	7,3	12,5
Soča	3,6	7,1	8,7	9,9	11,5	14,2	14,7	13,2	13,7	10,2	9,1	7,2	10,3
povprečje average	3,8	6,4	8,3	9,5	12,3	15,2	16,1	14,6	13,4	10,3	9,0	6,6	10,4

Merjenje temperature vode z živosrebrnim termometrom na vodomerni postaji Hasberg na Unici.
(foto: Niko Trišić)
Measurement of the water temperature with mercury thermometer at the gauging station Hasberg on the Unica river.
(photo: Niko Trišić)

February, March, June, November and December, while they were lower in January and August (Graph 10). The mean monthly temperatures of the lakes were higher, compared to the comparative period, in March, June, July, November and December, while they were lower in January.

The highest temperatures of both the rivers and the lakes were generally above average. The mean monthly temperature of the waters was highest in June; yet on some rivers temperature peaks are shown in August. The most marked temperature peak was one of 25.4 °C for the Krka River at Podbočje on the 1st August. On the 21st June, Lake Bled at Mlino was only 1.2 °C colder. The temperatures of Lake Bohinj at Sveti Duh with 23.2 °C, and those of the Mura River at Gornja Radgona with 21.7 °C, were also high.

Preglednica 4: Srednje mesečne in letne temperature izbranih rek (Ts) za večletno obdobje.
Table 4: The mean monthly and yearly temperatures of selected rivers (Ts) for the multi-annual period.

Ts obdobja period Ts	jan Jan	feb Feb	mar Mar	apr Apr	maj May	jun Jun	jul Jul	avg Aug	sep Sep	okt Oct	nov Nov	dec Dec	letna Ts annual Ts
Mura	3,0	4,3	6,9	9,1	12,1	14,8	16,8	17,2	14,2	11,1	6,9	3,5	10,0
Sava	4,3	4,6	6,2	8,2	10,9	12,8	14,5	14,7	12,6	9,9	7,2	5,1	8,5
Kamn. Bistrica	4,8	5,0	6,4	8,0	8,8	9,4	10,7	11,4	10,4	8,8	7,2	5,5	8,0
Ljubljanica	5,6	6,0	7,3	9,6	12,6	14,6	16,3	16,6	14,5	11,9	9,0	6,6	10,9
Krka	5,0	5,8	8,2	10,7	14,2	16,8	19,0	19,5	15,7	11,7	8,5	6,1	11,8
Soča	5,4	5,7	7,3	9,0	10,5	12,2	14,0	14,9	12,7	10,2	7,9	6,1	9,7
povprečje average	4,7	5,2	7,0	9,1	11,5	13,4	15,2	15,7	13,3	10,6	7,8	5,5	9,8

Preglednica 5: Srednje mesečne in letne temperature (Ts) obeh jezer v letu 2002.
Table 5: The mean monthly and yearly temperature (Ts) of both lakes in 2002.

Ts 2002	jan Jan	feb Feb	mar Mar	apr Apr	maj May	jun Jun	jul Jul	avg Aug	sep Sep	okt Oct	nov Nov	dec Dec	letna Ts annual Ts
Blejsko jezero	4,1	4,9	6,9	9,7	16,2	21,4	22,9	22,4	20	15,2	11,7	8,8	13,7
Bohinjsko j.	1,4	1,8	5,3	7,7	11,8	18,1	18,9	18,1	15,8	10,9	7,9	6,4	10,3
povprečje average	2,8	3,4	6,1	8,7	14,0	19,8	20,9	20,3	17,9	13,1	9,8	7,6	12,0

Preglednica 6: Srednje mesečne in letne temperature (Ts) obeh jezer za večletno obdobje.
Table 6: The mean monthly and yearly temperature (Ts) of both lakes for the multi-annual period.

Ts obdobja period Ts	jan Jan	feb Feb	mar Mar	apr Apr	maj May	jun Jun	jul Jul	avg Aug	sep Sep	okt Oct	nov Nov	dec Dec	letna Ts annual Ts
Blejsko jezero	4,3	4,0	5,6	9,5	15,9	19,6	22,3	22,9	19,4	15,7	10,4	6,4	13,0
Bohinjsko j.	2,8	1,6	2,9	6,6	10,6	13,9	17,0	18,0	15,0	10,8	7,2	4,8	9,3
povprečje average	3,5	2,8	4,3	8,0	13,3	16,8	19,6	20,4	17,2	13,2	8,8	5,6	11,1

VSEBNOST IN TRANSPORT SUSPENDIRANEGA MATERIALA V REKAH

Florjana Ulaga

Posledice premeščanja snovi v vodi so spremembe v in ob rečni strugi, zapolnjevanje vodnih zadrževalnikov in zablatenje rečnega dna zaradi usedanja drobnih zrn ter s tem povezane spremembe v vodnem krogu, predvsem pri povezavi površinskih in podzemnih voda.

Mreža postaj monitoringa suspendiranega materiala

Cilj meritev vsebnosti suspendiranega materiala v rekah je izračun skupne količine snovi, ki se premesti prek izbranega mesta v vodotoku v določeni časovni enoti. Dinamiki gibanja plavin v vodi sledimo z merjenjem vsebnosti suspendiranega materiala, iz katere pri izmerjenem pretoku izračunamo prenos materiala. Pogostost odvzema vzorcev je odvisna od značilnosti prispevnega območja in od pretočnega režima. Večina materiala se premesti ob visokih vodah. Zaradi tega je potrebno pogosto vzorčenje v času visokovodnih valov.

Redna merjenja vsebnosti suspendiranega materiala izvajamo na petih vodomernih postajah (karta 4). Enkrat dnevno se odvzame vzorec s prostornino enega litra, ki ga analiziramo v laboratoriju po klasični filtracijski metodi. Rezultati analiz so izmerjene vsebnosti suspendiranega materiala (c), izražene v g/m^3 vode. Na postajah primarne mreže poteka odvzem vzorcev ročno. Izjema je postaja Suha na Sori, kjer vzorce odvzemamo z avtomatskim vzorčevalnikom. Nekajkrat letno se na postajah opravljajo tudi profilne meritve suspendiranega materiala: vzorci se odvzamejo v posameznih točkah prečnega prereza. Na podlagi vsebnosti snovi v odvzetih vzorcih izračunamo srednjo vsebnost v prerezu, s pomočjo izmerjenega pretoka pa tudi trenutno količino prenosa suspendirane snovi. S pomočjo profilnih meritev lažje vrednotimo rezultate analiz redno odvzetih vzorcev.

Poleg rednega odvzema in analiziranja vzorcev poteka na devetih vodomernih postajah tudi odvzem vzorcev ob izrednih hidroloških razmerah (karta 4). S pomočjo analiz vzorcev te dopolnilne mreže pravilneje vrednotimo podatke rednih meritev, hkrati pa rezultati predstavljajo pregled stanja ob visokovodnih razmerah po vsej Sloveniji.

THE CONCENTRATION AND TRANSPORT OF SUSPENDED MATERIAL IN RIVERS

Florjana Ulaga

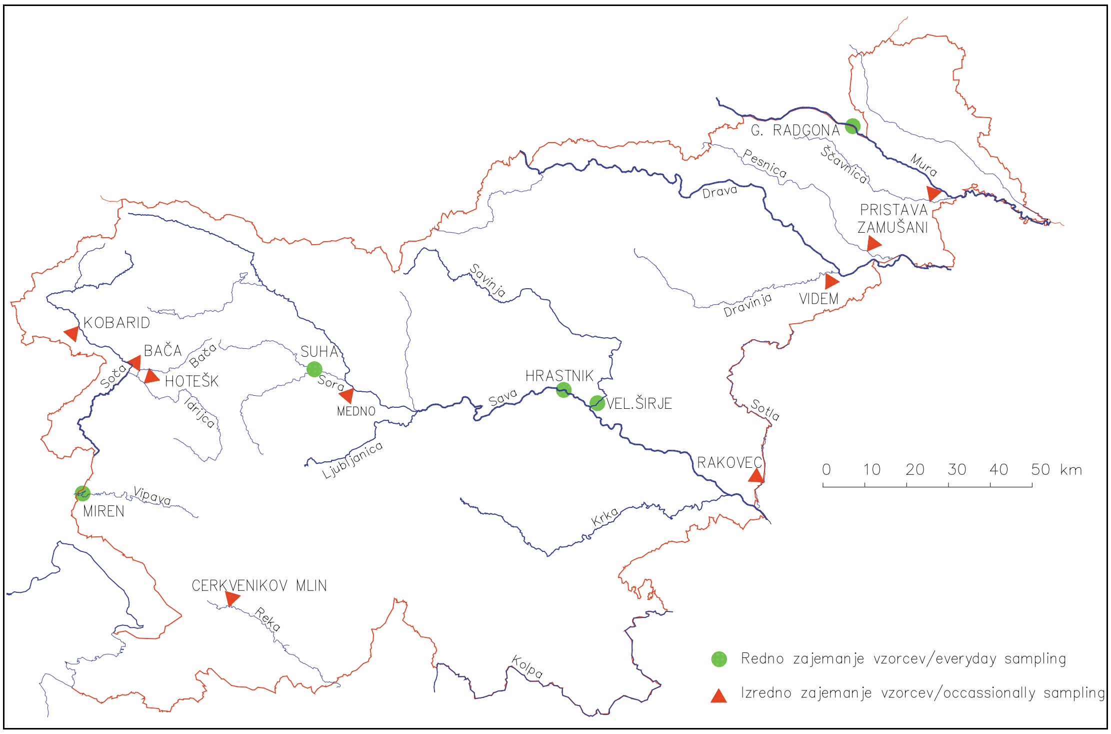
The consequences of transportation dynamics within the water include changes in the riverbed and along the banks and also the siltation of water reservoirs and rivers due to the sinking of small particles. It also causes corresponding changes in the water cycle affecting the exchange of water between the surface waters and the groundwater.

The Monitoring Network for Suspended Material

The aim of monitoring the suspended sediment in rivers is the calculation of the total amount of material that is transported through a chosen cross-section in the stream during a specific unit of time. The dynamics of the movement of solids in water can be determined by measuring the concentration of suspended sediment which is then multiplied by the water discharge to calculate the transport of the material. The frequency of sediment sampling depends on the characteristics of the area in question and on the regime of the river flow. Most of the sediment is transported during high water events. Thus, frequent sampling during high-water phases is necessary.

Regular measurements of suspended sediment are carried out at five gauging stations (Map 4). Once a day, a 1 litre sample is taken and analyzed in a laboratory according to the classical filtration method. The results of the analysis are the measured concentrations of suspended sediment (c) in g/m^3 of water. At the primary network stations the sample collection is carried out manually. The only exception to this is at the Suha station on the Sora River, where samples are taken by an automatic sampler. Cross-section measurements of suspended sediment are performed several times a year as well: the samples are taken at discrete points of the cross-section. On the basis of the sediment concentration in the samples, the mean concentration in the cross-section is calculated which is then multiplied by the value of the discharge measured to calculate the transport of suspended sediment at the time of sampling. The cross-section measurements enable easier evaluation of the results from analyses of the regular samples.

Along with the regular collection and analysis of samples, sampling in exceptional hydrological conditions takes place at nine water gauging stations (Map 4). With the help of the sample analyses of this supplementary network, the data from the regular



Karta 4: Vodomerne postaje z rednim in izrednim odvzemom vzorcev vsebnosti suspendiranega materiala v letu 2002.
Map 4: Water gauging stations with regular or occasional sampling of suspended material concentration in 2002.

Rezultati meritev vsebnosti suspendiranega materiala v letu 2002

Med petimi vodomernimi postajami z rednim dnevnim odvzemanjem vzorcev sta bili glede količine suspendiranih delcev v tem letu izjemni Mura in Vipava. Čas nastopa povečanih vsebnosti v Muri je bil avgusta, ko je bila srednja obdobna vsebnost presežena kar 22 dni. 13. 8. smo v vzorcu izmerili celo nad 2000 g/m^3 suspendiranega materiala, kar se je v preteklih 20 letih primerilo le trikrat. Velike vsebnosti suspendiranega materiala smo izmerili še v septembru, decembru in juniju. Izjemen je bil tudi rezultat analize vzorca, odvzetega v Vipavi 5. julija, ko je bila vsebnost 797 g/m^3, kar 49 krat presega srednjo obdobno vsebnost. Večje vrednosti so bile izmerjene le še leta 1997 (1066 g/m^3) in 1993 (1046 g/m^3). Visoke vsebnosti smo v Vipavi izmerili tudi novembra, kar je glede na dežno-snežni pretočni režim pričakovano. Vsebnosti suspendiranega materiala v Savinji v letu 2002 niso bile velike. Največja vsebnost je bila prav tako izmerjena v avgustu (732 g/m^3), čeprav bi jo pričakovali v jesenskih mesecih. Tudi v Savi v Hrastniku so bile vsebnosti suspendiranega materiala majhne, največja je bila 29. junija 452 g/m^3. V Sori je bila največja vsebnost izmerjena 19. julija (90 g/m^3), vendar so odvzemi vzorcev potekali le pet mesecev, žal ne ob visokih vodah v avgustu, oktobru in novembru.

measurements are evaluated more accurately and easily and, at the same time, the results present an overview of high-water conditions all over Slovenia.

The Measurements of the Concentration of Suspended Material in 2002

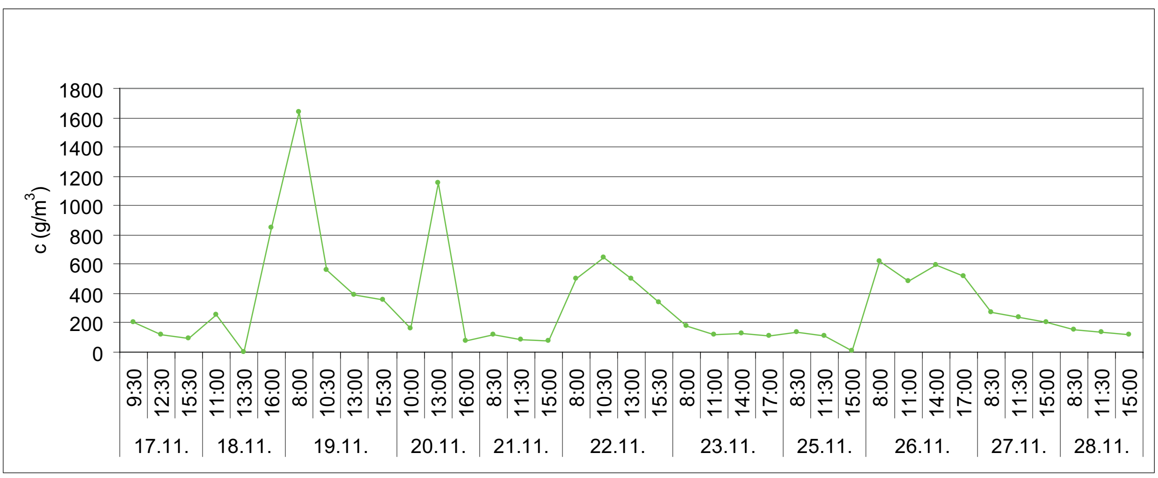
This year the Mura and Vipava Rivers stood out among the five water gauging stations with regular daily sampling of the amount of suspended sediment. The increased concentrations in the Mura River were measured in August when the mean concentration of the period was exceeded for 22 days. On the 13th August an amount of over 2000 g/m^3 of suspended sediment was measured in a sample, which had occurred only three times in the past 20 years. Large concentrations of suspended material were also measured in September, December and June. Especially extraordinary was the result of an analysis of the sample taken in the Vipava River on the 5th July, when the concentration was 797 g/m^3, which is 49 times larger than the mean period concentration. Higher concentrations were measured only in 1997 (1066 g/m^3) and in 1993 (1046 g/m^3). High concentrations were also measured in the Vipava River in November, which is to be expected considering the fluvio-nival regime of the river. By contrast, the concentrations of suspended material in the Savinja River in 2002 were not high. The high-

Preglednica 7: Največje vsebnosti suspendiranega materiala vzorcev postaj z enkrat dnevnim odvzemom v letu 2002 in v obdobju 1985-2001.
Table 7: The highest concentrations of suspended sediment at stations with one sampling per day in the year 2002 and in the period 1985-2001.

Postaja Gauging station	2002		1985 - 2001		
	vsebnost c (g/m³) concentration c (g/m³)	datum odvzema vzorca date of sampling	največja obdobna vsebnost c (g/m³) the highest concentration in the period c (g/m³)	datum največje obdobne vsebnosti date of the highest concentration in the period	srednja obdobna vsebnost mean concentration in the period
Gornja Radgona na Muri	2132	13.08.2002	2364	16.05.1996	48,1
Veliko Širje na Savinji	732	11.08.2002	6026	07.11.2000	55,5
Miren na Vipavi	797	05.07.2002	1066	14.09.1997	16,3

Preglednica 8: Največje vsebnosti suspendiranega materiala vzorcev odvzetih ob izrednih hidroloških razmerah.
Table 8: The highest concentrations of suspended material in the samples taken during exceptional hydrological conditions.

Postaja Gauging station	vodotok stream	2002		1990 - 2001			
		vsebnost c (g/m3) concentration c (g/m3)	datum odvzema vzorca date of sampling	največja obdobna vsebnost the highest concentration in the period			
				max c1	datum/date	max c2	datum/date
Pristava	Ščavnica	44	07. 12.	2623	29. 11. 1990	1730	22. 10. 1991
Zamušani	Pesnica	237	21. 04.	4780	25. 06. 1997	3729	25. 04. 1999
Videm	Dravinja	3212	01. 03.	4832	22. 05. 1999	4627	26. 01. 2001
Medno	Sava	656	11. 02.	2493	10. 12. 2000	2111	25. 12. 2000
Rakovec	Sotla	1818	14. 04.	758	11. 07. 1999	299	09. 01. 2001
Kobarid	Soča	1640	19. 11.	8112	17. 11. 2000	1656	07. 01. 2001
Hotešk	Idrijca	122	28. 11.	3743	09. 10. 1993	2988	01. 11. 1990
Bača pri Modreju	Bača	174	22. 11.	1959	27. 10. 1990	1088	07. 11. 1997
Cerkvenikov mlin	Reka	46	13. 01.	280	12. 11. 2001	131	16. 04. 2001



Graf 12: Vsebnosti suspendiranega materiala v Soči na vodomerni postaji Kobarid med 17. in 28. 11. 2002.
Graph 12: The concentrations of suspended material in the Soča River at the Kobarid gauging station between the 17th and the 28th November 2002.

Na postajah sekundarne mreže je bilo odvzetih precej vzorcev, v katerih smo izmerili velike vsebnosti suspendiranega materiala. **Največje so bile v Dravinji spomladi, 3212 g/m^3 (1. marec), in v jeseni, 2929 g/m^3 (24. oktober). To sta hkrati največji vsebnosti izmerjeni v letu 2002 na vseh odvzemnih mestih.** Tudi v Sotli je bila vsebnost suspendiranega materiala velika v pomladnih mesecih, 1818 g/m^3 14. aprila, kar je **največja vsebnost, do sedaj izmerjena v Sotli**. V Soči je bila vsebnost velika julija in novembra, v Kobaridu 19.11. celo 1640 g/m^3, kar je ena največjih vsebnosti izmerjenih v Soči. V dosedanjih meritvah je bil izjemen še november 2000, ko je zaradi zemeljskega plazu Stože in kamninskega drobirskega toka v povirju reke Koritnice vsebnost suspendiranega materiala v Soči presegla 8000 g/m^3.

Prenos suspendiranega materiala

Odnos med spreminjanjem pretoka in vsebnostjo suspendiranega materiala v določenem času ni linearen. Največja vsebnost suspenza v vodi je pogosto nekoliko pred viškom visokovodnega vala. Zaradi hitrega nastanka visokovodnega vala je načrtovanje zajema vzorcev, s katerimi bi izmerili največje vsebnosti, zelo težavno. Pri načrtovanju je potrebno upoštevati, v katerem delu vodozbirnega zaledja so bile padavine, kakšna je geološka zgradba območja, predhodno namočenost tal pa tudi čas od zadnjega visokovodnega vala.

Zmnožek vsebnosti suspendiranega materiala in pretoka vode skozi rečni prerez je prenos suspendiranega materiala S (kg/s). Rezultate vrednotenja vsakodnevnega odvzemanja vzorcev se sešteva v mesečne in letne vrednosti transportiranega materiala (preglednica 9). Največ, kar dobrih 508 tisoč ton materiala, je v letu 2002 prenesla Mura v Gornji Radgoni, od tega 60 odstotkov v mesecu avgustu. Tudi Savinja in Sava sta največ materiala prenesli avgusta, Vipava pa novembra.

Primerjave srednjih vrednosti z obdobjem 1985-2001 izkazujejo v letu 2002 povprečen transport na Muri in Vipavi, na Savinji pa precej podpovprečen letni transport, saj so bile vsebnosti suspendiranega materiala precej nizke, podpovprečen pa je bil tudi pretok (preglednica 10).

Največje prenesene količine suspendiranega materiala so bile ugotovljene v Muri 1681 kg/s, 13. avgusta, dan pred letnim najvišjim pretokom 829 m^3/s. **To je hkrati tudi največja prenesena količina suspendiranega materiala skozi profil Mure v Gornji Radgoni v 20 letnem obdobju.** Na Savinji je bila največja dnevna količina transportiranega materiala 98,5 kg/s (11. avgusta) hkrati najmanjša v obdobju meritev. Reka Vipava je največ transportirala 23. novembra 67 kg/s, kar je komaj srednja ob-

est concentration was measured also in August (732 g/m^3), although it would be expected in the autumn months. In the Sava River at Hrastnik, the suspended material concentrations were also low, the highest being 452 g/m^3 on the 29th July. In the Sora River, the highest concentration was measured on the 19th July (90 g/m^3). However, the samples were taken only for a period of five months and unfortunately not during the periods of high water in August, October and November.

At the secondary network stations, a considerable number of samples were taken, in which high concentrations of suspended material were measured. **The highest values were measured in the Dravinja River in the spring (1st March) at 3212 g/m^3, and in the autumn (24th October) at 2929 g/m^3. These are also the highest concentrations measured in 2002 from all the sampling sites.** The concentration of suspended material was also high in the Sotla River during the spring months, reaching 1818 g/m^3 on the 14th April, which is **the highest concentration ever measured in the Sotla River to date**. In the Soča River, the concentration was high in July and November. Specifically, at Kobarid on the 19th November it was as high as 1640 g/m^3, which is one of the highest concentrations measured in the Soča River. Up to now, measurements taken in November of 2000 were also exceptional, when the suspended sediment concentration in the Soča River exceeded 8000 g/m^3 due to the landslide at Stože and the debris flow of rocky in the headwaters of the Koritnica River.

The Transport of Suspended Material

The relation between the changes in discharge and the concentration of suspended material over a specific time is not linear. The highest concentration of sediment in water frequently appears just before the peak of the high-water wave. Due to the fast emergence of the high-water wave, it is very difficult to plan the sampling to measure the highest concentrations. When planning it is necessary to consider the area of the catchment where the rainfall occurred, the geological structure of the area, the preceding moisture of the soil and the time passed since the last high-water wave.

The product of the concentrations of suspended material and the discharge through the cross-section equals the transport of suspended sediment S (kg/s). The results of the evaluation of the daily samples are added up to find the monthly and yearly values of transported material (Table 9). The largest amount in 2002, as much as 508 thousand tons of sediment, was transported by the Mura River at Gornja Radgona, almost 60 percent of it in August. The Savinja and Sava Rivers also transported the

Preglednica 9: Mesečni in letni transport suspendiranega materiala.
Table 9: The monthly and yearly transport of suspended material.

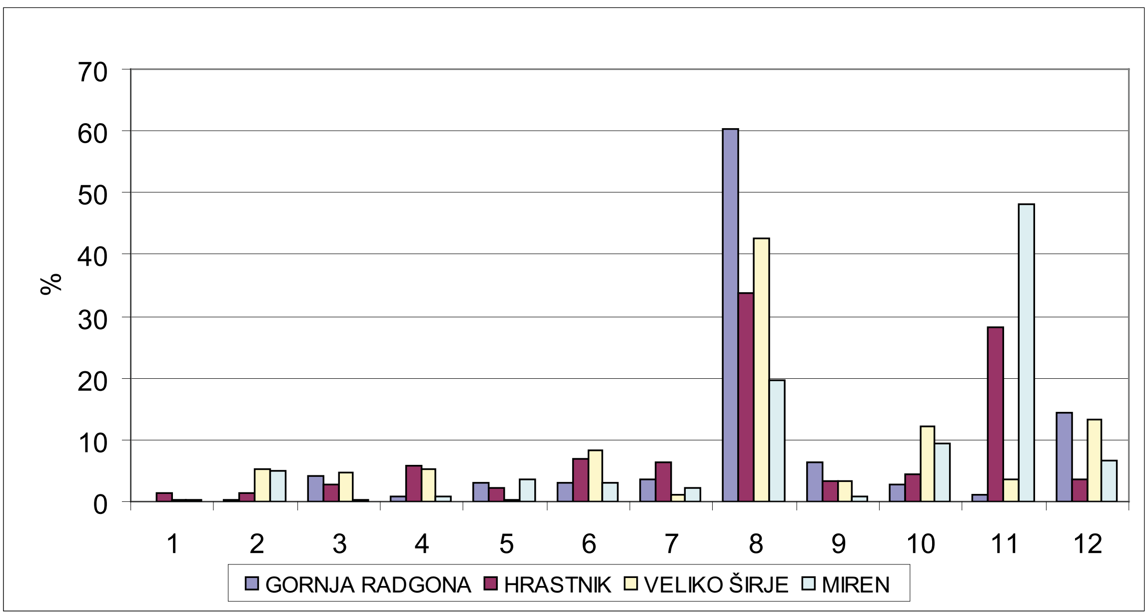
2002	Mura - Gornja Radgona		Sava - Hrastnik		Savinja - Veliko Širje		Vipava - Miren	
Mesec/Month	ton	%	ton	%	ton	%	ton	%
januar/January	459	0,09	1584	1,40	126	0,22	112	0,26
februar/February	1796	0,35	1569	1,38	2951	5,20	2067	4,86
marec/March	21684	4,26	3210	2,83	2657	4,68	176	0,41
april/April	3843	0,76	6446	5,69	2976	5,25	388	0,91
maj/May	15182	2,99	2505	2,21	172	0,30	1477	3,47
junij/June	16020	3,15	7895	6,97	4646	8,19	1298	3,05
julij/July	17860	3,51	7087	6,25	669	1,18	956	2,25
avgust/August	307061	60,39	38151	33,67	24182	42,63	8359	19,65
september/September	32219	6,34	3908	3,45	1907	3,36	387	0,91
oktober/October	13465	2,65	5134	4,53	6852	12,08	3979	9,35
november/November	6133	1,21	31832	28,10	2078	3,66	20489	48,17
december/December	72746	14,31	3979	3,51	7510	13,24	2849	6,70
Letni transport Yearly transport	508468	100	113298	100	56726	100	42536	100

dobna vrednost konic. Tudi največji transport Save je bil najmanjši v obdobju meritev. Na postajah sekundarne mreže je bilo največ materiala prenesenega v Dravinji (1. marca) 188,6 kg/s in v Soči (19. novembra) 364 kg/s.

Vsota letnih vrednosti transportiranega materiala je v 13 letih na Muri dosegla kar dobrih 5 milijonov ton, kar je veliko ob upoštevanju dejstva, da gre le za suspendiran material (preglednica 11).

majority of material in August, while the Vipava River did so in November.

Comparison of the mean values with those of the period 1985-2001 show an average yearly transport in 2002 on the Mura and Vipava Rivers and a below average transport on the Savinja River since concentrations of suspended sediment were quite low, while the discharge was also below average (Table 10).



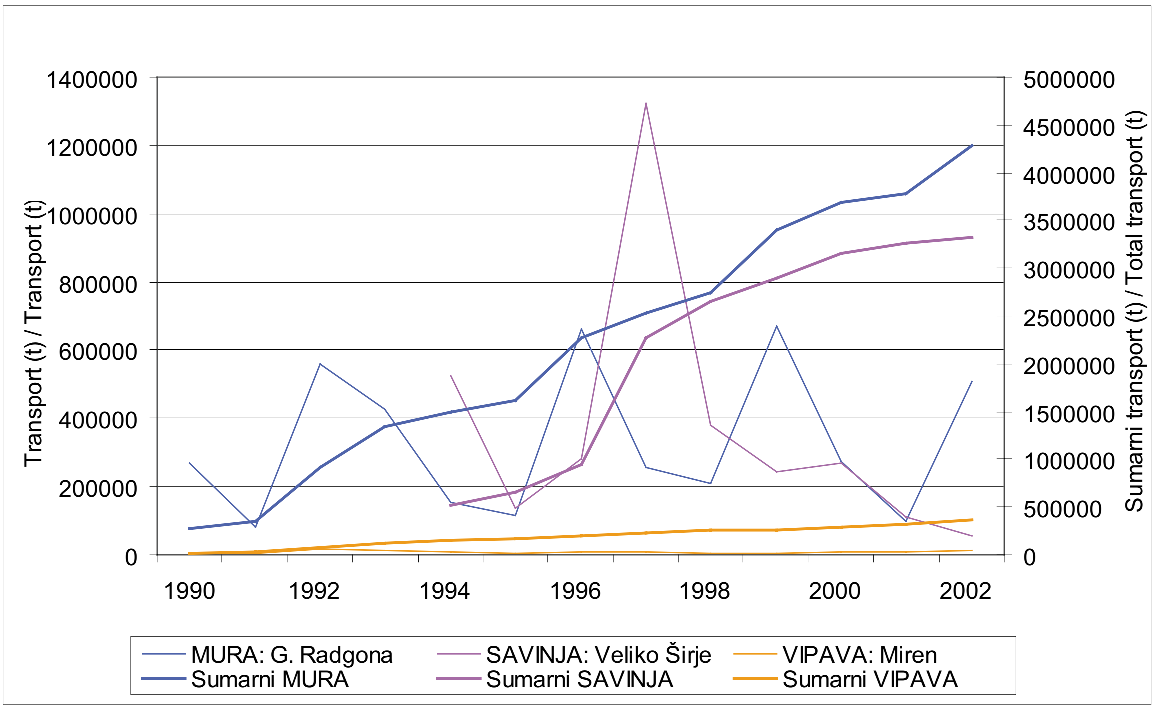
Graf 13: Delež transportiranega materiala po mesecih v letu 2002.
Graph 13: The share of the transported material by month in the year 2002.

Preglednica 10: Prikaz srednjih letnih in obdobnih vrednosti na postajah z dnevnim odvzemom vzorcev, ki imajo daljši niz spremljanja.
Table 10: A presentation of the mean yearly and periodic values at the stations with daily sampling, which have an extended period of monitoring.

Postaja Gauging station	2002			1985 -2001		
	Qs (m^3/s)	cs (g/m^3)	Ss (kg/s)	sQs (m^3/s)	scs (g/m^3)	sSs (kg/s)
Mura						
Gornja Radgona	136	50	16,1	157	48,1	13,3
Savinja						
Veliko Širje	30,5	21	1,8	43,9	55,5	8,34
Vipava						
Miren	16,4	22	1,35	17,2	16,3	0,89

Preglednica 11: Letne vrednosti prenesenega suspendiranega materiala (tisoč ton).
Table 11: Yearly values of the transported suspended sediment (thousand tons).

Postaja Gauging station	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	vsota sum
Mura: G. Radgona	268	831	561	428	154	116	661	255	211	670	275	96	508	5034
Savinja: Veliko Širje					525	136	283	1322	381	244	269	109	57	3326
Vipava: Miren	15	8	54	49	29	16	25	37	20	9	32	24	43	361



Graf 14: Transport suspendiranega materiala v obdobju 1990-2002.
Graph 14: The transport of the suspended sediment in the period 1990-2002.

Vipava je v istem obdobju prenesla skozi profil v Mirnu prek 360 tisoč ton, Savinja pa samo v devetih letih dobre 3,3 milijone ton. Na podlagi poznavanja velikosti porečja lahko ocenimo zniževanje zemeljskega površja v zaledju posamezne postaje. Vendar ob tem ne smemo pozabiti, da lahko na ta način ugotavljamo le kolikšno je povprečno znižanje površja v obdobju kot posledica odnašanja v vodi suspendiranega materiala. Ne moremo pa ugotavljati celotne erozije v porečju za kar bi morali meriti še vlečeni transport in kemično raztapljanje kamenin.

Vodomerna postaja Miren na Vipavi 15. maja 2002.
(foto: Bogomir Štolcar)
The gauging station Miren on the Vipava River on the 15th May 2002.
(photo: Bogomir Štolcar)

The largest transported amounts of suspended sediment were measured in the Mura River – 1681 kg/s on the 13th August, one day before the highest yearly discharge of 829 m^3/s. **At the same time, this also represented the highest amount of transported suspended sediment through the cross-section of the Mura River at Gornja Radgona in the-20 year period.** On the other hand, the highest daily amount of transported sediment in the Savinja River, 98.5 kg/s on the 11th August, was also the lowest throughout the period of measurements. The Vipava River transported the largest amount of material on the 23rd November with 67 kg/s, which is only the mean period value of the peaks. Also the largest transport of the Sava River was the lowest in the period of measurements. At the secondary network stations the majority of material was transported in the Dravinja River (1st March) with 188.6 kg/s and in the Soča River (19th November) with 364 kg/s.

Over 13 years the sum of the yearly values of transported sediment on the Mura River has reached the amount of 5 million tons, which is a considerable value considering the fact that this is only suspended sediment (Table 11). In the same period the Vipava River transported over 360 thousand tons through the cross-section at Miren, while the Savinja River, in only nine years, transported a good 3.3 million tons. On the basis of our knowledge of the area of the river catchment we can estimate the denudation of the earth's surface in the hinterland of the individual station. However we must also note that we can determine in this way only that part of the average denudation over the period that is the consequence of the transport of suspended sediment in water. We cannot determine the total erosion in the river basin, for in that case we would also have to measure bed load transport and the chemical dissolution of rocks.

VISOKE VODE REK IN POPLAVE

Janez Polajnar

Slovenske reke so bile visoke tudi leta 2002, časovna razporeditev visokih voda pa je bila običajna. Največ jih je bilo v jesenskem času. Reke so poplavljale v manjšem obsegu, večinoma na območjih vsakoletnih poplav. Prve visoke vode, ki so povzročale škodo, so se pojavile julija, predvsem na Gorenjskem in v osrednji Sloveniji, ko so sicer v večjem delu države prevladovale sušne razmere z zelo majhno vodnatostjo rek. Sledile so visoke vode v avgustu, ko je zaradi obilnih padavin v Avstriji najbolj narasla reka Mura ter reke in hudourniki na Štajerskem in v jugovzhodni Sloveniji. Katastrofalnih povodnji, kakršne so bile julija in avgusta v srednji Evropi, pri nas ni bilo. Jeseni so bile visoke vode običajne za ta letni čas. Visoke vode so bile pretežno v zahodni, osrednji ter južni Sloveniji, decembra tudi v vzhodni Sloveniji.

Pregled visokih voda leta 2002

Po podatkih Službe za spremljanje hidroloških stanj, napovedi in poročanje Agencije RS za okolje (ARSO) in Republiškega centra za obveščanje (CORS) so leta 2002 reke, potoki in morje 64-krat prestopili bregove in morsko obalo (graf 15). Morje se je 21-krat razlilo po nižjih delih obale, večje reke in nekateri hudourniki pa 43-krat, povečini na območjih vsakoletnih poplav.

Največ visokih voda je bilo novembra (18), oktobra (16) in decembra (10). Julija in avgusta so poplavljali večinoma hudourniki, jeseni pa so bile visoke vode na vodotokih po vsej državi (graf 15). Poplavna voda je povzročila gmotno škodo na stanovanjskih in gospodarskih objektih, prometnicah in kmetijskih površinah. Voda se je v večini primerov razlivala na območjih vsakoletnih poplav, z izjemo manjših hudournikov, ki so poplavljali in nanašali plavine na najbolj izpostavljenih mestih (preglednica 12).

Visoke vode avgusta leta 2002

Glede na velikost pretokov so bile visoke vode slovenskih rek v začetku avgusta povsem običajne, vendar je pojav visokih voda v tem letnem času nenavaden. Take hidrološke razmere so značilne za jesenske mesece, manj za poletne. Največji pretoki rek so dosegli vsakoletne visoke vode. Tudi manjša poplavljena območja ob Krki, Ljubljanici, Dravinji in Muri so bila v mejah vsakoletnih poplav. Povsem drugače je bilo v tem času v Avstriji, na Češkem, v Nemčiji in na Madžarskem. Tam je bilo julija, podo-

RIVER HIGH WATERS AND FLOODS

Janez Polajnar

Slovenian rivers were also high in 2002, their distribution during the year being usual. Most of the high waters occurred in the autumn. The rivers flooded to a limited extent, mainly in the annual flooding areas. The first high water events causing damage occurred in July, mainly in the region of Gorenjska and central Slovenia, while dry conditions with low waters still prevailed in the main part of the country. High waters followed in August when, due to abundant rainfall in Austria, the Mura River swelled as along with the rivers and torrents in the region of Štajerska and the south-eastern Slovenia. There were no catastrophic floods in Slovenia, such as occurred in Central Europe in July and August. In the autumn the high waters were as usual for this period of the year. High waters occurred mainly in the western, central and southern parts of Slovenia, while in December high water was also reported in eastern Slovenia.

Survey of High Waters in 2002

In the year 2002 there were 64 overflows and floods registered (rivers, streams and the sea) according to the Service for Monitoring Hydrological Conditions, Forecasts and Reports of the Environmental Agency of the Republic of Slovenia (ARSO) and the National Information Center (CORS) (Graph 15). The sea overflowed across the lower areas of the coast 21 times, while large rivers and torrents overflowed 43 times, mostly in the annual flooding areas.

High waters were most frequent in November (18), October (16) and December (10). In July and August, mostly it was torrents that overflowed, while in the autumn there were high waters on watercourses all over the country (Graph 15). The floods caused material damage to residential and economic facilities, traffic routes and agricultural areas. In most cases, the floods occurred in annual flooding areas, with the exception of the small torrents, which overflowed and brought down the alluviums at the most exposed places (Table 12).

High Waters in August 2002

Considering the amount of discharges, the high waters of the Slovenian rivers in the first part of August were normal, but the occurrence of high waters in this period of the year is not common. Such hydrological conditions are more typical of the autumn than the summer. The largest river disbno kot leta 1997, dolgotrajno izdatno deževje. Poplavljali so evropski veletoki Donava, Vltava, Elba, ki imajo obsežna vodozbirna zaledja. Poplavni valovi so se počasi pomikali po rečnem toku, količine vode so bile izjemno velike. Zaradi obsežnosti vodozbirnih območij in počasnega širjenja poplavnih valov vzdolž rek so bila opozorila pred poplavami v dolvodnih predelih ob rekah pravočasna in učinkovita. V Sloveniji se poplavni valovi širijo hitreje. Če se na omenjenih evropskih rekah poplavni valovi širijo več dni, tudi tednov, se v Sloveniji razširijo v nekaj urah. Pri nas poplave trajajo povprečno dan in pol do dva dni, le na kraških poljih tudi več – celo nekaj mesecev.

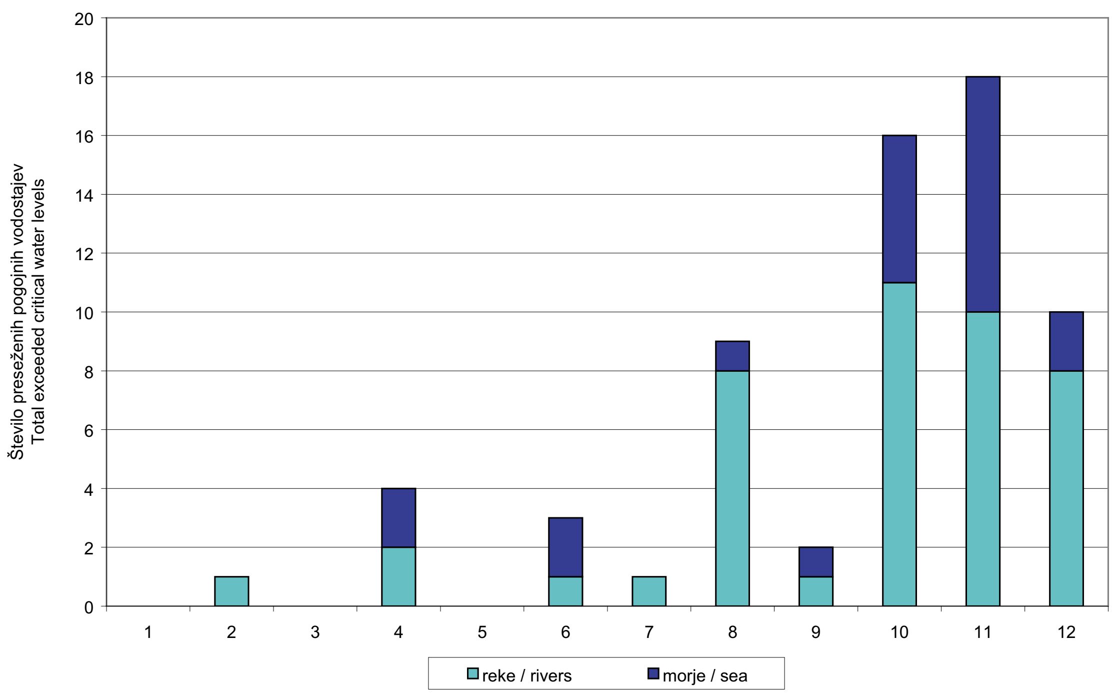
V začetku avgusta se je nad severnim Sredozemljem poglobilo območje nizkega zračnega pritiska, ki se je z vremensko fronto pomikalo prek Slovenije. Naši kraji so bili takrat na obrobju dolgotrajnih burnih vremenskih dogajanj.

Ponoči z 10. na 11. avgust je padlo največ dežja v predalpskem območju Julijskih Alp, na širšem območju Trnovskega gozda, v Kamniških Alpah in na območju Pohorja. V jutranjih urah so najbolj narasle reke na območjih zahodne in osrednje Slovenije: Soča, Idrijca, Vipava, Sava Bohinjka, Sori v zgornjem toku in Gradaščica. Čez dan so naraščale Ljubljanica, Sava v srednjem toku, Krka in reke v severni in severovzhodni Sloveniji: Savinja v zgor-

charges reached yearly high water levels. Also, the small flooded areas by the Krka, Ljubljanica, Dravinja and Mura rivers were within the limits of the yearly floods. The conditions at that time in Austria, the Czech Republic, Germany and Hungary were completely different. In July there was long-lasting and abundant rainfall similar to 1997. The large European rivers with extensive water catchments, the Danube, Vltava and Elbe, overflowed. The flood surges travelled slowly downstream while the water quantities were exceptionally high. Due to the large catchment areas and the slow spreading of the flood surges along the rivers, warnings regarding flooding along the rivers in the downstream areas were efficient and in time. In Slovenia, the flood waves spread faster. The flood waves on the above-mentioned European rivers travelled for several days and even weeks, while in Slovenia they travelled only for several hours. On average, floods in Slovenia last for a day and a half to two days at the most and they can only last longer in the karst plains – even up to several months.

In the first part of August an area of low air pressure deepened above the northern Mediterranean, which moved across Slovenia with the weather front. At that time Slovenia was on the edge of a long-lasting turbulent weather disturbance.

During the night from the 10th to the 11th



Graf 15: Število preseženih pogojnih vodostajev slovenskih rek na opazovanih vodomernih postajah in gladine morja ob slovenski obali leta 2002.
Graph 15: The number times the critical water levels of the Slovenian rivers were exceeded at the observation water gauging stations and the surface of the sea on the Slovenian coast in the year 2002.

njem toku, Meža, Mislinja, Dravinja in Oplotnica. Največji pretoki rek, z izjemo na Dravinji, niso bili večji od dveletne povratne dobe velikih pretokov.

V ponedeljek 12. avgusta so bili pretoki rek v večjem delu države veliki. Ponoči je večina rek v svojih povirnih delih že postopno upadla. Naraščali sta Krka in Sava v srednjem in spodnjem toku. Zaradi padavin v jugovzhodni Avstriji je zvečer zelo narasla Mura in ponoči z 12. na 13. avgust dosegla pretok z dveletno povratno dobo. Velik pretok reke Mure, ki je bil uravnavan tudi z izpuščanjem vode iz zadrževalnikov v Avstriji, je bil ves 13. avgust. Ponoči s 13. na 14. avgust se je pretok Mure povečal na največjo vrednost 829 m^3/s, z dve- do petletno povratno dobo. Mura je poplavila v območju visokovodnih nasipov in povzročila težave v prometu ter na gradbiščih ob strugi. Čez dan se je pretok Mure postopno zmanjšal pod pogojno vrednost.

Avgustovski največji pretoki so bili na ravni običajnih velikih letnih pretokov, le največja pretoka Dravinje in Mure sta presegla dveletno povratno dobo velikih pretokov.

Visoke vode jeseni leta 2002

Pretoki rek ob visokih vodah v novembru so bili običajni za jesenski čas. Ob obilnih padavinah ponoči s 17. na 18. november so narasle reke v jugozahodni, osrednji in vzhodni Sloveniji. Med njimi najbolj Ljubljanica in Reka, ki sta v manjšem obsegu poplavljali na območjih vsakoletnih poplav. Dravi se je v Dravogradu pretok povečal na 1500 m^3/s

August, the majority of rainfall was in the pre-Alpine area of the Julian Alps, on the wider area of the Trnovski forest, in the Kamnik Alps and in the area of Pohorje. During the morning hours, the rivers in the areas of western and central Slovenia increased the most: the Soča, Idrijca, Vipava and Sava Bohinjka Rivers, both the Sora rivers in their upper reaches, and also the Gradaščica River. During the day swelling also occurred in the Ljubljanica River, the middle reach of the Sava River, the Krka River and the rivers in the northern and north-eastern Slovenia: the upper reachs of the Savinja River and the rivers Meža, Mislinja, Dravinja and Oplotnica. The highest river discharges, with the exception on the Dravinja River, were no higher than the two-year return period of the high discharges.

On Monday the 12^{th} August there were high river discharges across the majority of the country. During the night the headwater areas of the majority of the rivers already began to gradually decrease. Only the Krka and Sava rivers increased in their middle and lower reaches. The Mura River increased in the evening and the night of the 12^{th} to the 13^{th} August due to the rainfall in Austria, reaching a discharge with a 2-year return period. The high discharge of the Mura River, regulated also by the retention of the water in the reservoirs in Austria, lasted for the whole day of the 13^{th} August. During the night of the 13^{th} to the 14^{th} August, the discharge of the Mura River increased to its highest value of 829 m^3/s with a 2- to 5-year return period. The Mura River overflowed within the area limited by high-

Preglednica 12: Visoke vode in njihovo razlitje leta 2002 (po podatkih ARSO in CORS).
Table 12: High waters and overflowing in 2002 (according to the data from ARSO and CORS).

	J	F	M	A	M	J	J	A	S	O	N	D
Drava											1	
Mura								1				1
Vipava								1			1	
Reka											1	
Ljubljanica								1		2	1	
Poljanska Sora										1		
Krka				1				1	1	2		1
Gradaščica										1	1	
Dravinja								1		1		1
Pesnica												1
Ščavnica												1
Mestinjščica												1
Tesnica								1				
Flisov potok							1					
Rovščica						1						
hudourniki						1	2	2				
kraška polja Notranjske										1		
morje ob slovenski obali				2		2		1	1	5	8	2

in v jutranjih urah je v manjšem obsegu poplavila izpostavljene dele cest. V teh dneh je bila vodnatost rek v večjem delu države velika. Ponoči z 21. na 22. november so padavine povzročile ponoven porast pretokov rek v zahodni in osrednji Sloveniji. Najbolj sta narasli Gradaščica in Poljanska Sora, ki je v Žireh dosegla pretok 90.5 m^3/s z dve- do petletno povratno dobo. Pogoste padavine in namočenost tal so ob koncu novembra vplivale na povečano vodnatost večine rek v državi. V začetku decembra se je nad Jadranom poglobilo območje nizkega zračnega pritiska, obilne padavine so bile v južni in vzhodni Sloveniji. Reke v južni in vzhodni Sloveniji so zelo narasle. Dne 6. decembra so najbolj narasle reke v vzhodni Sloveniji, nekatere so poplavljale. Reki Pesnica in Ščavnica sta dosegli največje pretoke z dve- do petletno povratno dobo, Dravinja je poplavljala v okolici Majšperka, poplavljala je tudi Mestinjščica. Ponovno je narasla reka Mura, v Gornji Radgoni je dosegla pretok z dveletno povratno dobo, 777 m^3/s, a ni poplavljala. Reka Krka je počasi naraščala in je v popoldanskem času poplavila več lokalnih cest na območju Šentjerneja in Kostanjevice. Največji pretok Krke, na vodomerni postaji Podbočje, 7. decembra, je bil 306 m^3/s, kar je manj od dveletne povratne dobe velikih pretokov.

Konica poplavnega vala na vodomerni postaji Dvor na Gradaščici 22. oktobra 2002.
(foto: Marko Burger)
The high – water peak on the Gradaščica River at Dvor on 22th October 2002.
(photo: Marko Burger)

water embankments, causing problems for traffic, as well as for the construction sites close to the river. During the day, the discharge of the Mura River gradually decreased below the critical value.

The highest discharges in August were on the level of the usual high yearly discharges; only the highest discharges of the Dravinja and Mura rivers exceeded the 2-year return period of high discharges.

High Waters in the Autumn of 2002

The river discharges at the time of the high waters in November were typical of the autumn period. At the time of abundant rainfall during the night of the 17th to the 18th November, the rivers increased in the south-western, central and eastern parts of Slovenia. Among them, the Ljubljanica and Reka Rivers increased the most, and overflowed to a small extent in the annual flooding areas. The discharge of the Drava River at Dravograd increased to 1500 m^3/s, thus flooding the vulnerable parts of roads to a small extent in the morning hours. On these days, the amount of water in the rivers was high across the majority of the country. During the night of the 21st to the 22nd November, rainfall caused a new increase of river discharges in western and central Slovenia. The Gradaščica and Poljanska Sora Rivers increased the most, with the Poljanska Sora River at Žire reaching a discharge rate of 90.5 m^3/s with a 2- to 5-year return period. Frequent rainfall and a high soil moisture at the end of November had an influence on the increased amount of water in the majority of rivers in the country. On the 6th December, the rivers in eastern Slovenia increased the most and some of them overflowed. The Pesnica and Ščavnica Rivers achieved the highest discharges with a 2- to 5-year return period, while the Dravinja River overflowed in the vicinity of Majšperk with the Mestinjščica River also overflowing. The Mura River increased again, reaching a discharge with a 2- to 5-year return period at Gornja Radgona of 777 m^3/s. It did not overflow, however. The Krka River swelled slowly and flooded several local roads in the area of Šentjernej and Kostanjevica in the afternoon. The highest discharge of the Krka River at the gauging station Podbočje on the 7th December was 306 m^3/s, which is less than the 2-year return period of high discharges.

NIZKE VODE REK IN HIDROLOŠKA SUŠA

Mira Kobold

V letu 2002 so se na slovenskih rekah nadaljevale nizkovodne razmere iz decembra 2001. Te so posledica male količine padavin, ki je bila že tretje leto zapored v večjem delu Slovenije pod dolgoletnim povprečjem 1971-2000. Časovna in količinska razporeditev padavin po državi sta zelo različni. Povprečna letna količina padavin je od 750 mm padavin na severovzhodu države (Prekmurje) do 3300 mm na severozahodu v Julijskih Alpah. Največ padavin je v letih 2000-2002 padlo na zahodu države (graf 16). Proti vzhodu države je količina padavin upadala. Najmanj padavin je bilo v Prekmurju, kjer je bil primanjkljaj tudi največji. Skupna letna količina padavin v letu 2002 v splošnem ni dosegla povprečnih obdobnih vrednosti. Največji primanjkljaj padavin je bil v severovzhodni Sloveniji, južna Slovenija pa je ponekod dobila več padavin od povprečja.

Nizkovodne razmere v letu 2002 smo beležili zlasti v prvih sedmih mesecih leta kot odraz majhne količine padavin, ki je bila v začetku leta precej pod obdobnim povprečjem (graf 17). V januarju je bilo padavin povsod po državi malo, manj kot polovica običajne januarske količine. Ponekod v severozahodni in severni Sloveniji so padavine dosegle le okrog 10 odstotkov dolgoletnega povprečja 1971-2000. Količina padavin v februarju je bila večja, vendar zelo različna. V večjem delu osrednje in vzhodne Slovenije ter na Primorskem je bila količina padavin v mejah običajnih februarskih padavin. V severozahodni Sloveniji dolgoletno povprečje februarskih padavin ni bilo doseženo, padavin je primanjkovalo tudi v Prekmurju. Dolgoletno povprečje je bilo preseženo v južni Sloveniji. V marcu je bilo padavin povsod manj od dolgoletnega povprečja. V južni Sloveniji je padlo okrog 30 odstotkov dolgoletnega povprečja, v severovzhodni Sloveniji okrog 40 in v zahodni Sloveniji okrog 80 odstotkov. V aprilu so padavine povsod, razen na severozahodu države, presegle dolgoletno povprečje, najbolj na območju Novega mesta. Vse do avgusta je bilo padavin v pretežnem delu države manj od dolgoletnega povprečja. V avgustu je bilo dolgoletno povprečje preseženo povsod razen v Prekmurju, kjer je padlo okrog 90 odstotkov povprečne avgustovske količine padavin. V ostalih mesecih do konca leta je bila količina padavin marsikje po državi večja od dolgoletnega povprečja 1971-2000. Najmanj padavin je bilo kot običajno v Prekmurju.

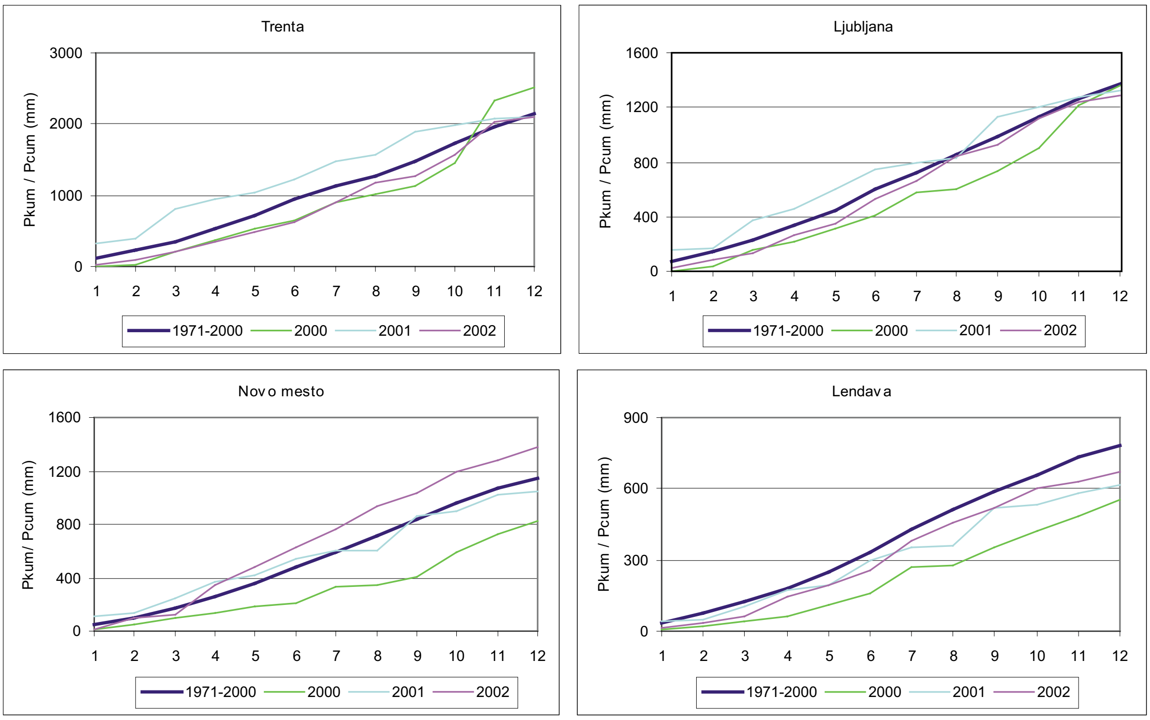
Glede na padavinske razmere so bili srednji mesečni pretoki v prvih sedmih mesecih leta po-

LOW FLOWS OF RIVERS AND HYDROLOGICAL DROUGHT

Mira Kobold

In the year 2002 the low flow conditions from December 2001 continued in the Slovenian rivers. Such conditions were a consequence of the small amount of precipitation, which had been felt over a large part of Slovenia. This was below the multi-annual mean of the period 1971-2000 for the third year in a row. The time and amount of the distribution of the precipitation differs across the country. The mean yearly amount of precipitation ranges from 750mm in north-eastern Slovenia (Prekmurje) to 3300mm in the northwest in the Julian Alps. The highest amount of precipitation in the period of 2000-2002 was in the western part of the country (Graph 16). Towards the eastern part of the country, the amount of precipitation decreased and the lowest amount of precipitation was in Prekmurje, where there was also the highest deficit. The total annual amount of precipitation in 2002 generally did not reach the mean period values. The highest deficit of precipitation was in the north-eastern part of Slovenia, while some places in southern Slovenia had more precipitation than average.

Low flow conditions in 2002 were recorded especially in the first seven months of the year as a consequence of the small amount of precipitation, which was considerably below the period mean in the first part of the year (Graph 17). In January, there was little precipitation over the entire country, less than half of the typical amount for the month. In several areas in northern and north-eastern Slovenia the amount of precipitation reached only around 10 percent of the multi-annual mean in the period 1971-2000. The amount of precipitation in February was the highest, yet very different. In a large part of central and eastern Slovenia, as well as in Primorska, the amount of rainfall was within the limits of typical rainfall for February. In north-eastern Slovenia though, the multi-annual mean of rainfall in February was not reached and there was a deficit of rainfall also in Prekmurje. The multi-annual mean was exceeded in the southern part of Slovenia. In March, the amount of rainfall was below the multi-annual mean in all areas. Rainfall amounted to around 30 percent of the multi-annual mean in southern Slovenia, around 40 percent in north-eastern Slovenia and around 80 percent in western Slovenia. In April, rainfall everywhere, except in the north-eastern part of the country, exceeded the multi-annual mean, the excess being highest in the area of Novo mesto. Until August, the amount of rainfall in the majority of the country was lower than the multi-annual mean



Graf 16: Kumulativna količina padavin.
Graph 16: Cumulative amount of precipitation.

večini v mejah srednjih malih obdobnih pretokov (sQnp), v ostalih mesecih pa v mejah srednjih obdobnih mesečnih pretokov (sQs). Najmanjši pretoki so bili v severovzhodni Sloveniji, kjer so bili srednji mesečni pretoki z izjemo decembra vseskozi v mejah srednjih malih obdobnih pretokov (sQnp). Najmanjši mesečni pretoki so bili skoraj vse leto pod srednjimi malimi obdobnimi pretoki in so se ponekod v prvi polovici leta približali najmanjšim obdobnim mesečnim pretokom (nQnp). V marcu so ponekod v severovzhodni Sloveniji padli pod najmanjše obdobne pretoke za ta mesec.

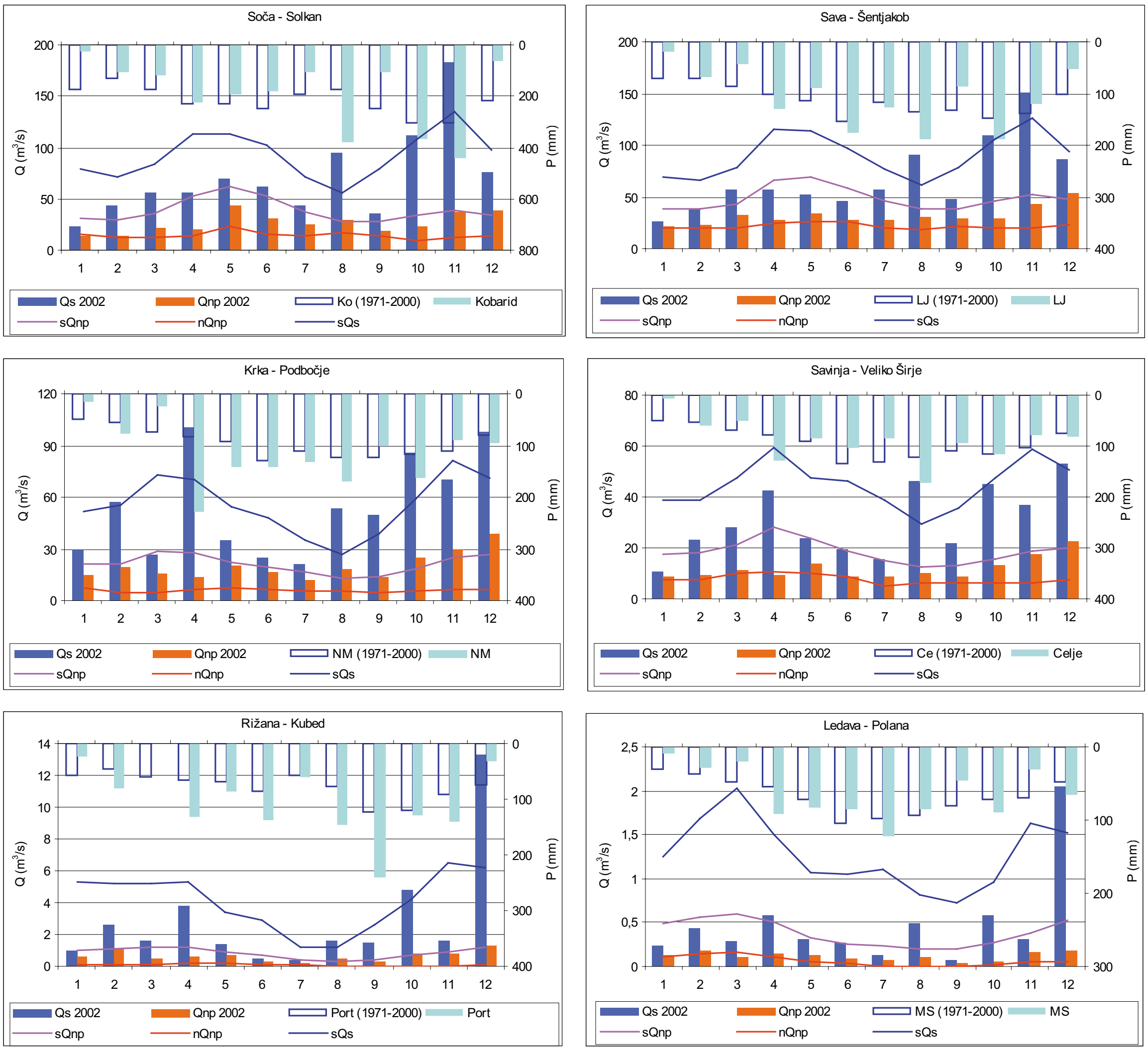
Nizkovodne razmere smo podrobneje analizirali za tri značilne postaje (graf 18). Primanjkljaj padavin iz decembra 2001, ki se je nadaljeval v letu 2002, je povzročil, da so bili pretoki v začetku leta večinoma pod srednjimi obdobnimi pretoki, v mejah srednjih malih pretokov. V januarju so se pretoki približali najmanjšim obdobnim pretokom za ta mesec. V zahodni in v večjem delu osrednje Slovenije ter na Muri smo v januarju in v začetku februarja beležili najmanjše pretoke v letu. Povratne dobe malih pretokov so bile do dveletne.

Padavine v februarju so vplivale na povečanje vodnatosti rek po državi le za kratek čas. Hidrološko sušno obdobje se je nadaljevalo do sredine aprila, ko so nekoliko obilnejše padavine vplivale na prehodno izboljšanje hidroloških razmer. V marcu in aprilu so najmanjši pretoki ponekod padli pod najnižje obdobne mesečne vrednosti. Manj padavin od

but in August, the multi-annual mean was exceeded everywhere except in Prekmurje, where 90 percent of the average amount of rainfall was recorded. In the remaining months until the end of the year, the amount of rainfall was higher in many places across the country than the multi-annual mean of the period 1971-2000. The lowest amount of rainfall was, as usual, in Prekmurje.

Allowing for the rainfall conditions, the mean monthly discharges in the first seven months of the year were mostly within the limits of the mean low discharges of the period (sQnp), while in the remaining months, they were within the limits of the mean monthly discharges of the period (sQs). The lowest discharges were noted in north-eastern Slovenia where the mean monthly discharges remained within the limits of mean low discharges of the period (sQnp), with the exception of December. The lowest monthly discharges remained below the mean low discharges of the period throughout most of the year and, at times in the first half of the year, came close to the minimum monthly discharges of the period (nQnp). In March, in an area of north-eastern Slovenia, they dropped below the minimum discharges of the period for that month.

The low flow conditions for three typical stations were analyzed in detail (Graph 18). The deficit in the rainfall from December 2001, which continued into the year 2002, caused discharges in the first part of the year to remain mostly below the mean



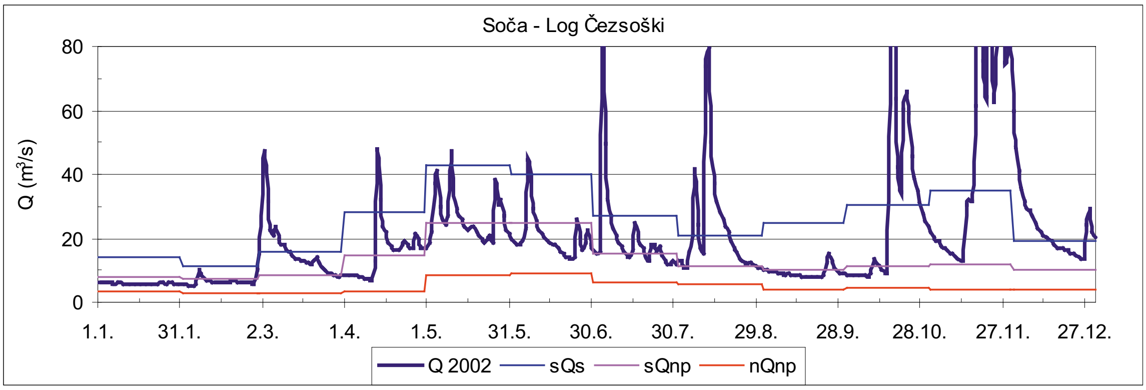
Graf 17: Srednji in minimalni mesečni pretoki v letu 2002, mesečna količina padavin ter obdobne mesečne vrednosti.
Graph 17: The mean and minimum monthly discharges in 2002, the monthly amount of precipitation and the monthly values of the period.

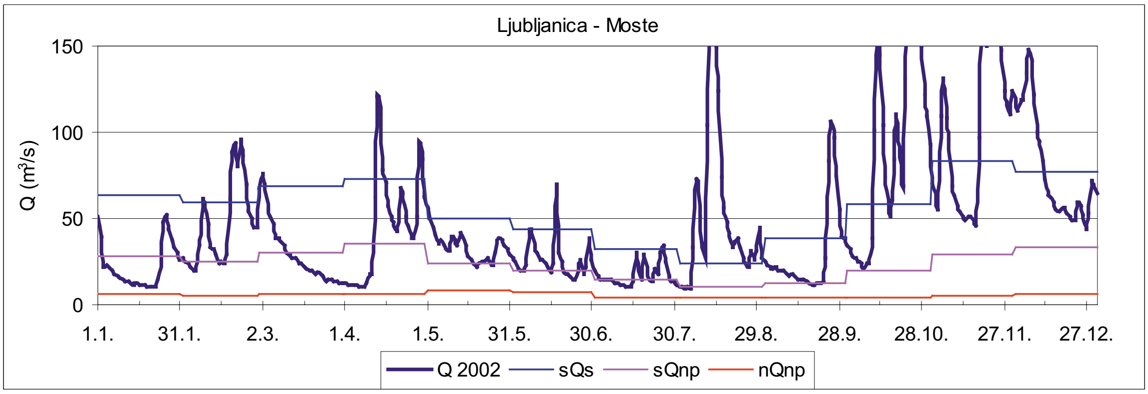
povprečja je bilo zopet maja, ki so bile tudi zelo neenakomerno porazdeljene po državi. Pretoki v maju so bili povečini v mejah srednjih malih pretokov. V poletnih mesecih juniju, juliju in avgustu je prevladoval nevihtni tip padavin. Najmanj padavin je padlo v severovzhodnem delu Slovenije. Kraški reki Ljubljanica in Krka sta imeli najmanjši pretok konec julija in prve dni avgusta, v mejah vsakoletnih malih pretokov.

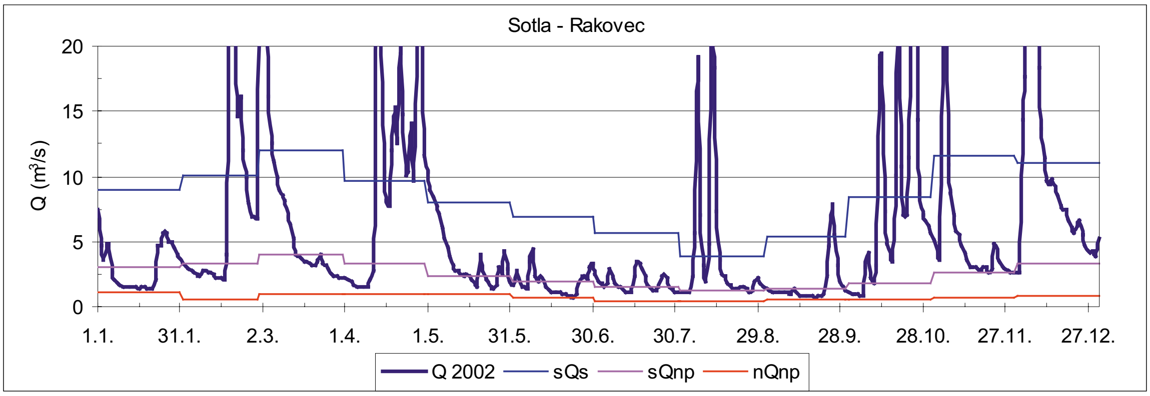
Pretoki v avgustu so zaradi obilnejših padavin presegli vrednosti srednjih obdobnih pretokov, vendar smo v septembru marsikje, zlasti v zahodni, vzhodni in severovzhodni Sloveniji, zopet beležili male pretoke. V vzhodni Sloveniji in Prekmurju so bili v septembru zabeleženi najmanjši pretoki v letu, z dve do petletno povratno dobo malih pretokov. V začetku oktobra se je končalo obdobje nizkovodnih razmer na površinskih vodotokih. Razen v južni Sloveniji, kjer je letna količina padavin presegla dolgoletno povprečje, je bila letna količina padavin po

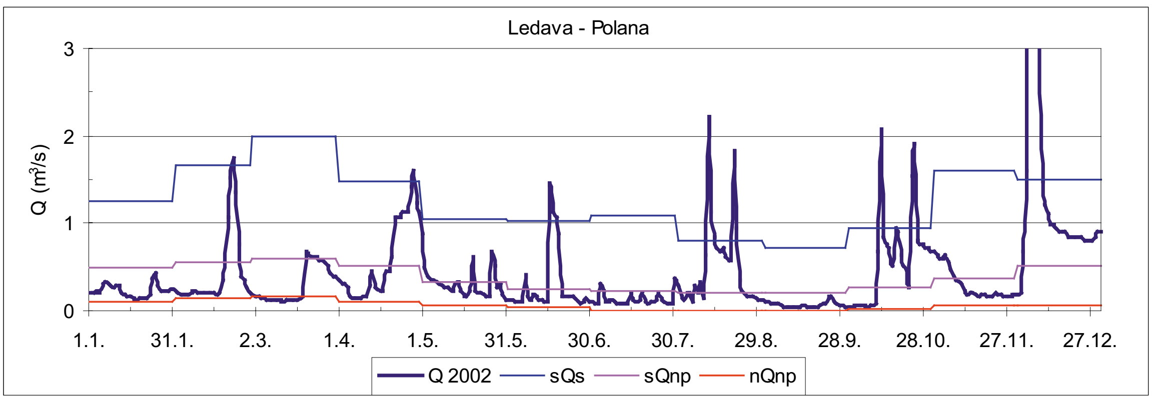
discharges of the period, being within the limits of the mean low discharges. However, in January the discharges came close to the minimum discharges of the period for that month. In western, the majority of central Slovenia and on the Mura River, the lowest discharges in the year were recorded in January and in the first part of February. Low discharges were up to the level of 2-year return period values.

The rainfall in February only caused an increase in the amount of water in the rivers across the country for a short time. The hydrological dry period continued until the middle of April, when somewhat more abundant rainfall influenced the transitional improvement of the hydrological conditions. In March and April, the lowest discharges dropped in places below the minimum monthly values of the period. In May again there was less rainfall than average, which was unequally distributed across the country. The discharges in May were mostly within the limits of the mean low discharges. During the









Graf 18: Srednji dnevni pretoki (Q2002) za leto 2002 in obdobni mesečni pretoki (sQs,sQnp, nQnp).
Graph 18: The mean daily discharges (Q2002) for the year 2002 and the monthly discharges for the period (sQs, sQnp, nQnp).

državi blizu dolgoletnemu povprečju obdobja 1971-2000.

Pojav hidrološke suše beležimo nepretrgoma že od leta 2000. Analize minimalnih pretokov in primanjkljajev odtoka (graf 19) kažejo na regionalni značaj suše in prizadetost posameznih območij. V letu 2002 smo beležili pojav hidrološke suše površinskih voda v manjšem obsegu kot v letih 2000 in 2001. Najbolj izrazita je bila v severni, vzhodni in severovzhodni Sloveniji, kjer je bil primanjkljaj padavin glede na povprečje obdobja 1971-2000 največji. Kraške reke v južni Sloveniji, kjer primanjkljaja padavin ni bilo, niso imele primanjkljaja odtoka.

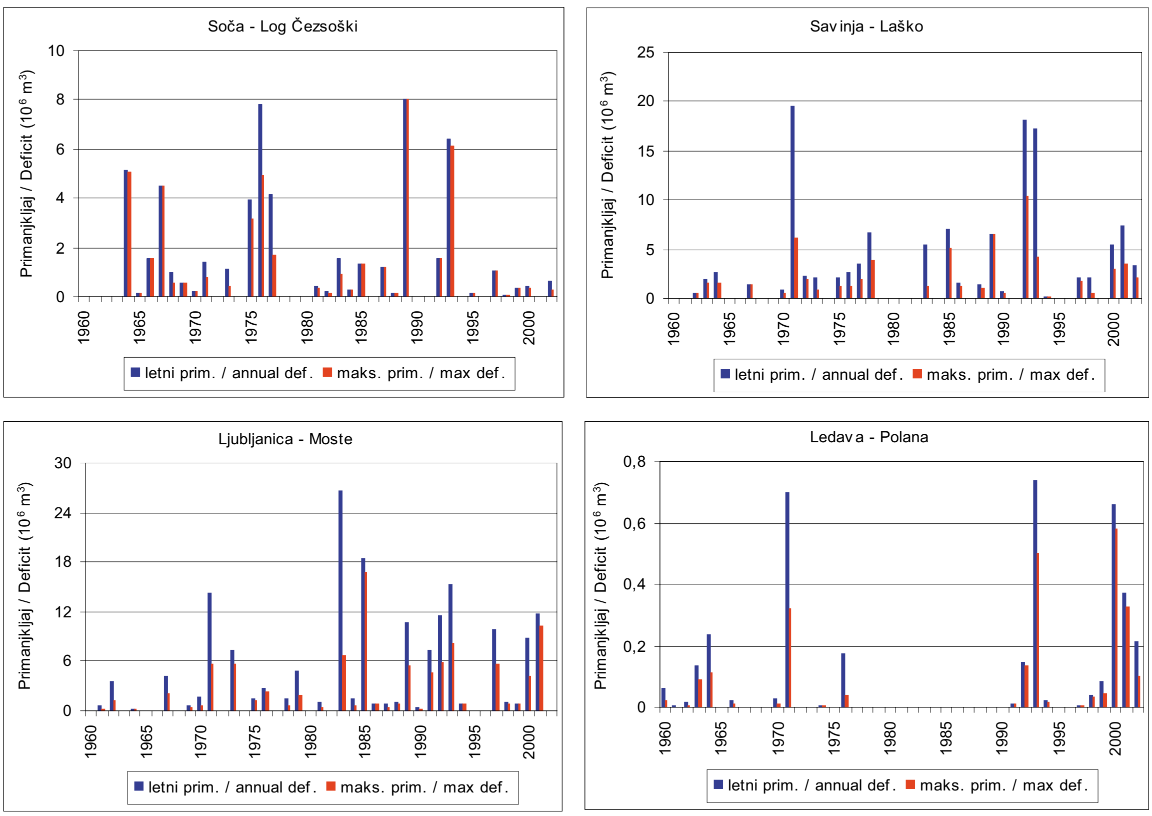
Analiza primanjkljaja odtoka za leto 2002 v splošnem ni dala višjih vrednosti primanjkljajev odtoka glede na leti 2000 in 2001. Za pretok praga smo vzeli 95 odstotni pretok (Q95) iz krivulje trajanja, ki se v hidrološki praksi običajno uporablja za pretok praga.

Primanjkljaj odtoka je povezan z dolžino trajanja malih pretokov; daljše je obdobje, večji je običajno primanjkljaj. V letu 2002 je bilo v Prekmurju in ponekod v osrednji Sloveniji obdobje trajanja z malimi pretoki daljše kot v predhodnih dveh letih, vendar posledice hidrološke suše niso bile tako hude, predvsem zaradi pojavljanja malih pretokov v zimskih mesecih. Količina in razporeditev padavin v

summer months of June, July and August, there was a prevalence of rainfall in the form of storms. The lowest amount of rainfall fell in the north-eastern part of Slovenia, while the karst rivers Ljubljanica and Krka had the lowest discharge in the latter part of July and the first days of August, still remaining within the limits of the yearly low discharges.

Due to the more abundant rainfall, the discharges in August exceeded the values of the mean discharges of the period. However, in September, low discharges were again recorded in many places, especially in the western, eastern and north-eastern parts of Slovenia. In September the lowest discharges of the year, with 2- to 5-year return periods, were recorded in the eastern part of Slovenia and in Prekmurje. In the first part of October the period of low flow conditions on surface watercourses ended. Except in southern Slovenia, where the yearly amount of rainfall exceeded the multi-annual mean, the yearly amount of rainfall all over the country was close to the multi-annual mean of the period 1971-2000.

The phenomenon of hydrological drought has been recorded without interruption since the year 2000. The analysis of the minimum discharges and the outflow deficits (Graph 19) show a regional character to the drought, which does not affect all parts of Slovenia equally. In 2002 the phenomenon of the surface water hydrological drought was recorded to



Graf 19: Prikaz letnih primanjkljajev odtoka in maksimalnih primanjkljajev odtoka neprekinjenega trajanja za obdobje od leta 1960 naprej.
Graph 19: The presentation of the yearly runoff deficits and the maximum runoff deficits of continuous duration for the period from 1960 onwards.

Preglednica 13: Število dni v letih 2000, 2001 in 2002, ko je bil pretok pod srednjim malim obdobnim pretokom (sQnp).
Table 13: The number of days in the years 2000, 2001 and 2002 with discharges below the mean low discharge of the period (sQnp).

Vodomerna postaja Gauging station	sQnp	2000	2001	2002
Mura - Gornja Radgona	59,6	1	23	28
Ščavnica - Pristava	0,234	61	34	98
Ledava - Polana	0,127	110	125	86
Pesnica - Zamušani	0,604	107	67	81
Dravinja - Loče	0,849	90	45	49
Meža - Otiški Vrh	4,18	34	39	69
Sava Dolinka - Sveti Janez	0,897	31	0	16
Sava - Šentjakob	29,1	15	24	36
Sava - Čatež	77,6	49	28	4
Sora - Suha	3,60	26	0	0
Kamniška Bistrica - Kamnik	2,10	18	12	28
Savinja - Nazarje	3,48	0	38	32
Savinja - Laško	7,90	22	32	11
Ljubljanica - Moste	7,89	23	33	0
Gradaščica - Dvor	0,450	33	10	10
Krka - Podbočje	9,85	46	29	0
Sotla - Rakovec	0,896	2	50	14
Kolpa - Radenci	6,26	47	35	0
Soča - Log Čezsoški	5,40	5	0	3
Soča - Solkan	20,0	23	38	33
Idrijca - Podroteja	1,67	39	0	0
Vipava - Dolenje	1,83	0	25	0
Rižana - Kubed	0,22	83	84	19

poletnih mesecih je bila ugodnejša kot v letih 2000 in 2001. Pojavljanje malih pretokov je najbolj izrazito v Prekmurju in na Primorskem, kjer so pretoki v zadnjih letih tudi tretjino leta pod srednjimi malimi pretoki (preglednica 13).

Izviri Save Dolinke v Zelencih 3. aprila 2002. Hidrološke sušne razmere so se nadaljevale že od pozne jeseni leta 2001.
(foto: Marko Burger)
The spring of the Sava Dolinka River at Zelenci on 3rd April 2002. The hydrological drought continued from the late autumn 2001.
(photo: Marko Burger)

a lesser extent than in the years 2000 and 2001. It was most significant in northern, eastern and north-eastern Slovenia, where the deficit of rainfall was the highest in comparison with mean of the period 1971-2000. The karst rivers in the southern parts of Slovenia, where there was no deficit of rainfall, had no runoff deficit.

The analysis of the runoff deficit for the year 2002 in general provided no higher values in comparison with the years 2000 and 2001. The discharge threshold of 95 percent (Q95) was used, taken from the duration curve that is common in hydrology as a discharge threshold.

The runoff deficit is linked to the duration of the low discharges; usually, the longer it is, the higher the deficit. In 2002 the period in Prekmurje and in an area in the central Slovenia with low discharges lasted longer than in the previous two years. However, the consequences of the hydrological drought were not as severe, mostly due to the appearance of low discharges during the winter months. The quantity and distribution of rainfall during the summer months was far more favourable than in the years 2000 and 2001. The appearance of low discharges is most apparent in Prekmurje as well as in Primorska where in recent years the discharges have spent as much as a third of the year below the mean low discharges (Table 13).

B. PODZEMNE VODE

GLADINE PODZEMNIH VODA V ALUVIALNIH VODONOSNIKIH

Zlatko Mikulič

Hidrološka suša v zadnjih treh mesecih predhodnega leta in velik primanjkljaj padavin v januarju so povzročili neugodne hidrološke razmere v vodonosnikih že v začetku leta 2002. Nekatere vodonosnike je zajela zimska hidrološka suša podzemnih voda, ki ni pogosta značilnost hidrološkega režima. V severovzhodni Sloveniji se je nadaljevala večletna hidrološka suša, ki je trajala celo leto. Zaradi neugodnega vodnega režima so bile v letu 2002 povprečne letne gladine podzemne vode povečini pod povprečjem (Hs) dolgoletnega primerjalnega obdobja, v vodonosnikih severovzhodne Slovenije pa zaradi izrazite hidrološke suše celo pod nizkim dolgoletnim povprečjem (Hnp) (graf 20, preglednica 14, karta 5). Nihanja gladin so bila razmeroma umirjena, vodne zaloge pa večji del leta povečini v razponu običajno pričakovanih. V splošnem so bile zaloge podzemne vode povsod večje na koncu leta kot v prvih mesecih.

Višine gladin podzemnih voda v aluvialnih vodonosnikih na Slovenskem so v splošnem odvisne od ravnovesja med dotoki vode na eni strani ter odtoki, izgubami in umetnimi odvzemi na drugi strani. Viri napajanja podzemne vode so padavine na območjih vodonosnikov in v njihovem padavinskem zaledju, kakor tudi pronicanje iz rek Ledave, Mure, Drave, Savinje, Kamniške Bistrice, Kokre, Save, Vipave in Soče ter ostalih manjših vodotokov na območju vodonosnikov. Odtoki podzemne vode so posledica dreniranja v vodotoke, izgube pa so posledica evapotranspiracije, ki je posebej pomemben dejavnik v plitvih vodonosnikih severovzhodne Slovenije. Umetni odvzemi so predvsem črpanja za oskrbo z vodo, v širšem pomenu tudi odvajanje podzemne vode z melioracijskimi posegi. Za tolmačenje vodnih razmer v vodonosnikih je torej potrebno upoštevati prostorsko in časovno spremenljivost količine padavin, evapotranspiracije in višino vode v rekah, ki mejijo na vodonosnike.

Podnebni dejavniki, ki najbolj vplivajo na režim podzemnih voda – količina padavin in temperatura zraka, so bili na območju vodonosnikov večinoma neugodni. Meteorološka suša se je iz pozne jeseni 2001 nadaljevala celo zimo, večino mesecev

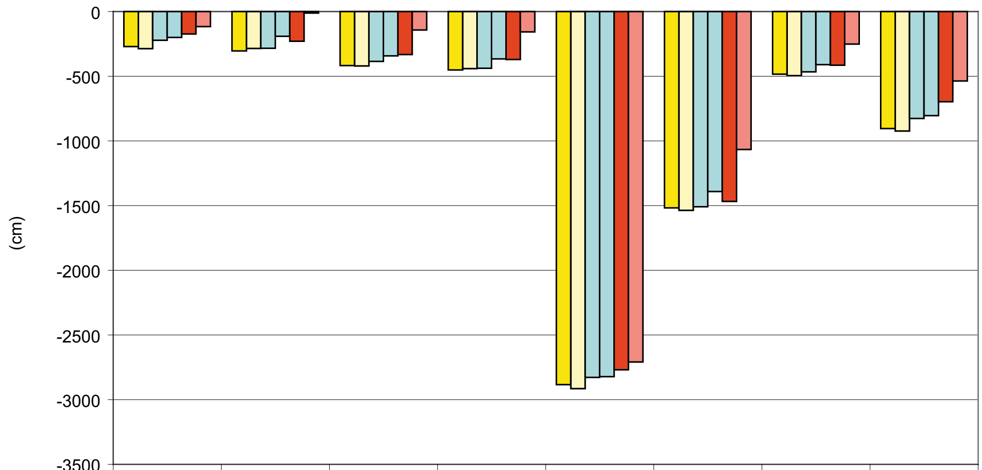
B. GROUNDWATERS

GROUNDWATER LEVELS IN ALLUVIAL AQUIFERS

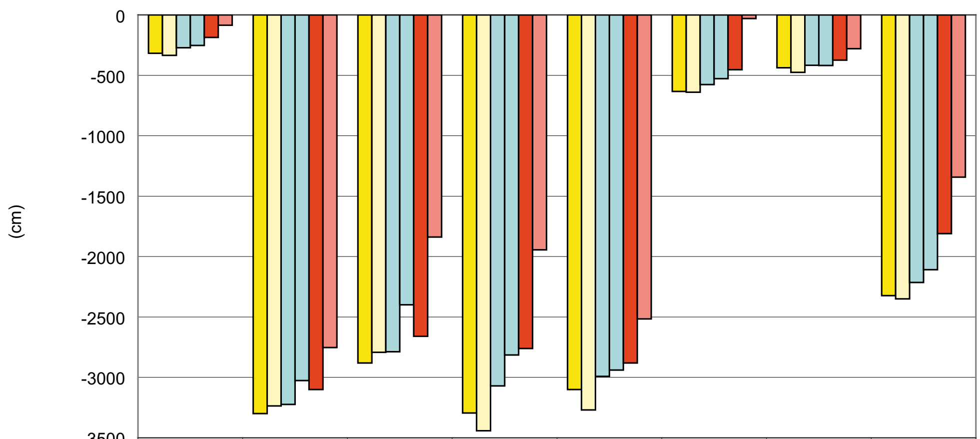
Zlatko Mikulič

The hydrological drought in the last three months of the previous year and a large deficit in precipitation in January already caused unfavourable hydrological conditions in the aquifers in the first part of the year 2002. Several aquifers were affected by the winter hydrological drought of groundwater, which is not a frequent characteristic of the hydrological regime. In north-eastern Slovenia the hydrological drought, already of several-years duration, continued, lasting throughout the whole year. Due to the unfavourable water regime, the mean water levels of groundwater in 2002 were mostly below the mean (Hs) of the multi-annual comparative period, while in the aquifers of north-eastern Slovenia, they were below even the minimum multi-annual mean (Hnp) (Graph 20, Table 14, Map 5) due to the severe hydrological drought. The fluctuations of the water levels were relatively steady, while the water reserves were within the ranges usually expected during the most of the year. In general, the reserves of groundwater were larger everywhere at the end of the year than during the first months.

The groundwater levels in the alluvial aquifers in Slovenia generally depend on the balance between the inflows of water on one hand, and outflows, losses and withdrawals on the other. The source of groundwater recharge is the rainfall in the area of the aquifers and the interflow from adjacent catchments, as well as the recharge from the rivers Ledava, Mura, Drava, Savinja, Kamiška Bistrica, Kokra, Sava, Vipava and Soča and other small watercourses in the area of the aquifers. Groundwater outflows are a consequence of drainage into watercourses, while the losses are a consequence of evapotranspiration, which is a particularly important factor in the shallow aquifers of the north-eastern part of Slovenia. The artificial withdrawals are mostly by pumping for the water supply though, in the broader meaning of the term, they also include the drainage of groundwater by melioration. For interpreting the groundwater regime of the aquifers, it is therefore important to consider the spatial as well as the temporal variability of the amount of precipitation, the evapotranspiration and the water levels in the rivers bordering on the aquifers.



	0970 Brezovica	3370 Rankovci	0400 Zg. Krapje	0120 M. Segovci	0080 Kamnica	0721 Tezno	0370 Dornava	0840 Šempeter
Hnk-2002	-271	-305	-417	-451	-2884	-1518	-484	-904
Hnk-obdobje / Hnk-period	-287	-286	-420	-441	-2915	-1537	-496	-923
Hs-2002	-222	-284	-385	-438	-2828	-1509	-466	-827
Hs-obdobje / Hs-period	-199	-191	-343	-366	-2822	-1391	-410	-804
Hvk-2002	-174	-229	-332	-370	-2769	-1467	-414	-697
Hvk-obdobje / Hvk-period	-116	-12	-142	-157	-2709	-1066	-252	-537



	VČ-5072 Latkova vas	0320 Meja	0360 Brnik	MP-0275 Mengeš	0541 Kleče	0152 Skopice	0111 Sp. S. Grad	0220 Šempeter
Hnk-2002	-317	-3299	-2881	-3294	-3101	-634	-438	-2323
Hnk-obdobje / Hnk-period	-335	-3236	-2792	-3442	-3269	-640	-476	-2350
Hs-2002	-271	-3224	-2788	-3071	-2991	-576	-417	-2214
Hs-obdobje / Hs-period	-253	-3026	-2399	-2815	-2939	-528	-419	-2109
Hvk-2002	-186	-3101	-2659	-2761	-2881	-453	-374	-1810
Hvk-obdobje / Hvk-period	-85	-2753	-1839	-1945	-2516	-30	-279	-1343

Graf 20: Primerjava značilnih gladin podzemnih voda v letu 2002 z značilnimi gladinami za primerjalno obdobje 1961-1990 (Hs = srednja letna / obdobna gladina, Hnk = najnižja letna / obdobna gladina, Hvk = najvišja letna / obdobna gladina).
Graph 20: Characteristic groundwater levels in the year 2002 compared to the multi-annual characteristic levels of the period 1961-1990 (Hs = the mean yearly / period level, Hnk = the lowest yearly / period level, Hvk = the highest yearly / period level).

skozi leto je na območju vodonosnikov padlo manj dežja od povprečja primerjalnega obdobja 1961-1990, srednja letna temperatura zraka pa je na nekaterih vodonosnikih presegla povprečje za več kot dve stopinji Celzija.

Razporeditev celoletne količine padavin po vodonosnikih je bila neenakomerna. Pri večini vodonosnikov so letne količine do ene desetine odstopale od povprečne vrednosti. Izjemi sta bili Dolenjska pri presežkih in severovzhodna Slovenija pri primanjkljajih. Na območju Krške kotline je padlo več dežja od dolgoletnega povprečja, s presežki v nekaterih predelih do ene četrtine nad povprečjem. V zgornje Vipavski dolini so bila povprečja presežena do ene desetine. V vseh preostalih vodonosnikih je primanjkovalo povečini do ene desetine povprečne količine dežja. Primanjkljaj padavin na celoletni ravni je bil na območju vodonosnikov severovzhodne Slovenije velik, več kot eno desetino. Največji primanjkljaji so bili zabeleženi na območju Prekmurja, kjer je bila meteorološka suša najhujša. V vzhodnem delu Prekmurja je bil celoletni primanjkljaj okoli ene četrtine povprečne letne količine dežja. Za režim podzemnih voda je še bolj kot prostorska bila pomembna časovna razporeditev primanjkljajev. Časovno so bili primanjkljaji sklenjeno razporejeni po celi Sloveniji v prvih treh mesecih leta. Največji primanjkljaj je bil januarja, ko je na območju vodonosnikov padla komaj ena petina povprečne količine padavin za ta mesec. Tedaj je meteorološka suša, kot nadaljevanje klimatskega odklona v zadnjih treh mesecih leta 2001 s približno polovičnim primanjkljajem padavin, dosegla vrhunec. Povečini so bili na območju vodonosnikov suhi še maj, junij, september, november in december. Ostali meseci so bili nekoliko bolj vodnati, s količinami nad povprečjem, še najbolj pa april in oktober, s presežki do ene polovice. Prva polovica leta je bila bolj suha od druge, kar je vplivalo na celo leto, saj ni bilo zadostne zadržane zaloge vode v snegu za uravnavanje režima podzemnih voda v toplejših mesecih. V celoti je bilo torej napajanje vodonosnikov iz padavin pod povprečjem, z izjemo vodonosnikov Krške kotline. V Prekmurju presežki padavin v vsega štirih posameznih mesecih leta niso mogli nadomestiti primanjkljajev, še posebej zato, ker so bili padavinski primanjkljaji zvezni tudi po več mesecev zapovrstjo.

Na območju vseh aluvialnih vodonosnikov so bile v letu 2002 izgube vode z evapotranspiracijo nadpovprečno velike, predvsem zaradi višje temperature zraka in nadpovprečnega sončnega obsevanja. Trajanje sončnega obsevanja je bilo na območjih vseh vodonosnikov okoli ene desetine nad povprečjem, na območju Celjske kotline pa celo več kot eno petino. Na območju vseh vodonosnikov, z izjemo Vipavsko Soške doline, je bila srednja letna temperatura za okoli dve stopinji Celzija višja od

The climatic factors which mostly influence the groundwater regime – the amount of precipitation and the air temperature – were mostly unfavourable in the area of the aquifers. The meteorological drought continued from the late autumn of 2001 throughout the whole of the winter. In the majority of the months throughout the year the amount of rain in the area of the aquifers was lower than the mean of the comparative period 1961-1990, while the mean yearly air temperature at some aquifers exceeded the mean by more than two degrees Celsius.

The distribution of the yearly amount of rainfall among the aquifers was not equal. At the majority of aquifers the yearly amounts deviated from the mean value by up to one tenth. The two exceptions were the region of Dolenjska (with surpluses) and north-eastern Slovenia (with deficits). In the area of the Krško Basin, the amount of rain was higher than the multi-annual mean, with surpluses in some parts of up to one quarter higher than the mean. In the Upper Vipava Valley means were exceeded by up to one tenth. At all the other aquifers there was a deficit in the amount, mostly of up to one tenth of the average quantity of rain. The precipitation deficit at the yearly level in the area of the aquifers of north-eastern Slovenia exceeded one tenth. The highest deficits were recorded in the area of Prekmurje where the meteorological drought was at its most severe. In the eastern part of Prekmurje, the yearly deficit was around one quarter of the average yearly amount of rain. The temporal distribution of deficits is even more important than the spatial one for the groundwater regime. Temporally, the deficits were distributed all over Slovenia without interruption in the first three months of the year. The highest deficit occurred in January, when only one fifth of the average amount of precipitation for that month fell in the area of the aquifers. At that time, the meteorological drought, as the continuation of the climatic deviation in the last three months of 2001, reached its highest point with an approximate 50 percent deficit in precipitation. Mostly dry in the area of the aquifers were also the months of May, June, September, November and December. During the other months, the amount of water was somewhat higher with amounts above the mean, the wettest being April and October with surpluses of up to one half. The first half of the year was dryer than the second, which had an influence on the whole year, since there were no satisfactory reserves of snow accumulation for balancing the groundwater regime during the warmer months. In general, the recharging of aquifers from precipitation was below the mean, with the exception of the aquifers in the Krško Basin. In Prekmurje, a precipitation surplus in just four months could not make up for the deficits, especially since the precipitation deficits lasted for several months in a row.

Preglednica 14: Primerjava značilnih gladin podzemnih voda v letu 2002 z značilnimi gladinami primerjalnega obdobja 1961-1990.
Table 14: The characteristic groundwater levels in the year 2002 compared to the multi-annual characteristic levels of the comparative period 1961-1990.

POSTAJA LOCATION	VODONOSNIK AQUIFER	2002			OBDOBJE / PERIOD					
		Hnk (cm)	Hs (cm)	Hvk (cm)	časovni niz (leta) time series (years)	Hnk (cm)	Hnp (cm)	Hs (cm)	Hvp (cm)	Hvk (cm)
0970 Brezovica	PREKMURSKO POLJE	271	222	174	1980-2000	287	251	199	140	116
3370 Rankovci	PREKMURSKO POLJE	305	284	229	1971-2000	286	244	191	102	12
0400 Zgornje Krapje	MURSKO POLJE	417	385	332	1964-2000	420	383	343	283	142
0120 Mali Segovci	APAŠKO POLJE	451	438	370	1991-2000	441	409	366	274	157
0080 Kamnica	VRBANSKI PLATO	2884	2828	2769	1981-2000	2915	2877	2822	2757	2709
0721 Tezno	DRAVSKO POLJE	1518	1509	1467	1971-2000	1537	1479	1391	1268	1066
0370 Dornava	PTUJSKO POLJE	484	466	414	1961-1990	496	445	388	311	135
0840 Šempeter	SP. SAVINJSKA DOLINA	904	827	697	1982-2000	923	888	804	641	537
VČ-5072 Latkova vas	DOLINA BOLSKE	317	271	186	1975-2000	335	306	253	166	85
0320 Meja	SORŠKO POLJE	3299	3224	3101	1987-2000	3236	3095	3026	2891	2753
0360 Brnik	KRANJSKO POLJE	2881	2788	2659	1987-2000	2792	2618	2399	2012	1839
MP-0275 Mengeš	D. KAMNIŠKE BISTRICE	3294	3071	2761	1976-2000	3442	3148	2815	2332	1945
0541 Kleče	LJUBLJANSKO POLJE	3101	2991	2821	1974-2000	3269	3080	2939	2735	2516
0152 Skopice	KRŠKO POLJE	634	576	453	1980-2000	640	564	528	316	30
0111 Spodnji Stari grad	BREŽIŠKO POLJE	438	417	374	1971-2000	476	452	419	339	279
0220 Šempeter	VIPAVSKO-SOŠKA D.	2323	2214	1810	1971-2000	2350	2264	2109	1761	1343

povprečja 1961-1990. Tudi v Vipavsko Soški dolini je bila nadpovprečna, višja za poldrugo stopinjo Celzija. Dni z najvišjo temperaturo zraka nad 25 stopinj Celzija je bilo na območju večine vodonosnikov vsega skupaj za dobra dva meseca, v zahodni Sloveniji in v Prekmurju pa za okoli tri mesece. V takih razmerah je povečana evapotranspiracija v severovzhodni Sloveniji v obdobju vegetacije rastlin izrazito načenjala že tako pičle vodne zaloge zaradi podpovprečne količine padavin.

Opisana razporeditev padavin se je kazala v časovni in prostorski porazdelitvi pretokov oziroma višine vode rek, ki mejijo na vodonosnike. Praviloma so bili vodotoki manj vodnati v vzhodni polovici države, z najmanjšimi pretoki v severovzhodni Sloveniji. Prvih sedem mesecev leta je bilo hidrološko suhih. Kot posledica podpovprečne količine padavin v tem mesecu in primanjkljaja iz zadnjih mesecev prejšnjega leta je bila hidrološka suša najbolj izrazita januarja. Ker ni bilo zadostnih zalog snega, pa tudi ne velikih količin padavin v naslednjih mesecih, so se nizki pretoki nadaljevali vse do avgusta. Ta izpad vodnih količin je bil tako hud, da ni bil nadomeščen vse do konca leta. Večina vodotokov je bila na letni ravni manj vodnatih od dolgoletnega povprečja 1971-2000. Najizrazitejše pomanjkanje vodnih količin je bilo v Prekmurju, kjer je imela Ledava le štiri desetine povprečnega letnega pretoka.

The water losses in 2002 by evapotranspiration were above average in all alluvial aquifers, mainly due to the high air temperature and the insolation, which was also above average. The duration of the solar insolation in the areas of all the aquifers was around one tenth above average, while in the area of the Celje Basin it was even in excess of one fifth. In the area of all the aquifers, with the exception of the Vipava Soča Valley, the mean yearly temperature was around 2 °C higher than the mean of the period 1961-1990. It was above average also in the Vipava Soča Valley, higher by 1.5 °C. In the area of most of the aquifers, the daily temperature remained for more than 60 days at above 25 °C. In the western part of Slovenia, as well as in Prekmurje, such temperatures lasted even longer, about 90 days. In such conditions the increased evapotranspiration in north-eastern Slovenia during the period of plant vegetation caused the water reserves, already scarce due to the precipitation deficit, to decrease still further.

This distribution of precipitation was reflected in the temporal and spatial distribution of discharges and water levels in rivers bordering the aquifers. As a rule, the watercourses in the eastern part of the country had lower amounts of water, the lowest discharges appearing in north-eastern Slovenia. The first seven months of the year were hydrologically dry. The hydrological drought was at

Suha struga Save Dolinke na opuščeni vodomerni postaji Podkoren 3. aprila 2002.
(foto: Marko Burger)
Dry riverbad of the Sava Dolinka river at Podkoren on the 3rd April 2002.
(photo: Marko Burger)

Za obnavljanje vodnih zalog podzemnih voda je bila zelo pomembna velika vodnatost rek v avgustu, ko so ponekod pretoki dosegli večkratnik povprečnih avgustovskih pretokov. S tem je bila, razen severovzhodne Slovenije, preprečena poletna suša v večini vodonosnikov. V Prekmurju je bil pretok Ledave tudi v avgustu pod povprečjem, kar je dodatno prispevalo k intenziviranju hidrološke suše v vodonosnikih. V splošnem je bil vpliv površinskih voda na višine gladin podzemne vode v prvih sedmih mesecih leta neugoden, v zadnjih petih pa ugoden. Od tega odstopa območje severovzhodne Slovenije, kjer pičle količine ponikle površinske vode v podzemlje niso omilile hude hidrološke suše podzemnih voda vse leto.

Opisane meteorološke in hidrološke razmere so pomembno vplivale na režim nihanja vodnih zalog podzemnih voda med letom, skupno so se odrazile tudi v letnih statističnih značilnostih višine vode.

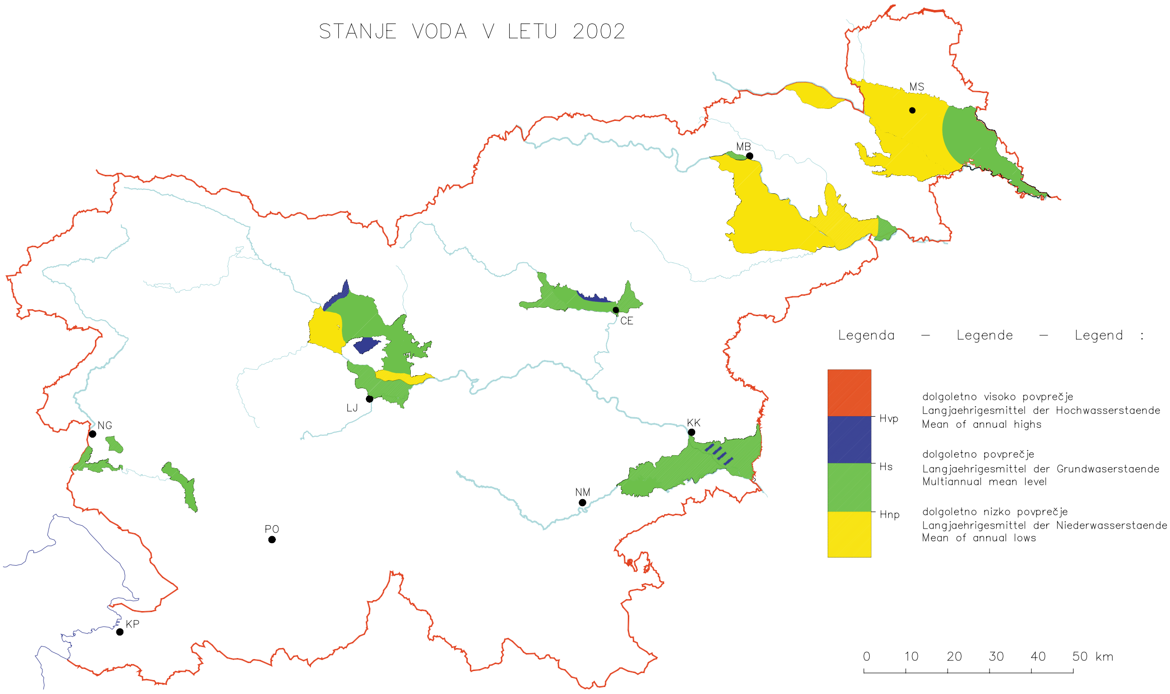
Statistike značilnih letnih gladin Hnk, Hs in Hvk (graf 20) so grobi pokazatelj vodnih zalog, oziroma statistično povprečenega režima na celoletni ravni. Ti statistični parametri omogočajo grobo oceno spremenljivosti v prostoru, ne morejo pa zajeti časovne spremenljivosti med letom. Primerjava srednjih letnih gladin (Hs) kaže vodne zaloge v letu 2002 pod povprečnimi. Največja odstopanja so v vodonosnikih Kranjskega in Sorškega polja zaradi zmanjšanega pronicanja vode iz Save na odseku vodnega zadrževalnika HE Mavčiče. Nekoliko višje od primerjalnega obdobja so bile srednje letne gladine le v dveh primerih: na Vrbanskem platoju in na nizki terasi Brežiškega polja. V obeh zaradi ugodnega vpliva površinskih voda. Na spodnji terasi Brežiškega polja že nekaj let opažamo boljše vodno stanje od preostalih delov vodonosnikov Krške

its most severe in January due to the below-average quantity of precipitation in that month and to the deficit from the last months of the previous year. As accumulation of snow was low and there were no large amounts of precipitation during the following months, the low discharges lasted until August. This shortage of water was so severe that it was not made up for until the end of the year. On the yearly level, the water quantities of most rivers were lower than the multi-annual mean of the period 1971-2000. The most significant deficit of water amounts occurred in Prekmurje, where the Ledava River had only four tenths of the mean yearly discharge.

Very important for the renewal of the groundwater reserves was the amount of water in the rivers in August when, in some areas, the discharges reached a multiple of the mean discharges in August. This occurrence prevented a summer drought in most aquifers, with the exception of the north-eastern part of Slovenia. In Prekmurje, the discharge of the Ledava River was also below average in August, contributing additionally to the increased intensity of the hydrological drought in the aquifers. Generally, the influence of surface waters on the groundwater levels was unfavourable during the first seven months of the year, but favourable in the last five months. This was not the case in the area of north-eastern Slovenia however, where the scarce amounts of surface water recharging the aquifers did not mitigate the severe hydrological drought of groundwater throughout the whole year.

These meteorological and hydrological conditions had an important influence on the fluctuations of the reserves of groundwater during the year; in their total, they were reflected also in the yearly statistical characteristics of the water levels.

The statistics of the characteristic annual water levels Hnk, Hs and Hvk (Graph 20) roughly show the water reserves with the statistical average regime on a yearly basis. These statistical parameters allow a rough estimation of the spatial variability, but they cannot explain the temporal variability during the year. The comparison of the mean annual groundwater levels (Hs) indicates that the water reserves in 2002 were below average. The highest deviations/deficits occur in the aquifers of the Kranj and Sora plains due to the decreased infiltration of water from the Sava River at the section near the Mavčiče hydro power plant water reservoir. In only two cases were the mean annual water levels somewhat higher than in the comparative period: at the Vrbanski plateau and at the low terrace of the Brežice Plain; in both cases, due to the favourable influence of the surface waters. At the lower terrace of the Brežice Plain a water situation that is better than that of the rest of the Krško Basin aquifers has



Karta 5: Srednje letne gladine leta 2002 v največjih slovenskih aluvialnih vodonosnikih.
Map 5: Mean water levels in 2002 in major Slovenian alluvial aquifers.

kotline. To pripisujemo ugodnemu vplivu zajezitve Save za jedrsko elektrarno Krško s povečanim pronicanjem iz reke. Domnevamo, da v tem zadrževalniku ni takega zamuljevanja kot v zadrževalniku HE Mavčiče, ker ima Sava v času vsakoletnih večtedenskih vzdrževalnih del jedrske elektrarne naravni hitri tok z večjo erozijsko močjo. Na Vrbanskem platoju je režim podzemne vode drugačen od preostale severovzhodne Slovenije, saj ni odvisen od lokalnih podnebnih razmer. Vodonosnik se pretežno napaja iz Drave, ki ima povirje v visokih avstrijskih Alpah in ugoden snežni režim z velikimi pretoki v poletnem času. V severovzhodni Sloveniji, razen opisane izjeme Vrbanskega platoja, kaže izrazito hidrološko sušo tudi primerjava nizkih letnih konic (Hnk), saj so se tam gladine podzemne vode v letu 2002 že drugo leto zapovrstjo znižale pod raven najnižjih gladin primerjalnega obdobja. Kot posledica suše na tem območju so bile najvišje letne konice (Hvk) pod obdobnimi, v nekaj primerih so bile celo nižje od srednjih obdobnih gladin. V severovzhodni Sloveniji je bil v letu 2002 že drugo leto zapovrstjo celotni razpon nihanja gladin premaknjen navzdol. Nizke so bile visoke letne konice tudi na območju Kranjskega in Sorškega polja, vendar tam zaradi že opisanega umetnega vpliva. V vseh vodonosnikih so bile visoko vodne konice nižje od obdobnih, kar pomeni da v letu 2002 ni bilo obdobij zelo intenzivnega napajanja vodonosnikov.

Režim nihanja gladin oziroma zalog podzemnih voda v letu 2002 je bil poleg uvodoma opisanih dejavnikov vodne bilance pogojen tudi z

been registered for several years. This is ascribed to the favourable influence of the water retention level of the Sava River for the Krško nuclear power plant and to an increase in infiltration from the river. It is assumed that siltation is less intensive in this reservoir than in the water reservoir of the Mavčiče hydro power plant, because during the yearly several-week long maintenance works at the nuclear plant it is seen that the Sava River has a natural fast current with a greater power of erosion. At the Vrbanski plateau, the groundwater regime is different from the rest of north-eastern Slovenia as it is not dependant on the local climatic conditions. The aquifer is mainly recharged from the Drava River with its headwaters in the high Austrian Alps and from a favourable nival regime with high discharges during the summer period. In north-eastern Slovenia, with the exception of the aforementioned case of the Vrbanski plateau, the explicit hydrological drought is reflected also by the comparison of the low annual peaks (Hnk) since groundwater levels in 2002 already dropped below the low levels of the comparative period for the second year in a row. As a consequence of the drought in this area, the highest annual peaks (Hvk) were below the mean peaks of the period; in some cases they were even lower than the mean levels of the period. In north-eastern Slovenia the entire range of the water level fluctuations in 2002 was shifted downwards for the second year in a row. The high annual peaks in the area of the Kranj and Sora plains were low, but this was due to the previously described artificial influence. In all the aquifers, the maximum water režimom v predhodnem letu. Zaradi polovičnega primanjkljaja padavin v zadnjih treh mesecih leta 2001, je izostalo običajno pozno jesensko obnavljanje zalog podzemne vode. Tako je bilo izhodiščno stanje zalog podzemne vode na začetku leta 2002 povsod neugodno, še posebej v severovzhodni Sloveniji. Pomanjkanje padavin v prvih treh mesecih je samo še poslabšalo razmere.

Glede časovne spremenljivosti režima v letu 2002 so bile tako velike razlike med vodonosniki severovzhodne Slovenije in vodonosniki v preostalem delu države, da ta dva prostorska sklopa opisujemo ločeno. Že od leta 2000 naprej v severovzhodni Sloveniji opažamo drugačen vodni režim od vodonosnikov v preostalem delu države.

Glavne značilnosti režima podzemnih voda v severovzhodni Sloveniji so bile:
- hidrološke sušne razmere v nekaterih predelih vodonosnikov vse leto,
- širitev območij vodonosnikov zajetih s hidrološko sušo preko leta,
- razmeroma ustaljen režim z malimi amplitudami nihanja gladine podzemne vode,
- gladine podzemne vode pod obdobnim minimumom – zabeležene rekordno nizke gladine,
- do konca leta se vodne zaloge v vodonosnikih Prekmurja niso obnovile na raven povprečnih,
- različen režim v vodonosniku Vrbanskega platoja od preostalih vodonosnikov tega območja.

V severovzhodni Sloveniji hidrološka suša v vodonosnikih traja neprekinjeno od leta 2000, kar je nov pojav »večletne suše«. V letu 2002 smo v Prekmurju prvič zabeležili nov zaskrbljujoči pojav. Gladine so bile večji del leta pod najnižjo ravnijo v zadnjih petdesetih letih. Vse do konca leta se vodne zaloge niso obnovile na povprečno raven. To pomeni, da je bil vsak odvzem podzemne vode črpanje statičnih zalog. Če se vodo črpa brez obnove zalog, je to rudarjenje podzemne vode, podobno kot izkoriščanje neobnovljivih zalog naravnih surovin – na primer črpanje nafte. Prekmurje je bilo sušno vse leto, prav tako Apaško polje, le na Murskem polju so bila krajša obdobja ugodnejših vodnih zalog, čeprav tudi tedaj pod srednjo obdobno letno gladino.

Večja izjema od opisanih razmer severovzhodnega dela države je bil že omenjeni vodonosnik Vrbanskega platoja. Tam smo hidrološke sušne razmere beležili le januarja in februarja, v preostalem delu leta so bile zaloge povprečne, včasih celo nad srednjo obdobno letno gladino.

V preostalih vodonosnikih po državi so bile višine vodnih gladin med letom precej spremenljive. Leto se je začelo z manj ugodnimi vodnimi zalogami, glavne značilnosti režima podzemnih voda pa so bile:

peaks were lower than the mean peaks of the period, meaning that in 2002 there were no periods of very intensive recharging of the aquifers.

The regime of fluctuations of the groundwater reserves, e.g. the levels in 2002, was not only conditioned by the factors previously mentioned. It is also affected by the regime of the preceding year. Due to the 50 percent deficit of precipitation in the last three months of the year 2001, there was no usual renewal of groundwater reserves in late autumn. Thus, the groundwater reserves in the first part of 2002 were insufficient everywhere, especially in north-eastern Slovenia. The precipitation shortage in the first three months only worsened the conditions.

As far as the temporal variability of the hydrological regime in 2002 is concerned, there were substantial differences between the aquifers of north-eastern Slovenia and those elsewhere, so they are discussed separately. Since 2000 onwards, a water regime is being observed in the north-eastern part of Slovenia that is different from the aquifers in the rest of the country.

The main characteristics of the groundwater regime in north-eastern Slovenia were:
- drought in some parts of the aquifers from the beginning of the year,
- the areas affected by the drought have been extending over the course of the year,
- a relatively stable regime with low groundwater fluctuation amplitudes,
- groundwater levels are below the period minimum – the record low water levels registered,
- by the end of the year, the water reserves in the aquifers of Prekmurje had not renewed to the average level,
- at the Vrbanski plateau aquifer there is a regime that is different again from the rest of the aquifers in the area.

In the north-eastern part of Slovenia the hydrological drought in the aquifers has persisted without interruption since the year 2000, which represents a new phenomenon of "multi-annual drought". In 2002 a new worrying phenomenon was registered in Prekmurje for the first time. During most of the year, the water levels remained below the lowest level recorded in the last fifty years and by the end of the year the water reserves had not renewed to the average level. This meant that each extraction of groundwater was in fact the pumping of the static reserves. If the water is being pumped without renewal of the reserves then this is, in fact, mining of the groundwater similar to the exploitation of the non-renewable reserves of natural raw materials – for example, oil-pumping. Prekmurje and the Apače Plain remained dry throughout the year, while the Mura Plain experienced short periods of more favourable

- vodne zaloge pretežno v mejah običajnih letnih nihanj,
- nizke vodne zaloge, ponekod suša v prvih treh mesecih leta,
- ugodne zaloge podzemne vode nad srednjo dolgoletno ravnijo v zadnjih treh mesecih leta,
- izostanek običajne poletne hidrološke suše,
- razmeroma umirjena nihanja brez ekstremno visokih gladin in
- zaloge podzemne vode pod obdobnim letnim povprečjem večji del leta.

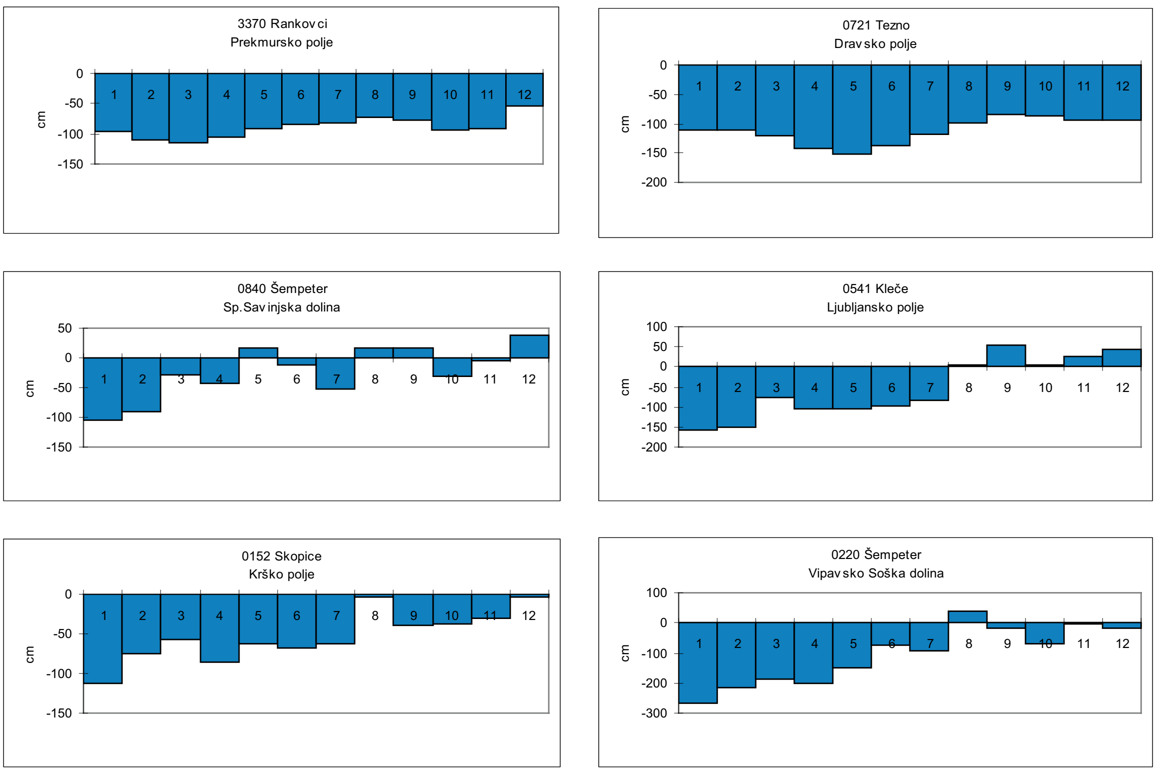
Primanjkljaj padavin v januarju je poslabšal že neugodne vodne zaloge podzemne vode iz jeseni 2001. Tedaj je ob severovzhodni Sloveniji hidrološka suša zajela še vodonosnike v dolini Kamniške Bistrice, Krškega polja, doline Bolske in Vipavsko Soške doline. V slednji se je suša obdržala še do srede aprila. Kljub pičlim padavinam razmere zaradi nizke evapotranspiracije drugod niso bile kritične. Vse do avgusta so bile zaloge podzemne vode povsod blizu povprečja, pod srednjo obdobno letno gladino. V teh sedmih mesecih so bili edina izjema vodonosniki Celjske kotline, ki so imeli občasno zaloge nad srednjo obdobno letno gladino. Od avgusta naprej, z izjemo septembra, so bile vodne zaloge nad srednjo obdobno letno gladino, posebej ugodne pa v zadnjih treh mesecih. Med vsemi vodonosniki je po dobrem vodnem stanju najbolj izstopalo območje

water reserves, although remaining even at that time below the mean yearly water level of the period.

A deviation from these conditions of the north-eastern part of the country was the aforementioned Vrbanski plateau aquifer. There the hydrological dry conditions were registered only in January and February and during the rest of the year the reserves were average, sometimes even above the mean water level of the period.

In other aquifers across the country, the water levels during the year were quite variable. The year started with less favourable water reserves, the main characteristics of the groundwater regime being:

- water reserves mostly within the limits of the usual yearly fluctuations,
- low water reserves in some places and drought in the first three months of the year,
- favourable groundwater reserves above the mean multi-annual level in the last three months of the year,
- the absence of the usual hydrological drought in the summer,
- relatively steady fluctuations without extremely high water levels,
- for most of the year, the groundwater reserves were below the yearly mean of the period.



Graf 21: Odstopanja srednjih mesečnih gladin podzemne vode v letu 2002, glede na srednje mesečne gladine za primerjalno dolgoletno obdobje 1961-1990.
Graph 21: The deviations of the mean monthly groundwater levels in the year 2002 from the mean monthly water levels in the comparative multi-annual period 1961-1990.

Celjske kotline. Kljub ugodnejšim padavinskim razmeram na Dolenjskem slabše vodne razmere v Krški kotlini od Celjske razlagamo z izjemno neugodnim izhodiščnim hidrološkim stanjem na začetku leta.

Mesečna odstopanja gladin v letu 2002 od mesečnih povprečij za primerjalno dolgoletno obdobje (graf 21) ponazarjajo opisane posebnosti režima tega leta. Izstopa celotno območje vodonosnikov severovzhodne Slovenije, kjer se je celoletna hidrološka suša kazala v negativnih odstopanjih mesečnih povprečij. Na tem območju so bila odstopanja nenavadno velika, še posebej v prvi polovici leta. Vodonosniki vse Slovenije kažejo nekaj skupnih posebnosti režima. Razmere so bile slabše v prvem kot v drugem delu leta, prevladujejo odstopanja navzdol. Presežki mesečnih povprečij so bili redki, največkrat so bili v Ljubljanski in Celjski kotlini.

Pri letnem poteku nihanja gladin so bile zabeležene visoke konice leta večinoma decembra, ali v nekaj primerih konec novembra. Izjema je vodonosnik doline Kamniške Bistrice, kjer so bili letni maksimumi ob decembru tudi avgusta in oktobra. Pri letnih minimumih je večja raznolikost. V večini države so bili na začetku leta največkrat januarja, manj februarja. Pogosti so bili tudi julija in sicer v Prekmurju, na Brežiškem polju in Šentjernejskem polju. Posebnost je Dravsko polje, kjer je bil letni minimum povečini oktobra. V severovzhodni Sloveniji so bile leta 2002 na nekaj postajah zabeležene do tedaj najnižje gladine v vsem dolgoletnem opazovalnem obdobju. Povsod po državi so bile gladine podzemne vode ob koncu leta višje od gladin v začetku leta. V severovzhodni Sloveniji je bilo zvišanje gladin premajhno za prekinitev pojava večletne hidrološke suše.

Po splošnih značilnostih režima podzemnih voda je bilo leto 2002 dokaj običajno, z izjemo celoletne hidrološke suše v vodonosnikih Severovzhodne Slovenije. Praviloma so bile gladine najvišje ob koncu leta. Izjemno nizka raven zalog podzemnih voda na koncu leta 2001 in primanjkljaj padavin v prvih treh mesecih sta v letu 2002 pogojevali podpovprečne zaloge podzemne vode prvih sedem mesecev. Zadnji trije meseci leta so bili najbolj ugodni, z največ zalog podzemne vode v letu.

Leto je zaznamovala izrazita hidrološka suša v nekaterih predelih vodonosnikov severovzhodne Slovenije, kjer je trajala vse leto. V teh predelih je neprekinjena večletna hidrološka suša že od pomladi leta 2000. V vročem in suhem poletju se je hidrološka suša stopnjevala z znižanjem na najnižjo zgodovinsko zabeleženo raven podzemnih voda. Kljub izboljšanju stanja proti koncu leta se tam gladine podzemne vode niso vrnile na povprečno raven.

The deficit of precipitation in January worsened the already unfavourable reserves of groundwater from the autumn of 2001. Besides north-eastern Slovenia, the hydrological drought at that time also affected the aquifers in the Kamniška Bistrica Valley, the Krško Plain, the Bolska Valley and the Vipava-Soča Valley. In the Vipava-Soča Valley the drought continued until the middle of April but, in spite of the scarce rainfall, the conditions elsewhere were not critical due to low evapotranspiration. Until August the groundwater reserves were close to the mean everywhere, but still below the mean water level of the period. In these seven months the aquifers of the Celje Basin presented the only exception, since they occasionally had reserves above the mean yearly water level of the period. From August onwards, with the exception of September, water reserves were above the mean annual water level of the period, especially in the last three months. Among all the aquifers, the area of the Celje Basin stood out due to the good state of the water there. Despite the more favourable precipitation conditions in Dolenjska, the water conditions in the Krško Basin were worse than in the Celje Basin, which is explained by the exceptionally unfavourable preliminary hydrological situation from the beginning of the year.

The monthly deviations of water levels in 2002 from the monthly means for the comparative multi-annual period (Graph 21) are illustrated by the aforementioned special features of the regime in that year. The entire area of the aquifers of north-eastern Slovenia stands out as where this year's hydrological drought was reflected in the negative deviations from the monthly means. Deviations in this area were unusually high, especially in the first half of the year. The aquifers show some common features throughout Slovenia. The conditions in the first part of the year were worse than in the second, with the prevalence of downward deviations. Levels in excesses of the monthly means were rare and mostly in the Ljubljana and Celje Basins.

High yearly peaks were mainly recorded in December, and only in some cases at the end of November. The exception was the aquifer of the Kamniška Bistrica Valley where yearly maximums also occurred in August and October. The yearly minimums showed a greater diversity. In the majority of the country, they occurred in the first part of the year mainly in January, less in February. They were also frequent in July, especially in Prekmurje, as well as at on the Brežice and Šentjernej Plains. The Drava Plain was a special case since the yearly minimum there was mostly registered in October. In 2002 the lowest water levels in the multi-annual observation period were recorded in some stations in the north-eastern part of Slovenia. Everywhere across the country the groundwater levels at the end of the year were higher than the levels at the first part of the year. In north-eastern Slovenia though, the increase of water levels was too low to interrupt the phenomenon of the multi-annual hydrological drought.

Regarding the general features of the groundwater regime, the year 2002 can be described as quite usual, with the exception of the year-long hydrological drought in the aquifers of north-eastern Slovenia. As a rule, the water levels were highest at the end of the year. An exceptionally low level of groundwater reserves at the end of 2001, as well as the deficit of rainfall in the first three months of 2002 caused the below-average reserves of groundwater in the first seven months. The last three months of the year were much more favourable, with the highest amount of groundwater reserves in the year.

The year was marked by a severe hydrological drought in some areas of the aquifers of north-eastern Slovenia which lasted throughout the year. In these areas the multi-annual hydrological drought continues without interruption since the spring of 2000. During the hot and dry summer the hydrological drought intensified, decreasing to the lowest registered level of groundwater in history. Despite the improvement of conditions towards the end of the year, groundwater levels there did not return to the normal level.

Kraški izvir Rižane 25. oktobra 2002.
(foto: Niko Trišić)
Karstic spring of the Rižana river on the 25th October 2002.
(photo: Niko Trišić)

PRELOMNA HIDROLOŠKA SUŠA PODZEMNIH VODA

Zlatko Mikulič

Hidrološka suša podzemnih voda v letu 2002 je zajela predvsem aluvialne vodonosnike severovzhodne Slovenije. Tam je trajala celo leto (preglednica 15), bila je izrazita in je bila po svojih značilnostih prelomnega značaja. Dosežene so bile najnižje vodne gladine od leta 1952, vodne zaloge pa so se znižale do ravni statičnih zalog. Hidrološka suša v severovzhodni Sloveniji je bila prelomna predvsem zato, ker se v vsem letu vodne zaloge niso vrnile v območje običajnih nihanj. Podzemne vode so kot del naravnega hidrološkega kroženja vode v naših aluvialnih vodonosnikih v normalnih razmerah obnovljivi vir. Pri normalnem režimu se primanjklaji in viški podzemne vode bolj ali manj izravnavajo med sezonami znotraj enega hidrološkega leta.

Med letom so bila občasno zajeta s hidrološko sušo tudi druga manjša območja, ki niso prikazana v preglednici 15, saj smo za prizadete označili le tiste vodonosnike, v katerih so bila nizka vodna stanja na pretežnem območju.

THE HYDROLOGICAL DROUGHT OF GROUNDWATER – A TURNING POINT

Zlatko Mikulič

The hydrological drought of the groundwater in 2002 mainly hit the alluvial aquifers of north-eastern Slovenia and lasted throughout the whole year (Table 15). The conditions were severe and have the characteristics of a turning point. The groundwater levels reached were the lowest since 1952, while the water reserves decreased to the level of static reserves. The hydrological drought in north-eastern Slovenia was a turning point because the water reserves in that year did not return to the range of their usual fluctuations. The groundwater as a part of the natural hydrological circulation of water in our alluvial aquifers is a renewable resource under normal conditions. In a normal regime the deficits and surpluses of groundwater more or less balance themselves between the seasons within one hydrological year.

During the year, other smaller areas were also occasionally hit by drought, but these are not presented in Table 15 since we marked as affected only those aquifers in which the low water state occurred in the predominant area.

Preglednica 15: Aluvialni vodonosniki, ki jih je v letu 2002 zajela suša.
Table 15: The alluvial aquifers affected by the drought in 2002.

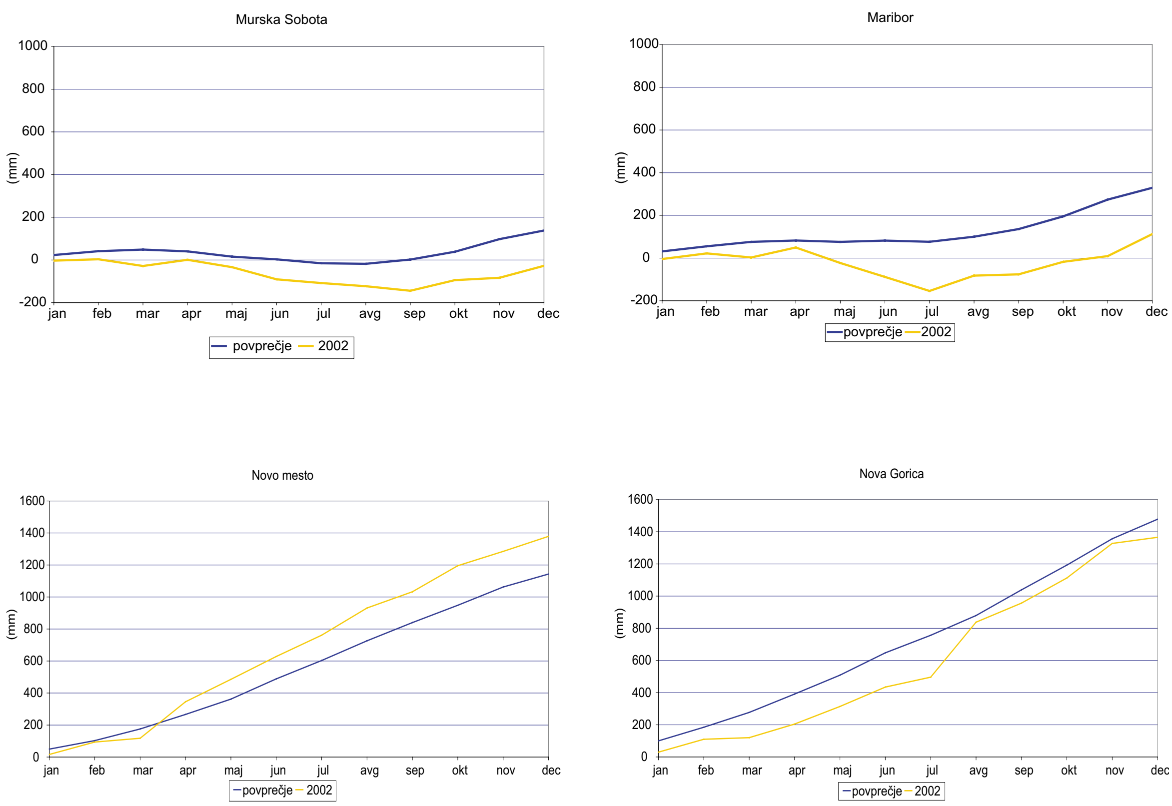
	J	F	M	A	M	J	J	A	S	O	N	D
Apaško polje	●	●	●	●	●	●	●	●	●	●	●	●
Prekmursko polje	●	●	●	●	●	●	●	●	●	●	●	●
Mursko polje	●	●	●	●	●	●	●		●	●	●	●
Vrbanski plato	●											
Dravsko polje	●	●	●	●	●	●	●	●	●	●	●	●
Ptujsko polje	●	●	●	●	●	●	●	●	●	●	●	●
Kranjsko polje												
Sorško polje												
Dolina Kamniške Bistrice	●											
Ljubljansko polje												
Krško polje	●		●									
Brežiško polje												
Čateško polje												
Šentjernejsko polje												
Območje Krakova												
Dolina Bolske	●											
Spodnja Savinjska dolina												
Dolina Hudinje												
Vipavsko Soška dolina		●	●	●								

Nizko vodno stanje in hidrološka suša v letu 2002 sta imeli zametke v klimatskih razmerah in režimu podzemnih voda predhodnega leta. V letu 2001 je bil v poletnih mesecih velik primanjkljaj dežja, ker pa so bile tudi temperature zraka nadpovprečno visoke, je to povzročilo hidrološko sušo v vseh vodonosnikih severovzhodne in vzhodne Slovenije ter v Vipavsko-Soški dolini. Po deževnem septembru je bil v treh zadnjih mesecih leta 2001 polovičen primanjkljaj padavin. Ta primanjkljaj je odločujoče vplival na nadaljnji razvoj dogodkov, saj običajno prav obilne oktobrske in še posebej novembrske padavine izravnajo vodne zaloge na letni ravni. Zaradi suhe jeseni se je hidrološka suša v severovzhodni Sloveniji neprekinjeno nadaljevala iz poletja do konca leta, v ostalih vodonosnikih pa so se gladine vso jesen zniževale. Na prehodu iz leta 2001 v leto 2002 se je v pretežnem delu vodonosnikov začela huda zimska hidrološka suša.

Meteorološka in hidrološka suša ob začetku zime 2001/2002 sta bili vzrok slabemu izhodiščnemu stanju vodnih zalog na začetku leta 2002. Primanjkljaj padavin, ki je sledil v prvih treh mesecih leta, je povzročil nadaljnje zniževanje vodnih gladin. Posebej hudo je bilo pomanjkanje v januarju, ko je

The low water state and the hydrological drought in 2002 had its origins in the climatic conditions and the ground water regime of the previous year. In 2001 a high deficit of rain took place during the summer months, together with above average air temperatures which caused hydrological drought in all the aquifers of eastern and north-eastern Slovenia, as well as in the Vipava-Soča Valley. After the rainy September, the last three months of 2001 saw a 50 percent deficit of rainfall. This deficit decisively influenced the further development of events, since it was usually the abundant rainfall in October and especially in November that balanced the water reserves at the yearly level. Due to the dry autumn the hydrological drought in north-eastern Slovenia continued without interruption from the summer until the end of the year while the water levels decreased in the remaining aquifers throughout the whole autumn. At the transition from 2001 to 2002 a severe winter hydrological drought began in the majority of aquifers.

The meteorological and hydrological drought at the end of the 2001/2002 winter caused a poor starting condition in the water reserves at the beginning of 2002. The deficit of precipitation which



Graf 22: Kumulativne efektivne padavine (mm) v letu 2002 (rumena črta) v primerjavi s povprečnimi kumulativnimi efektivnimi padavinami primerjalnega večletnega niza (modra črta).
Graph 22: The cumulative effective precipitation (mm) in 2002 (yellow line) in comparison to the mean cumulative effective precipitation in the comparative multi-annual series (blue line).

padla komaj četrtina običajne količine padavin. Od primanjkljajev padavin v naslednjih mesecih sta bila pomembna še maj in junij, ki sta bila povezana z nadpovprečno visokimi temperaturami zraka in povečanimi izgubami vode z evapotranspiracijo.

Primanjkljaji iz začetnih mesecev niso bili nadomeščeni niti do konca leta. Na celoletni ravni je bilo manj padavin od povprečja na območju vseh vodonosnikov razen Dolenjske. V Prekmurju je na celoletni ravni primanjkovalo tudi do četrtine običajne količine padavin. Od pozne pomladi do zgodnje jeseni je bila bilanca padavin na večini vodonosnikov negativna (graf 22), kar pomeni, da se je z evapotranspiracijo vrnilo v atmosfero več vode, kot je bilo dežja. Izjema je bilo območje Dolenjske s pozitivno bilanco na celoletni ravni.

Glavni vzroki nizkih vodnih stanj in hidrološke suše so bili v prizadetih aluvialnih vodonosnikih v letu 2002 sledeči:

- primanjkljaji padavin na celoletni ravni in povišane temperature na letni ravni, pri tem pa še posebej
- velik primanjkljaj padavin v obdobju od oktobra 2001 do marca 2002 in
- nadpovprečno visoke temperature zraka v vegetacijski sezoni in s tem povezane nadpovprečne izgube vode z evapotranspiracijo.

Hidrološka suša v severovzhodni Sloveniji v letu 2002 je bila tako huda in tako dolgotrajna, da so bile celo srednje letne gladine podzemne vode v vodonosnikih na tem območju v razponu nizkih vodnih stanj dolgoletnega primerjalnega obdobja. V preostalih vodonosnikih so bila letna povprečja znotraj razpona običajnih letnih nihanj, vendar povečini pod srednjimi gladinami dolgoletnega primerjalnega obdobja. To tudi kaže na neugodna nihanja vodnih zalog znotraj leta.

V severovzhodni Sloveniji so bile gladine podzemne vode večji del leta pod absolutnimi minimumi dolgoletnega primerjalnega obdobja (graf 23). Proti koncu leta so se gladine nekoliko zvišale, vendar le na raven nizkih gladin. To pomeni, da se v celem letu zaloge podzemne vode niso obnovile v območje običajnih nihanj. Drugod so bile razmere nekoliko boljše, saj so se po suši vodne zaloge na koncu leta obnovile.

Hidrološka suša v letu 2002 ni zajela vseh vodonosnikov v istem času in enako izrazito. V nekaterih vodonosnikih se je nadaljevala iz prejšnjega leta in se je potem različno razvijala.

Že iz prejšnjega leta so bile sušne razmere v januarju v vseh vodonosnikih severovzhodne Slovenije, ki so se nato tam nadaljevale vse do konca leta. Največja prostorska razširjenost hidrološke suše na tem območju je bila v juniju (karta 6). Izjema v vsej

followed in the first three months of the year caused a further decrease of water levels. Especially severe was the shortage in January, when hardly a quarter of the usual amount of precipitation fell. Among the precipitation deficits in the following months, May and June were also important, which were connected to the above-average air temperatures and the increased water losses by evapotranspiration.

The deficits from the initial months were not made up throughout the year. At the yearly level, precipitation was below the average in the areas of all the aquifers with the exception of Dolenjska. In Prekmurje there was a yearly shortage of up to one quarter of the usual amount of precipitation. From the late spring until the early autumn the balance of rainfall at the majority of the aquifers was negative (Graph 22), meaning that more water returned to the atmosphere through evapotranspiration than there was rain. The only exception was Dolenjska which had a positive balance on the yearly level.

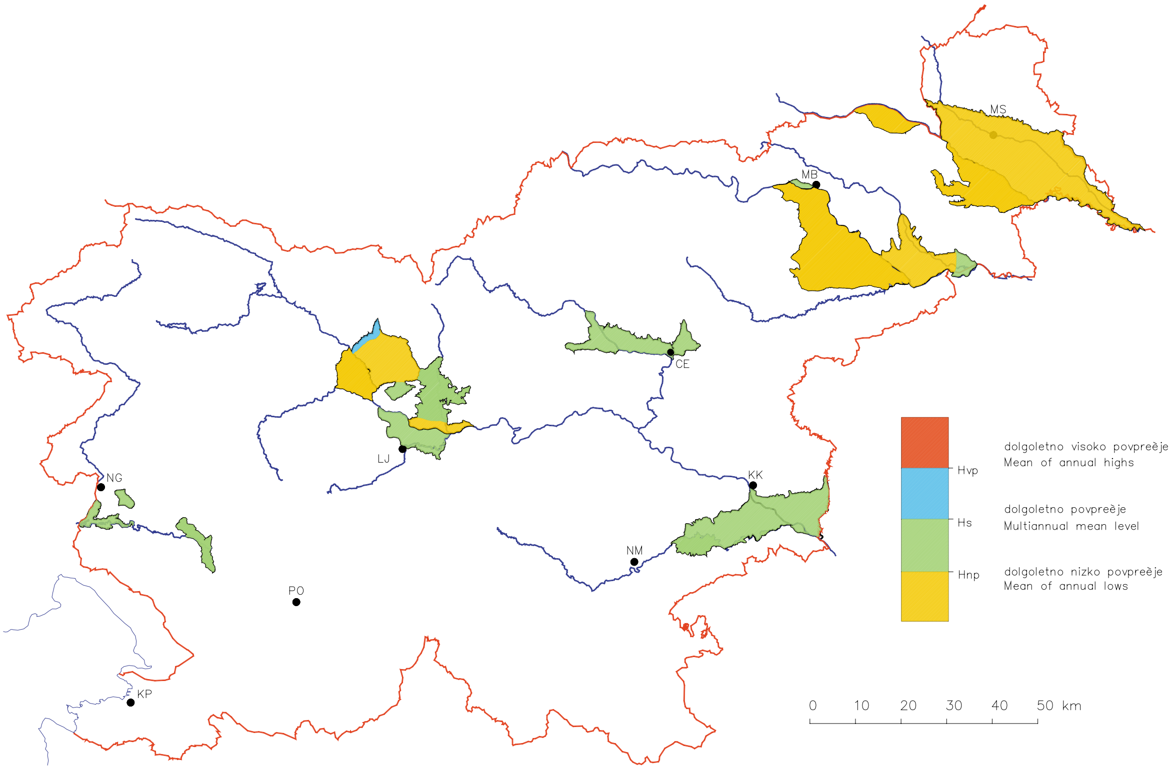
The main causes for the low water states and the hydrological drought in the affected alluvial aquifers in the year 2002 were the following:

- the deficits of rainfall at the yearly level and the increased temperatures on the yearly level, including especially
- a high deficit of rainfall in the period from October 2001 until March 2002, as well as
- the above-average air temperatures during the vegetation season and the corresponding above-average water loss by evapotranspiration.

The hydrological drought in north-eastern Slovenia in 2002 was so severe and long-lasting that even the mean yearly levels of groundwater in the aquifers in that area were in the range of the low waters in the multi-annual comparative period. In the rest of the aquifers the annual means were within the range of the usual yearly fluctuations, but mostly below the mean water levels in the multi-annual comparative period. This was also due to the unfavourable hydrological conditions of the fluctuations in the water reserves during the year.

In the north-eastern part of Slovenia, groundwater levels were below the absolute minimums of the multi-annual comparative period (Graph 23) for the most part of the year. The water levels increased to some extent towards the end of the year, but only to the level of the earlier low water levels. This means that the water reserves did not renew to the range of the usual fluctuations during the whole year. The conditions elsewhere were somewhat better since, after the drought, the water reserves did renew towards the end of the year.

The hydrological drought in 2002 did not hit all the aquifers at the same time and was not



Karta 6: Stanje vodnih zalog v aluvialnih vodonosnikih v juniju 2002, ko je bila hidrološka suša v severovzhodni Sloveniji najbolj razširjena.
Map 6: The amount of the water reserves in the alluvial aquifers in June 2002 when the hydrological drought in north-eastern Slovenia was most extended.

severovzhodni Sloveniji je bil vodonosnik Vrbanskega platoja, kjer je pretežni vir napajanja podzemne vode s pronicanjem iz reke Drave. Zaradi snežnega pretočnega režima Drave je tam spomladi prišlo do izboljšanja vodnih zalog. V poletnih mesecih celo nad srednjo gladino. V preostalih vodonosnikih na tem območju so se zaloge občasno izboljševale le v ozkem rečnem pasu ob Muri in v zadnjih dveh mesecih tudi v vzhodnem delu Prekmurja.

V januarju so bile sušne razmere izrazite tudi v vodonosnikih doline Bolske, Krškega polja, zahodnega dela Ljubljanskega polja in pretežnega dela doline Kamniške Bistrice, nakar se je v naslednjih mesecih vodno stanje na vseh teh območjih izboljšalo. Do poletja občasno celo nad raven srednjih zalog. V preostalih vodonosnikih so se sušne razmere občasno pojavljale na Mirensko-Vrtojbenskem polju in v južnem delu vodonosnika doline Kamniške Bistrice.

Hidrološka suša v letu 2002 je bila izjemen pojav zaradi nekaterih posebnosti. Po prostorski razširjenosti je imela višek v mesecu januarju, kar je zelo redek pojav. Zadnja zimska je bila pred trinajstimi leti, poletne suše pa se, čeprav včasih zelo kratkotrajne, pojavljajo skoraj vsako leto.

equally intense. In some aquifers, the drought continued from the previous year and afterwards, developed differently.

In January, there were already dry conditions from the previous year in all the aquifers of north-eastern Slovenia, which continued until the end of the year. The largest spatial expansion of the hydrological drought in this area occurred in June (Map 6). The only exception in north-eastern Slovenia was the Vrbanski plateau aquifer, where infiltration from the Drava River is the main source of groundwater. Due to the nival discharge regime of the Drava River there was an improvement of water reserves in the spring. During the summer months it was even above the mean water level. In the rest of the aquifers in this area though, the reserves occasionally improved only in the narrow river zone along the Mura River and also in the eastern part of Prekmurje during the last two months.

In January the dry conditions were significant also in the aquifers of the Bolska Valley, the Krško Plain, the western part of the Ljubljana Plain and the main part of the Kamniška Bistrica Valley. During the following months though, the water state in all these areas improved. Until the summer it was occasionally even above the level of average reserves. In the rest of the aquifers, dry conditions occasionally occurred in the Miren-Vrtojba Plain

V severovzhodni Sloveniji je bila hidrološka suša po svojih značilnostih prelomni dogodek. Tam so se gladine podzemne vode znižale pod absolutni minimum primerjalnega obdobja pred letom 2000. Ker se tudi do konca leta zaloge niso obnovile do normalnega stanja (graf 23), pomeni, da je bilo tam v letu 2002 črpanje podzemne vode izkoriščanje statičnih zalog.

V normalnih razmerah, ko so podzemne vode obnovljive, za naše potrebe rabimo dinamične zaloge. To so tisti variabilni del skupnih zalog v vodonosniku, ki se spreminja v času. Ko posežemo v statične zaloge, to je v bazni volumen vode, ki je stalno v vodonosniku, govorimo o rudarjenju podzemnih voda. Bistveno pri rudarjenju podzemnih voda je dejstvo, da se vodne zaloge ne obnavljajo (Prekmursko polje in Dravsko polje na grafu 23).

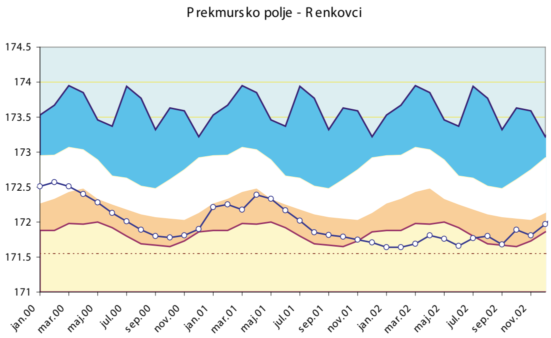
Hidrološka suša podzemnih voda leta 2002 v severovzhodni Sloveniji je le zadnja v vrsti suš na tem območju, ki se vrstijo od leta 2000 naprej. Bila je tudi najbolj huda hidrološka suša na tem območju and in the southern part of the Kamniška Bistrica Valley aquifer.

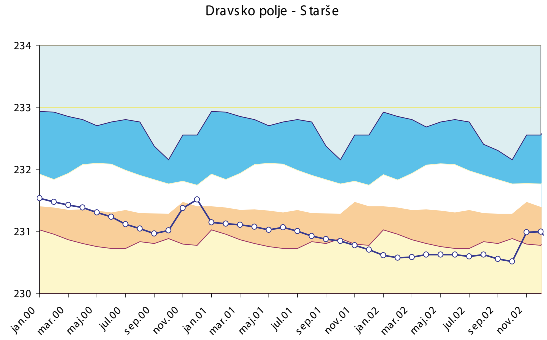
Due to several special features, the hydrological drought in 2002 was an exceptional phenomenon. Considering the spatial expansion it had its peak in January, which is a very rare phenomenon. The last winter drought occurred thirteen years prior to this, while summer droughts occur almost every year, although sometimes short-lasting.

Considering its characteristics, the hydrological drought in north-eastern Slovenia was a turning point. The groundwater levels there decreased below the absolute minimum of the comparative period before the year 2000. Since the reserves were not renewed to the normal level until the end of the year 2002 (Graph 23), the pumping of groundwater there meant the exploitation of static reserves.

In normal conditions, when the groundwater is renewable, we make use of dynamic reserves for our own needs. This is the variable part of the total reserves in the aquifer, which changes over time.

Graf 23: Mesečne mediane gladin podzemnih voda v letu 2002 (modri krogci) v primerjavi z značilnimi gladinami, prikazanimi v percentilih, dolgoletnega primerjalnega obdobja (beli pas = normalne vodne gladine, modri pas = visoke vodne gladine, temno rumeni pas = nizke vodne gladine, svetlo rumeni pas = območje statičnih zalog podzemne vode).
Graph 23: The monthly medians of the groundwater levels in 2002 (blue circles) in comparison to the characteristic water levels in the multi-annual comparative period presented in percentages (white zone = normal water levels, blue zone = high water levels, dark yellow zone = low water levels, light yellow zone = areas of static reserves of groundwater).





Graf 24: Mesečne mediane gladin podzemnih voda v letih 2000-2002 v severovzhodni Sloveniji (modri krogci) v primerjavi z značilnimi gladinami, prikazanimi v percentilih, dolgoletnega primerjalnega obdobja (beli pas=normalne vodne gladine, modri pas=visoke vodne gladine, temno rumeni pas=nizke vodne gladine, svetlo rumeni pas=območje statičnih zalog podzemne vode).
Graph 24: The monthly medians of groundwater levels in the year 2000-2002 in north-eastern Slovenia (blue circles) in comparison to the characteristic water levels, presented in percentages, in the multi-annual comparative period (white zone = normal water levels, blue zone = high water levels, dark yellow zone = low water levels, light yellow zone = areas of static reserves of groundwater).

v triletnem obdobju nenavadno nizkih gladin podzemne vode (graf 24).

Za leto 2002 je bil značilen pojav regionalne hidrološke suše v vsej severovzhodni Sloveniji. Čeprav v ostalih vodonosnikih po državi stanje vodnih zalog ni bilo kritično, so bile povsod značilne nizke vodne gladine na meji sušnih razmer. Obdobja stanja vodnih zalog nad srednjo letno ravnijo so bila zelo kratkotrajna in največkrat omejena na manjše dele vodonosnikov.

Primerjava z letom 1993, ko je bila najhujša suša zadnjega desetletja dvajsetega stoletja, kaže nekaj posebnosti. Suša v letu 1993 je zajela praktično vse aluvialne vodonosnike Slovenije, medtem ko je bila v letu 2002 prizadeta predvsem severovzhodna Slovenija. V tej regiji, na območju vodonosnikov Prekmurja, Murskega polja in Apaškega polja, so bile dosežene bistveno nižje gladine podzemne vode v letu 2002, medtem ko so bile leta 1993 gladine nižje na območjih Dravskega in Ptujskega polja. V ostalih vodonosnikih države primerjava ne kaže bistvenih razlik med obema letoma, čeprav so bile gladine na več območjih nekoliko nižje leta 1993, na manjšem delu pa leta 2002.

When we reach into the static reserves, i.e. the fundamental volume of water that is permanently in the aquifer, we talk about mining the groundwater. And an essential fact when mining groundwater is that the water reserves do not recover (Prekmurje Plain and Drava Plain in Graph 23).

The 2002 hydrological drought of groundwater in the north-eastern part of Slovenia is only the last in the sequence of droughts in this area taking place since the year 2000 onwards. It was the most severe hydrological drought in this area during the three-year period of unusually low groundwater levels (Graph 24).

The phenomenon of the hydrological drought in the entire north-eastern part of Slovenia is characteristic of the year 2002. Although in other aquifers across the country the state of water reserves was not critical, there were characteristic low water levels everywhere else that bordered on dry conditions. The periods when the water reserve states rose above the mean yearly level, however, were short-termed and limited in many cases to just small portions of the aquifers.

Comparison with the year 1993, when the severest drought of the last decade of the 20th century took place, shows several special features. The drought in 1993 hit practically all the alluvial aquifers of Slovenia, while in 2002 mainly the north-eastern part of Slovenia was affected. In the area of the aquifers of Prekmurje, the Mura and the Apače plains, there were considerably lower groundwater levels reached in 2002. However, in 1993 the water levels were lower in the areas of the Drava and Ptuj plains. In the rest of the aquifers in the country the comparison does not show significant differences between the two years, although in 1993, the water levels were somewhat lower in more areas.

C. IZVIRI

VODOSTAJI, TEMPERATURE IN SPECIFIČNE ELEKTRIČNE PREVODNOSTI IZVIROV

Niko Trišič / Zlatko Mikulič

Leto 2002 pomeni novi mejnik v razvoju hidrološkega monitoringa izvirov, saj so ob podatkih vodomernih postaj Divje jezero in Podroteja vključeni še podatki meritev izvira Kamniške Bistrice. Ker so izviri koncentrirani iztoki podzemne vode hidrogeološko reprezentančni za geografsko razmeroma velika vodozbirna območja, se naše znanje z dosedanjega idrijskega območja, ki ga predstavljata izvira Divje jezero in Podroteja, širi na območje Kamniško Savinjskih Alp.

Nizi podatkov vodostajev, temperatur vode in specifične električne prevodnosti vode so zaradi okvar merskih naprav občasno prekinjeni. Zaradi vrzeli v podatkovnih nizih leta 2002 sicer ni možno izračunati vseh statističnih vrednosti, vendar so vrzeli časovno tako razporejene, da je na podlagi skupnih značilnosti možno razložiti nekatere posebnosti režimov obravnavanih izvirov.

Izvira Divje jezero in Podroteja sta imela tudi v letu 2002 podoben režim vodostajev, saj sta zelo blizu in si delita skupno vodozbirno zaledje. Nihanji gladin sta bili časovno usklajeni. Najnižje gladine v letu so bile zabeležene v mesecu januarju, najvišje pa avgusta. Na Podroteji (graf 25) manjkajo podatki za jesenski čas, zato ni povsem zanesljivo, ali so bile tam avgustovske visoke vode konec novembra celo presežene, saj so na Divjem jezeru vodostaji v teh dveh mesecih podobno visoki. Najnižja vodostaja sta za obe postaji zelo zanesljiva. Tudi na izviru Kamniške Bistrice sta bila iz nepopolnih razpoložljivih podatkov zabeležena letni minimum januarja, maksimum pa avgusta. Tudi v tem primeru je letni minimum dokaj zanesljiv. Pri letnem maksimumu je verjetno, da so bile najvišje vode v letu ravno v času izpada delovanja merilnih naprav, ko se je topil sneg v visokogorju Kamniško Savinjskih Alp. Na to trditev napeljuje potek vrednosti temperature in specifične električne prevodnosti vode v mesecu maju.

Temperature vode na izvirih Podroteja in Divje jezero so imele trend naraščanja od začetka leta do septembra, potem so se nekoliko znižale in

C. SPRINGS

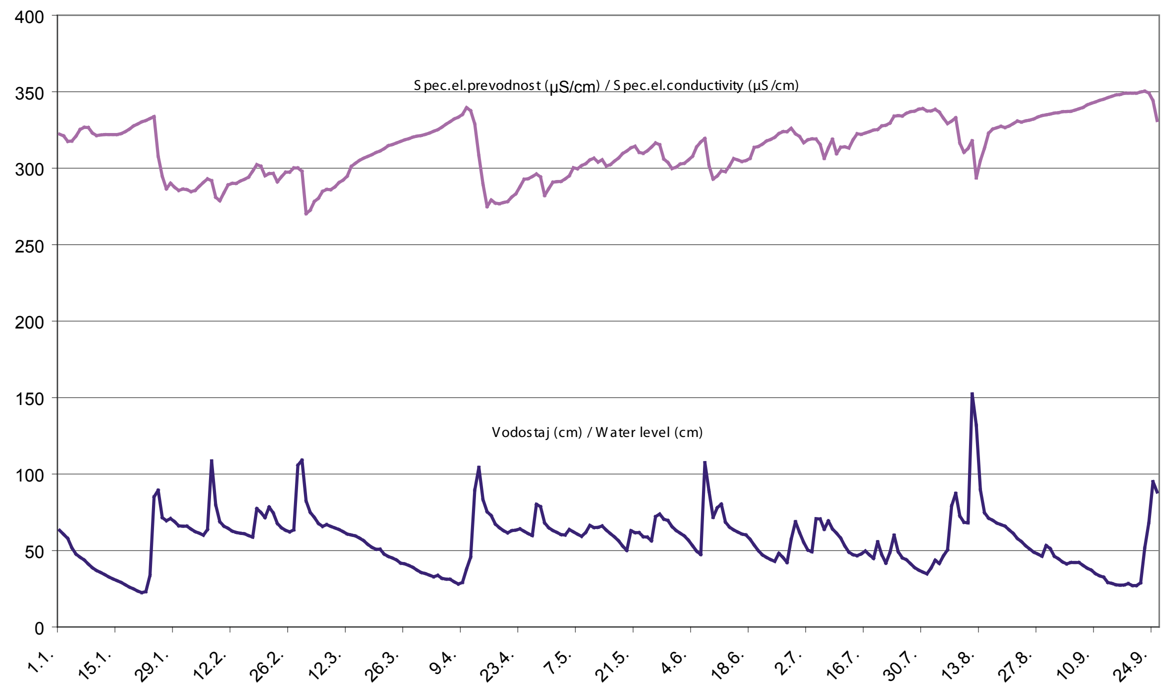
THE WATER LEVELS, TEMPERATURES AND SPECIFIC ELECTRICAL CONDUCTIVITY OF SPRINGS

Niko Trišič / Zlatko Mikulič

The year 2002 represents a new milestone in the development of the hydrological monitoring of springs, because the data from measuring the source of the Kamniška Bistrica River is also included alongside the data of the Divje jezero and Podroteja water gauging stations. Since the springs are concentrated outflows of groundwater hydrogeologically representing the geographically relatively large water catchment areas, our knowledge is now spread from the area of Idrija (represented by the springs Divje jezero and Podroteja) to the area of the Kamnik-Savinja Alps.

The series of temporal data on the water levels, water temperatures and the specific electrical conductivity of the water were occasionally interrupted due to the malfunction of the measuring devices. Due to the gaps in the data sets for the year 2002 it is not possible to calculate all the statistical values, yet the time gaps are distributed in such a manner that it is possible, based on common characteristics, to explain some of the special features of the regimes of these springs.

Also the Divje jezero and Podroteja springs had a similar regime of water levels in 2002 , since they are very close and share the same water catchment. The fluctuations of their water levels are temporally synchronized. The lowest water levels in the year were registered in January and the highest in August. At Podroteja (Graph 25), there is data missing on the autumn period. Therefore, while it is possible that the high waters of August were actually exceeded there in November, such an idea is not entirely reliable in spite of the water levels at Divje jezero being similarly high in these two months. The lowest water levels for both stations are very reliable however. At the spring of the Kamniška Bistrica River the incomplete data available also provided a record of the yearly minimum in January and the maximum in August. In this case also, the minimum is quite reliable but it is very likely that the highest waters in the year occurred sometime during the disruption to the operation of the measuring devices, when the snow melted in the high mountains of the

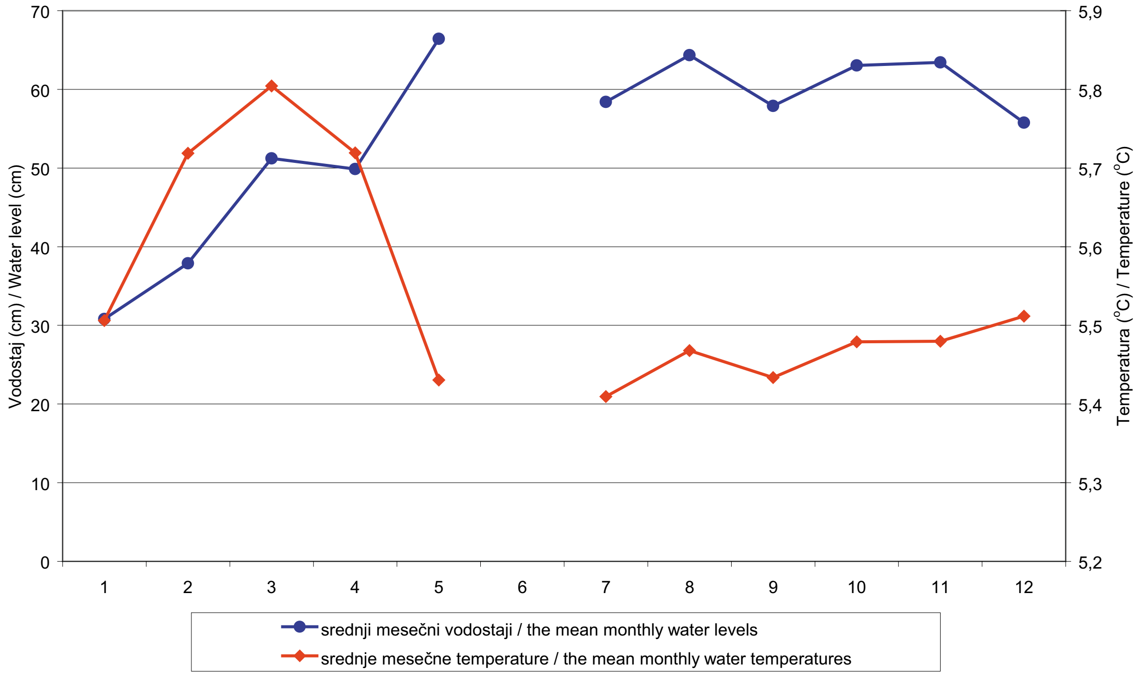


Graf 25: Primerjava poteka vodostajev in specifične električne prevodnosti na izviru Podroteja.
Graph 25: Timeline of water levels and electrical conductivity at the Podroteja spring.

ostale razmeroma ustaljene do konca leta. Temperature vode na Podroteji so reprezentančne za podzemno vodo zaledja, medtem ko so na Divjem jezeru zaznavni vplivi zastajanja vode v iztočnem jezeru in dogodkov na obrežju. Režim na Divjem jezeru kaže mešanje vpliva podzemne vode in procesov v zajezeni površinski vodi. Amplituda nihanja temperature je bila v letu 2002 preko štirikrat večja kot na bližnjem izviru Podroteja, vendar okoli trikrat manjša kot v Blejskem ali Bohinjskem jezeru. Zabeleženi sta bili tudi dve nenavadni znižanji temperature v januarju in na prehodu iz marca v april. Domnevamo, da sta ti dve znižanji posledici snežnih plazov, ko naj bi v jezero splazeli sneg naglo znižal temperaturo vode. Na to sklepamo tudi po hkratnem porastu specifične električne prevodnosti vode, ki je najbrž posledica vnosa snovi z obrežja. Praviloma je specifična električna prevodnost normalno odvisna od temperature vode, torej bi se morala ob padcu temperature praviloma znižati in ne zvišati. Letna amplituda nihanja temperature vode na Podroteji je znašala okoli poldrugo stopinjo Celzija. Vrzel v podatkovnem nizu za izvir Kamniške Bistrice je bila ravno v času, ko naj bi se kazala glavna posebnost režima tega izvira. Iz grafičnega prikaza letnega poteka temperature vode se da razbrati zniževanje temperature v spomladansko poletnem času. Tolmačimo ga s taljenjem snega v razpokah visokogorja Kamniško Savinjskih Alp. Ker se snežnica zadrži v podzemlju razmeroma kratek čas, le ta zniža temperaturo vode izvira. Najnižje letne temperature v Divjem jezeru in Podroteji so bile v zimskem času na začetku leta, najvišje pa v

Kamnik Savinja Alps. This statement is backed by the sequence of values for the temperature and the specific electrical conductivity of the water in May.

The water temperature at the springs of Podroteja and Divje jezero experienced an upwards trend from the beginning of the year until September, decreasing a bit after that and remained relatively stable until the end of the year. The water temperatures at Podroteja are representative of the groundwater of the hinterland, while at Divje jezero the effects of the stagnancy of the water in the outflow lake and also the events on the banks could be perceived. The regime at Divje jezero shows the mixing of the groundwater influence and the processes in action in the dammed surface water. In 2002 the amplitude of the temperature fluctuation was over four times greater than at the nearby spring of Podroteja, but around three times smaller than in Lake Bled or Lake Bohinj. There were also two unusual temperature drops registered, one in January and one at the transition between March and April. It is assumed that these drops were the consequences of snow avalanches when the water temperature was rapidly decreased by the snow sliding down into the lake. This is supported also by the simultaneous increase in the specific electrical conductivity of the water, which is a most likely the consequence of the input of material from the bank. As a rule, the specific electrical conductivity is normally dependant on the water temperature. Therefore it should decrease, not increase during a temperature drop. The yearly



Graf 26: Kamniška Bistrica – potek srednje mesečnih vrednosti vodostajev in temperature.
Graph 26: Timeline of monthly mean water levels and temperatures at the spring of the Kamniška Bistrica River.

avgustu in septembru. Za izvir Kamniške Bistrice so podatki o letnem poteku temperatur nepopolni zaradi že omenjene vrzeli v podatkovnem nizu. Srednje mesečne vrednosti so bile najvišje v februarju, najnižje pa v maju (graf 26). Čeprav ni bilo možno izračunati srednjih letnih temperatur vode, se da iz razpoložljivih podatkov sklepati, da je voda na izviru Kamniške Bistrice okoli tri stopinje hladnejša od Podroteje. Nižja temperatura je najbrž posledica večje nadmorske višine zaledja in krajše poti oziroma zadrževalnega časa vode v podzemlju.

Letni potek vrednosti specifične električne prevodnosti vode kaže v hidrogeologiji znano inverzno odvisnost od vodostaja najbolj jasno na izviru Podroteja (graf 25). Ob nizkih vodostajih je električna prevodnost visoka zaradi baznega iztoka iz vodonosnika. To je iztok vode, ki ima najdaljši zadrževalni čas v podzemlju in je zato najbolj mineralizirana. Na Divjem jezeru je podoben režim, le da je zabrisan z vplivi z obrežja jezera. Izvir Kamniške Bistrice kaže popolnoma drugačen režim. Iz razporeda poteka vodostajev in primerjave s potekom temperatur sklepamo, da imamo v času nizkih zimskih vodostajev opraviti z baznim iztokom iz globljega dela vodonosnika, kjer je voda nekoliko toplejša in ima zaradi večje mineralizacije višjo specifično električno prevodnost. Vir iztoka v poletnih mesecih je že omenjena snežnica z nižjo temperaturo in nižjo električno prevodnostjo zaradi manjše mineralizacije. V vseh treh izvirih je bila v letu 2002 normalna

amplitude of the fluctuation of water temperature at Podroteja was around 1.5 °C. The gap in the data sets for the spring of the Kamniška Bistrica River occurred at the time when the most noticeable feature of this spring should have been visible. In the graphical representation of the yearly course of the water temperature, a temperature decrease during the spring-summer period can be observed. This is explained by the snow melting in the high mountain rock fractures of the Kamnik-Savinja Alps. Since snow-water stays underground for a relatively short time, it decreases the water temperature of the spring. By contrast, the lowest yearly temperatures at Divje jezero and Podroteja were in the winter, at the beginning of the year, while the highest were registered in August and September. The data on the yearly course of temperatures at the spring of the Kamniška Bistrica River were incomplete due to the previously mentioned gap in the data sets. The mean monthly values were at their highest in February, while the lowest were in May (Graph 26). Although it was not possible to calculate the mean yearly water temperatures, it can be concluded from the data available that the water at the spring of the Kamniška Bistrica River was around three degrees cooler than that of Podroteja. The lower temperature is most likely a consequence of the hinterland's greater height above sea level and the shorter distance or duration that the water has underground.

Preglednica 16: Primerjava značilnih nizkih, visokih (nk, vk) in srednjih letnih (s) vrednosti vodostajev in temperature na izviru Podroteja.
Table 16: Comparison of characteristical low, high and mean annual water levels and temperatures at the Podroteja spring.

	vodostaj (cm) water level (cm)			temperatura (ºC) temperature (ºC)			spec.el.prevodnost (μS/cm) spec.el.conductivity (μS/cm)		
	Hnk	Hs	Hvk	Tnk	Ts	Tvk	EPnk	EPs	EPvk
1999	27,2	67,9	167	7,7	8,6	10,2	251	314	357
2000	20,2	67,3	187	8,0	8,6	10,1	226	310	355
2001	14	64	226	8,2	8,7	9,7	-	-	-
2002	21	57	178	8,2	8,7	9,8	254	314	357

odvisnost med specifično električno prevodnostjo in temperaturo vode razen v času omenjenih motenj v Divjem jezeru. Ob višji temperaturi je raztapljanje mineralov na poti vode skozi podzemlje večje in je tako večja tudi njena mineralizacija.

Za izvir Podroteja je bila opravljena analiza niza podatkov za vse štiriletno obdobje delovanja vodomerne postaje od leta 1999 naprej. Leto 2002 je bilo najbolj sušno, saj je bil srednji letni vodostaj najnižji, oziroma je bila količina v celem letu iztekle vode najmanjša (preglednica 16). Temperatura vode je bila ustaljena, kar je razvidno iz skoraj enakih srednjih letnih vrednosti v vseh štirih letih in malih odstopanj pri letnih konicah. Razpon letnih ampli-

V času sledilnega poskusa na Voglu smo zajemali vzorce tudi na izvirih Suhe nad Ribčevim Lazom.
(foto: Niko Trišić, 24. oktober 2002)
During the water tracing experiment on the Vogel plateau samples were taken at the springs of the Suha creek above the Ribčev Laz.
(photo: Niko Trišić, 24th October 2002)

The yearly course of values of the specific electrical conductivity of water shows in the hydrogeologically known inverted dependency on the water level, which is most clearly visible at the Podroteja spring (Graph 25). At the time of low water levels, the electrical conductivity is high due to the base outflow from the aquifer. This is the outflow of water that has spent the longest time underground, which is why it is mostly mineralized. There is a similar regime at Divje jezero, only that it is blurred by the influences from the banks of the lake. The spring of the Kamniška Bistrica River shows a completely different regime however. From the course of the water levels in comparison with the course of the temperatures, it can be concluded that throughout the period of winter low water levels, the base outflow from the deeper part of the aquifer does appear, but the water is somewhat warmer and also has a higher specific electrical conductivity due to the greater mineralization. The source of the outflow during the summer months is the snow-water already mentioned, which has a lower temperature and a lower electrical conductivity due to the lower mineralization. In 2002 there was a normal dependency at all three springs between the specific electrical conductivity and the water temperature, except during the abovementioned disturbances at Divje jezero. At a higher temperature the dissolution of minerals in the path of the water through the ground is higher, which is why its mineralization is also higher.

For the Podroteja spring, an analysis was made of the data sets for the entire four-year period of water gauging operations since 1999. The year 2002 was driest because the mean annual water level was lowest, e.g. the amount of water discharged throughout the year was the lowest (Table 16). The water temperature was stable, which is visible from the mean annual values remaining almost constant over all four years and from the low deviations at the yearly peaks. The range of the yearly amplitudes was from 1.5 °C to 2.5 °C. Also, the differences between the mean annual specific electrical conductivities were small.

The characteristics of the regime of the observed springs in 2002 confirmed some of our matud je bil od poldruge do dve in pol stopinje Celzija. Tudi razlike srednjih letnih specifičnih električnih prevodnosti vode so bile majhne.

Značilnosti režima opazovanih izvirov v letu 2002 so potrdile nekaj naših pomembnih strokovnih izhodišč, ki jih upoštevamo pri razvoju hidrološkega monitoringa izvirov. Pomembno je vzporedno merjenje vseh treh obravnavanih fizikalno-hidroloških veličin, saj se dopolnjujejo in je tolmačenje njihove medsebojne odvisnosti ključnega pomena za razumevanje režima izvirov. Vplivi mikrolokacije merske postaje in razmere na merskem mestu so zelo pomembne, kot so pokazale opisane posebnosti Divjega jezera. Te posebnosti so ključne za razumevanje hidroloških in hidrogeoloških procesov, kakor tudi za vrednotenje in tolmačenje izmerjenih veličin. Širitev mreže hidrološkega monitoringa izvirov na območja drugih vodnih teles po Sloveniji je nujna, saj že primerjava med vodozbirnima območjema idrijskega in Kamniško Savinjskih Alp kaže veliko pestrost režimov.

jor professional starting points that are considered in the development of the hydrological monitoring of springs. The parallel measurement of all three of the physical and hydrological quantities is important since they supplement each other, while the interpretation of their mutual dependencies is of key importance for our understanding of the regime of springs. The effects of the water gauging station's micro-location and the conditions at the gauging site are very important, as shown above by the special features of Divje jezero. These special features are crucial for the understanding of hydrological and hydrogeological processes, as well as for the evaluation and interpretation of the data measured. The expansion of the network of hydrological monitored springs to include the areas of other water bodies across Slovenia is essential, since the comparison between the water catchment areas of Idrija and the Kamnik-Savinja Alps already shows the great diversity of the regimes.

Kraški izvir Kamniške Bistrice.
(foto: Niko Trišić, 10. april 2002)
Karstic spring of the Kamniška Bistrica.
(photo: Niko Trišić, 10th April 2002)

D. MORJE

PLIMOVANJE MORJA

Mojca Robič

Plimovanje je poleg valovanja najizrazitejši pojav spreminjanja gladine morja.

Spreminjanje gladine je posledica astronomske plime, meteoroloških dejavnikov in lastnega nihanja Jadranskega morja. V Jadranskem morju se navadno dnevno izmenjata dve plimi in dve oseki.

Na plimovanje v največji meri vpliva gravitacijska privlačnost med Luno, Soncem in Zemljo, kar imenujemo astronomska plima. To je zaradi znanega cikličnega gibanja nebesnih teles možno napovedati vnaprej. V času mlaja in ščipa, ko sta Sonce in Luna v konjunkciji oz. opoziciji, se vplivi plimotvornih sil seštevajo in amplitude plimovanja so velike. Ob prvem in zadnjem krajcu, ko sta Sonce in Luna v kvadraturi, so amplitude manjše (graf 27).

Razliko med izračunano astronomsko in dejansko izmerjeno višino morja imenujemo residualna višina. Njena vrednost je odvisna največkrat od meteoroloških dejavnikov, včasih pa tudi od lastnega nihanja morja.

D. SEA

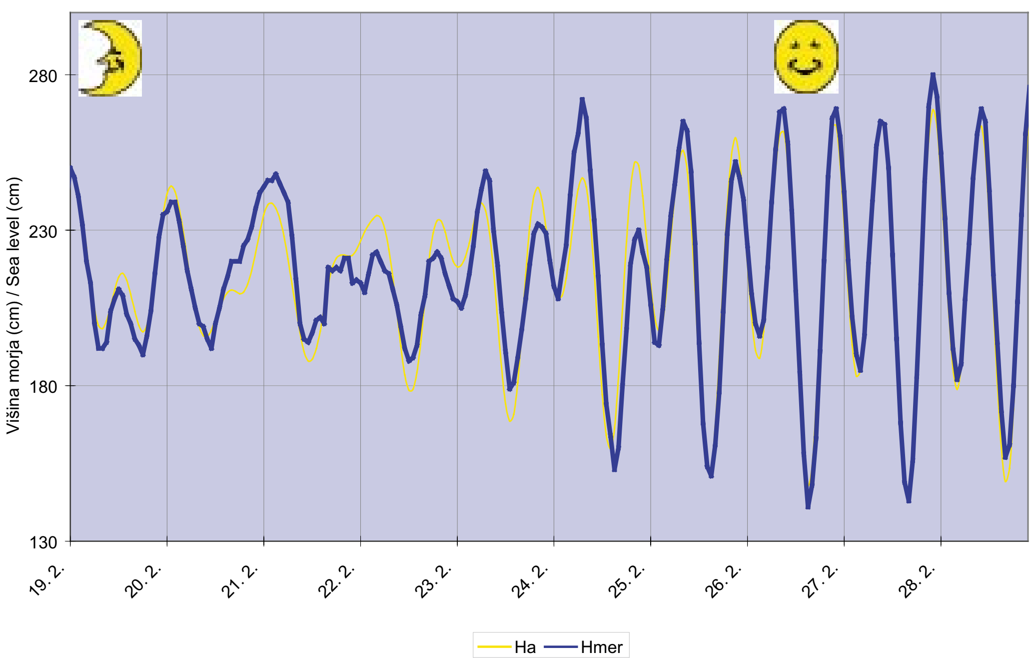
SEA LEVELS

Mojca Robič

Besides the motion of waves, the tide is the most noticeable phenomenon of the changing of sea level.

Changes of sea level are caused by the astronomic tide, meteorological forcing and the self induced oscillation of the Adriatic Sea. In the Adriatic Sea there are usually two ebb tides and two flow tides interchanging daily.

The greatest influence on the tide is the gravitational attraction between the Moon, the Sun and the Earth, which is called the astronomic tide. Due to the known circular movements of the heavenly bodies, it is possible to forecast the tide in advance. During the new or the full moon, when the Sun and the Moon are in conjunction or in opposition, the effects of their tide-forming forces are added together and tide amplitudes are at their greatest. During the waxing and the waning moon on the other hand, when the Sun and the Moon are in quadrature, the amplitudes are smaller (Graph 27).



Graf 27: Astronomska (Ha) in merjena (Hmer) višina morja ob prvem krajcu in ob polni luni kažeta občutno razliko v amplitudi plimovanja.
Graph 27: The astronomic (Ha) and the measured (Hmer) sea level at the waxing moon and the full moon show a substantial difference in the amplitude of the tide.

Od meteoroloških dejavnikov sta najbolj vplivna veter in zračni pritisk. Z zniževanjem zračnega pritiska se gladina morja zviša. Južni ali jugovzhodni veter nariva vodne mase na obalo in prav tako povzroči zvišanje gladine. Obratno burja znižuje gladino, saj piha s kopnega proti odprtemu morju. Na zvišanje gladine morja v Kopru lahko vpliva tudi močnejši južni veter v Dalmaciji.

Lastno nihanje morja se pojavi v zaprtih in delno zaprtih morjih. V Jadranu ima ob južnem vetru periodo okoli 21 ur, ob jugozahodniku pa le nekaj ur.

Pri spremljanju gladine morja obravnavamo urne (to so trenutne vrednosti ob polnih urah) in ekstremne vrednosti (navadno po dve visoki in dve nizki vodi v dnevu). Iz urnih podatkov izračunamo srednjo dnevno vrednost (SDV v tabeli D.3), iz teh srednjo mesečno (SMV v tabeli D.3) in iz teh srednjo letno vrednost (SLV v tabeli D.3).

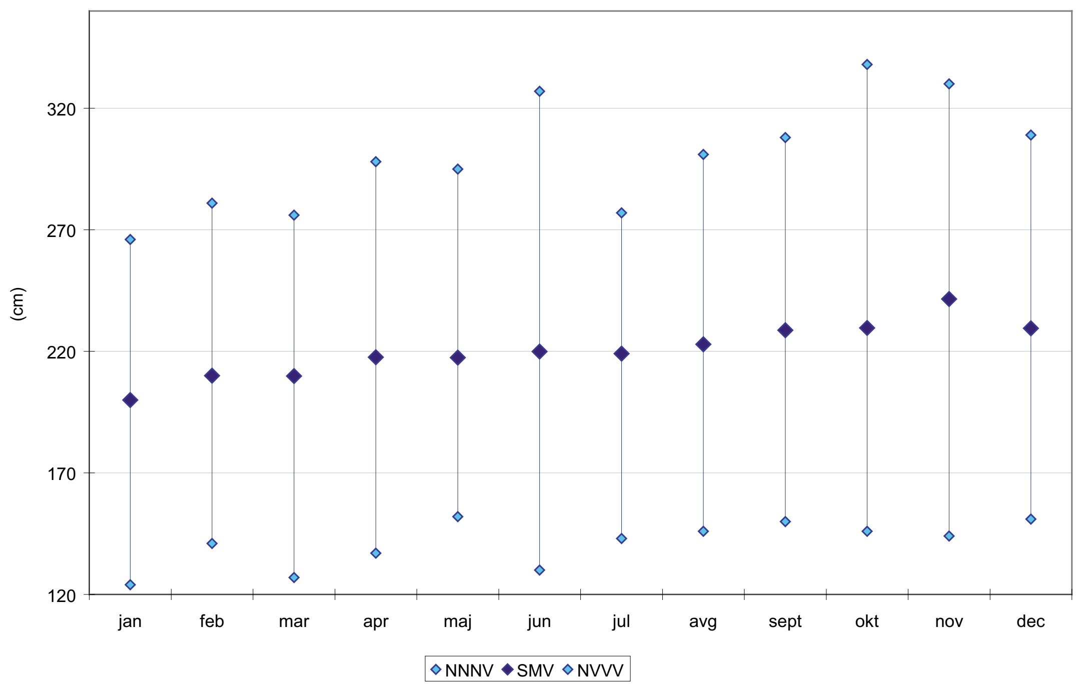
Pri opazovanju visokih voda določimo, katera od visokih voda v dnevu je bila višja (VVV) in iz njih izračunamo povprečje (SVVV v tabeli D.2). Izračunamo tudi srednjo visoko vodo, ki je povprečje obeh visokih voda v dnevu, oz. vseh v mesecu ali letu (SVV v tabeli D.2) Določimo tudi najvišjo gladino morja v mesecu ali letu (NVVV v tabeli D.2 in D.4).   Podobno velja za nizke vode, kjer določamo nižjega od obeh ekstremov (NNV) ter iz njih računamo povprečje (SNNV v tabeli D.2). Srednja

The difference between the calculated astronomic sea level and the actual, measured sea level is called the residual sea level. Its value depends mostly on meteorological factors and sometimes also on the self induced oscillation of the sea.

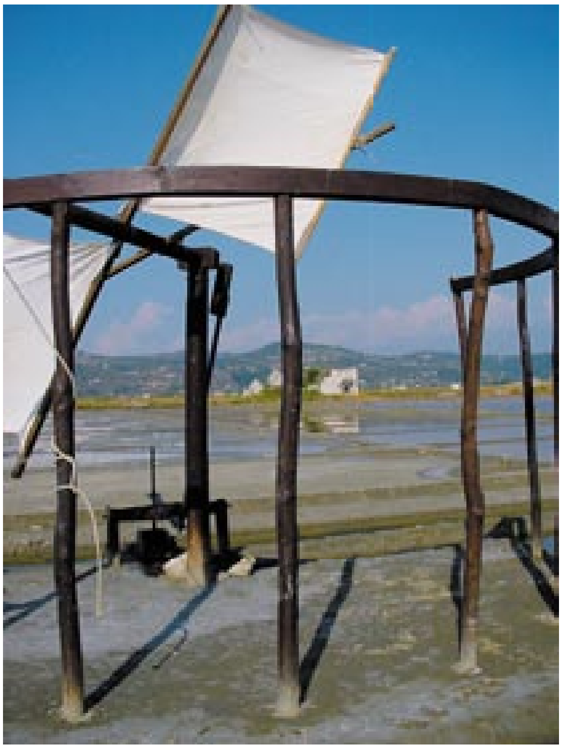
Among the meteorological factors, the wind and air pressure have the most influence. By decreasing the air pressure, the sea level increases. Also, the southern or south-eastern wind pushes the water masses towards the coast, thus causing the sea level to rise. In the opposite direction, the north-eastern, bora wind decreases the sea level, since it blows from out towards the open sea. Also a strong southern wind in Dalmatia can cause the sea level in the area of Koper to increase.

The self induced oscillation of the sea appears in confined and partially confined seas. On the Adriatic Sea it has a period of 21 hours during southerly wind , with a period of only a few hours when south-westerly.

When monitoring the sea level, we look at both the hourly values (these are the momentary values taken on the hour) and the extreme values (usually two high and two low tides per day). From the hourly data we calculate the mean daily value (SDV in Table D.3), from these the mean monthly values can be calculated (SMV in Table D.3) and in turn the mean annual value (SLV in Table D.3).



Graf 28: Srednje mesečne višine morja (SMV), najvišje (NVVV) in najnižje (NNNV) gladine morja po mesecih v letu 2002.
Graph 28: The mean (SMV), the highest (NNNV) and the lowest (NNNV) sea levels by month in the year 2002.



Sečoveljske soline.
(foto: Jože Uhan)
The saltworks Sečoveljske soline.
(photo: Jože Uhan)

nizka voda (SNV v tabeli D.2) je povprečje vseh nizkih voda v dnevu, mesecu ali letu. Najnižja gladina morja v mesecu ali letu je označena z NNNV in jo najdemo v tabelah D.2 in D.4.

V letu 2002 so bile gladine morja višje kot v primerjalnem obdobju 1961-2000. Srednja letna višina morja (tabela D.3) je bila 220,5 cm, kar je zelo visoka vrednost. To je le 0,3 cm manj od najvišje vrednosti v primerjalnem obdobju leta 1994.

Srednje mesečne višine morja so se povečini zviševale od prvega do enajstega meseca v letu (graf 28). Tudi najvišje in najnižje mesečne gladine kažejo podobne značilnosti. Visoke vrednosti so za jesen in začetek zime običajne zaradi meteoroloških vplivov, saj so prehodi ciklonov v tem času pogostejši. Junij izstopa po presenetljivi najvišji vrednosti ter veliki amplitudi, kar je neobičajno za ta letni čas.

Letni ekstremi so v primerjavi z dolgoletnimi značilnimi vrednostmi nadpovprečni. Čas nastopa letnih ekstremov je bil običajen, najvišja voda v letu je bila izmerjena v novembru, najnižja pa v januarju. Srednja visoka in srednja nizka voda sta bili blizu obdobnemu povprečju.

V **januarju** je bila gladina morja nizka. Srednja mesečna gladina morja je bila najnižja v letu, 200 cm, to je 15 cm pod dolgoletnim povprečjem. Tudi vse ostale karakteristične vrednosti so

When observing the high tides, we determine which daily high water was the highest (VVV) and calculate the mean from them (SVVV in Table D.2). We also calculate the mean high water as the average amount of both high waters in a day or throughout a month or a year (SVV in Table D.2), also determining the highest sea level in a given month or year (NVVV in Tables D.2 and D.4). The situation is similar at low tides, where we determine the lower of the two extremes (NNV) and calculate the mean from them (SNNV in Table D.2). The mean low water in a given month or year is marked NNNV and is found in Tables D.2 and D.4.

In 2002 the sea levels were higher than in the comparative period of 1961-2000. The mean annual sea level (Table D.3) was 220.5 cm, which is a very high value. This is only 0.3 cm less than the highest value in the comparative period, from the year 1994.

The mean monthly sea levels increased mainly from the first until the eleventh month of the year (Graph 28). Also the highest and lowest monthly sea levels show similar characteristics. High values are characteristic in the autumn and at the beginning of the winter due to meteorological forcing, as the transitions of cyclones are more frequent in that period. June of 2002 stands out due to its surprising maximum value and great amplitude, which is unusual for that period of the year.

The yearly extremes were above average compared to the multi-annual characteristic values. The time of the occurrence of the annual extremes was normal with the highest water of the year measured in November and the lowest in January. The mean high and mean low water were close to the period mean.

In **January** the sea level was low. The mean monthly sea level was the lowest throughout the year at 200 cm, which is only 15 cm below the multi-annual mean. Also, all the other characteristic values were below the period mean.

The lowest sea level in 2002 was registered as early as the 11th January in the afternoon, at 124 cm.

The mean monthly sea level in **February** was similar to the period mean. The mean daily sea levels in the first part of the month were visibly lower than average, the deviations later on, were smaller. Also other characteristic values (the highest, the mean high, the lowest and the mean low sea level) were similar to the mean period values.

The mean daily values in the first part of **March** were average, with the exception of the 6th March when the sea level was very high all day bile pod obdobnim povprečjem.

Že 11. januarja popoldan je bila zabeležena najnižja gladina morja v letu 2002, 124 cm.

Februarska srednja mesečna višina morja je bila podobna obdobnemu povprečju. Srednje dnevne gladine morja so bile v začetku meseca opazno nižje od povprečja, kasneje so bila odstopanja manjša. Tudi ostale značilne vrednosti (najvišja, srednja visoka, najnižja in srednja nizka gladina morja) so bile podobne srednjim obdobnim.

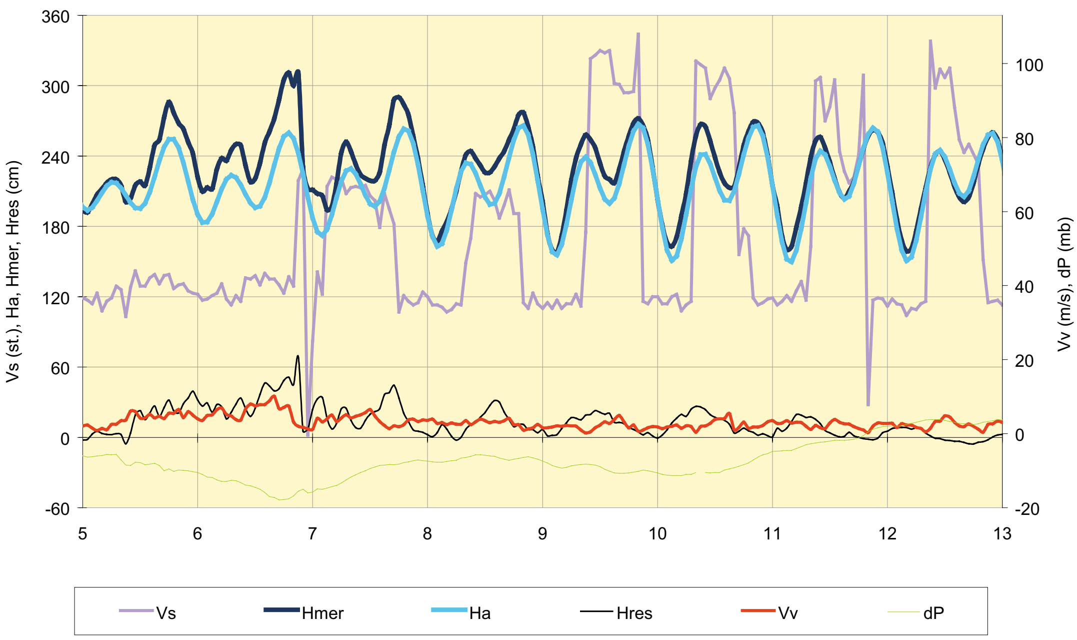
Srednje dnevne vrednosti v začetku **marca** so bile povprečne, z izjemo 6. marca, ko je bilo zaradi meteoroloških dejavnikov, predvsem južnega vetra, morje ves dan močno povišano. Srednja dnevna višina tega dne je bila 236 cm. Prvič v letu so se pojavile residualne višine preko 40 cm. Do 20. marca so bile residualne višine pozitivne, kasneje pa negativne. Največje odstopanje navzgor je bilo 6. marca +47 cm, navzdol pa 24. marca -47 cm.

Od **aprila** do konca leta so bile srednje mesečne višine morja nadpovprečne. Gladina morja se je 12. aprila prvič močno približala kritični vrednosti 300 cm, ko morje poplavi nižje ležeče dele obale. Tega dne zjutraj je doseglo višino 298 cm. Najvišji mesečni gladini morja sta botrovali znižanje zračnega pritiska in močan južni veter, ki je potiskal vodne mase proti obali. Zaradi meteoroloških dejavnikov

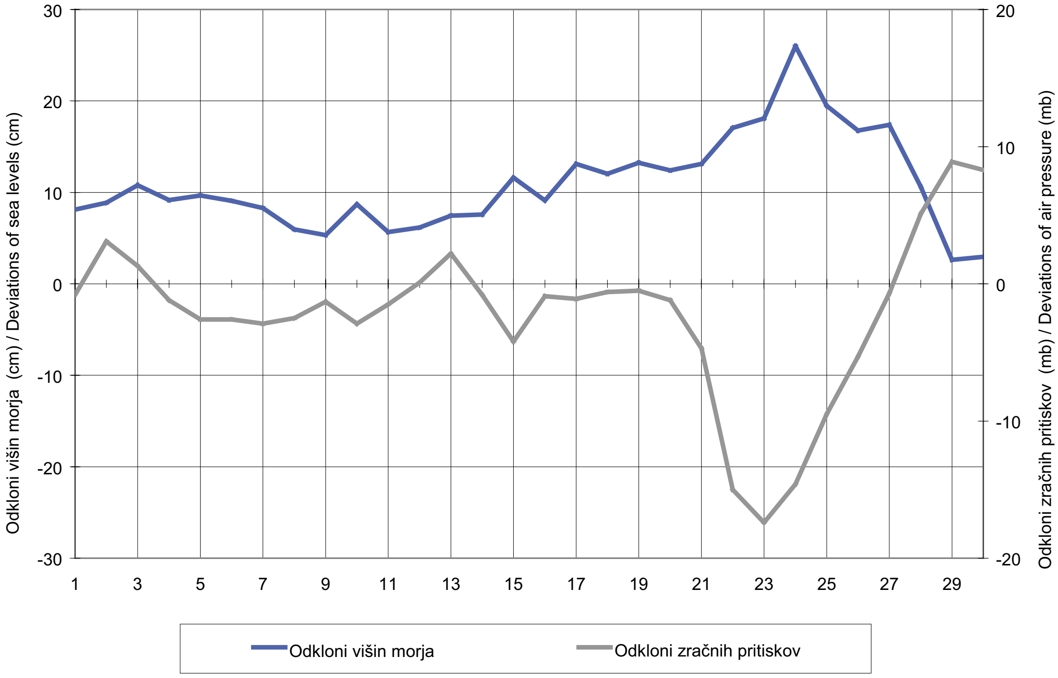
due to meteorological forcing, especially from the southerly wind. The mean daily sea level on that day was 236 cm. Also, residual heights of over 40 cm appeared for the first time in the year. The residual heights were positive until the 20th March, becoming negative later on. The highest deviation upwards occurred on the 6th March with a measurement of +47 cm, while the highest downwards was on the 24th March at -47 cm.

From **April** until the end of the year, the mean monthly sea levels were above the mean. On the 12th April, for the first time, the sea level rose very close to the critical value of 300 cm, which is when the sea overflows into the low-lying coastal areas. On the morning of that day it reached the level of 298 cm. The highest monthly sea level was caused by a decrease of air pressure and a strong southerly wind that pushed the water masses in towards the coast. Due to this meteorological forcing, the sea was half a meter higher than the astronomically predicted sea level.

The mean monthly sea level in **May** was almost 2 cm lower than the period mean. For the majority of the month the sea was lower than the forecasted levels, the deviations being small. The sea level increased in the last third of the month, however. Also the other characteristic values were average.



Graf 29: Višina gladine morja v juniju ob posebnih meteoroloških razmerah.
Legenda: Vv = hitrost vetra, dP = razlika zračnega pritiska do srednje vrednosti 1016 mb, Vs = smer vetra v stopinjah, Hmer = izmerjena višina morja, Ha = astronomska višina morja, Hres = residualna višina je razlika med napovedano in izmerjeno višino morja.
Graph 29: The height of the sea level in June during the special meteorological conditions.
Legend: Vv = wind speed, dP = deviation of air pressure from the mean value of 1016 mb, Vs = wind direction in degrees, Hmer = measured sea level, Ha = astronomic sea level, Hres = residual sea level (the difference between the forecasted and the measured sea level).



Graf 30: Srednje dnevne višine morja v septembru so bile vse dni v mesecu nad dolgoletnim povprečjem.
Graph 30: The mean daily sea levels in September were above the multi-annual mean on all the days of the month.

je bilo morje za pol metra višje od astronomsko pričakovanega.

Srednja mesečna višina morja v **maju** je bila slaba 2 cm nad obdobnim povprečjem. Morje je bilo večino meseca nižje od napovedanega, odstopanja so bila majhna. Morje pa je bilo povišano v zadnji tretjini meseca. Tudi ostale značilne vrednosti so bile povprečne.

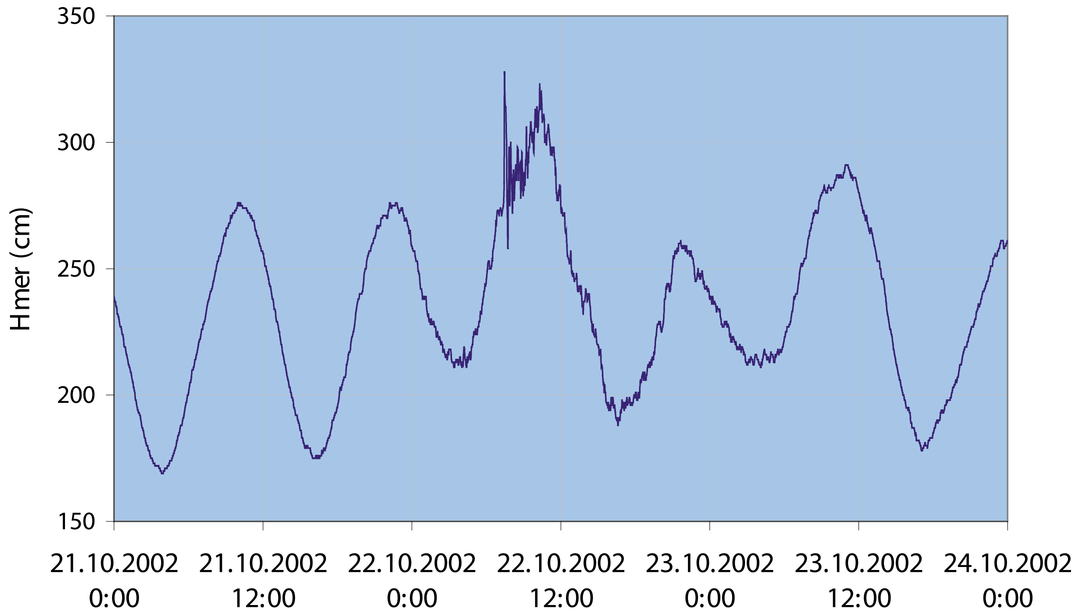
Gladina morja v **juniju** je bila nekoliko nadpovprečna, z izstopajočim viškom 6. v mesecu. Najvišja gladina je bila zaradi posebne meteorološke situacije, nizkega zračnega pritiska, pod 1000 mb, ter močnega juga, ki je pihal že drugi dan in je narival vodne mase na obalo, izmerjena tega dne ob osmih zvečer. Ob precej visoki astronomski plimi je morje doseglo najvišjo gladino v mesecu, izjemnih 327 cm (graf 29). To je bilo prvič v letu 2002, da je gladina morja presegla kritično točko 300 cm. Za krajši čas so bili poplavljeni nižje ležeči deli obale. Najvišja mesečna višina je bila višja celo od najvišje izmerjene za ta mesec v obdobju 1961-2000. Najnižja gladina morja je bila nekoliko podpovprečna. Razlika med najvišjo in najnižjo gladino v mesecu je bila zato zelo velika.

V **juliju** je bilo morje večino meseca višje od napovedanega, največja pa so bila odstopanja v začetku in ob koncu meseca. Srednja mesečna višina morja je bila nekaj cm višja od srednje obdobne. Toda nobena od značilnih vrednosti ni bila izjemna.

The sea level in **June** was somewhat above average, with an outstanding peak on the 6th. The high sea level measured at eight o'clock in the evening of that day was due to the special meteorological situation: low air pressure below 1000 mb and a strong southerly wind blowing for the second day running and pushing the water into the coast. At the time of the already substantially high astronomic tide, the sea reached the highest level of the month, an outstanding 327 cm (Graph 29). This was the first time in 2002 that the sea level had exceeded the critical point of 300 cm. For a short time low-lying coastal areas were flooded. The highest monthly sea level was even higher than the highest sea level measured in that month anywhere in the period 1961-2000, while the lowest sea level was somewhat below the mean. The difference between the highest and the lowest sea level in the month was therefore very high.

In **July** the sea was higher than the forecast level for most of the month, with the highest deviations occurred at the beginning and at the end of the month. The mean monthly sea level was several cm higher than the mean period level. Yet none of the characteristic values was outstanding.

In **August** the sea level was considerably above average. For the majority of the month the sea level was higher than the forecasted level. Deviation was highest in the first half of the month and the highest monthly sea level was 301 cm high, signifi-



Graf 31: Mesečni maksimum je bil dosežen ob močnem vplivu meteoroloških dejavnikov 22. oktobra zjutraj.
Graph 31: The monthly maximum was reached at the time of heavy meteorological forcing in the morning of the 22nd October.

Avgusta je bilo morje nadpovprečno visoko. Morje je bilo večino meseca višje od napovedanega. Odstopanje je bilo največje v prvi polovici meseca. Najvišja mesečna gladina 301 cm je bila visoka, precej nadpovprečna za ta letni čas. Srednja mesečna višina je bila le 3 cm nižja od najvišje v primerjalnem obdobju. Tudi najnižja mesečna gladina je bila nad povprečjem.

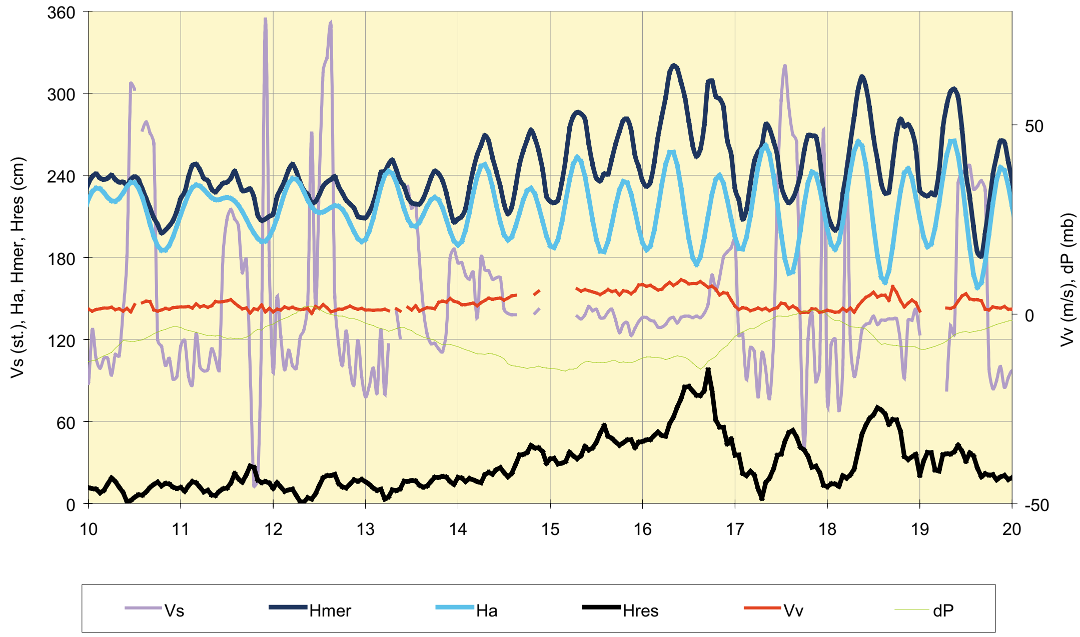
Ves **september** je bila gladina morja višja od napovedane. Odstopanje je bilo največje v zadnji tretjini meseca (graf 30). Najvišja gladina 307 cm je bila zabeležena 24. septembra. Vse značilne vrednosti so bile v primerjavi z obdobjem močno nadpovprečne.

Tudi v **oktobru** je bila gladina morja visoka. 22. oktobra dopoldan je morje za nekaj ur poplavilo nižje ležeče dele obale. Najvišja gladina (338 cm) je bila dosežena tega dne zjutraj. V noči z 21. na 22. oktober je Slovenijo prešla vremenska fronta. Krajevno so se pojavljale nevihte in močnejši nalivi. Ena od neviht se je 22. oktobra zjutraj razvila nad Tržaškim zalivom in se pomikala proti Slovenski obali. Povzročila je močno valovanje in narivanje vodnih mas na obalo. Pod tem vplivom je morje močno in hitro naraslo ter upadlo. Mesečni maksimum je bil dosežen ob 6:25, štiri ure pred napovedano astronomsko najvišjo vodo (graf 31). Z izjemo najnižje vode v mesecu, ki je bila nekoliko podpovprečna, so bile ostale (srednja mesečna, srednja visoka, srednja nizka in najvišja voda) nadpovprečne.

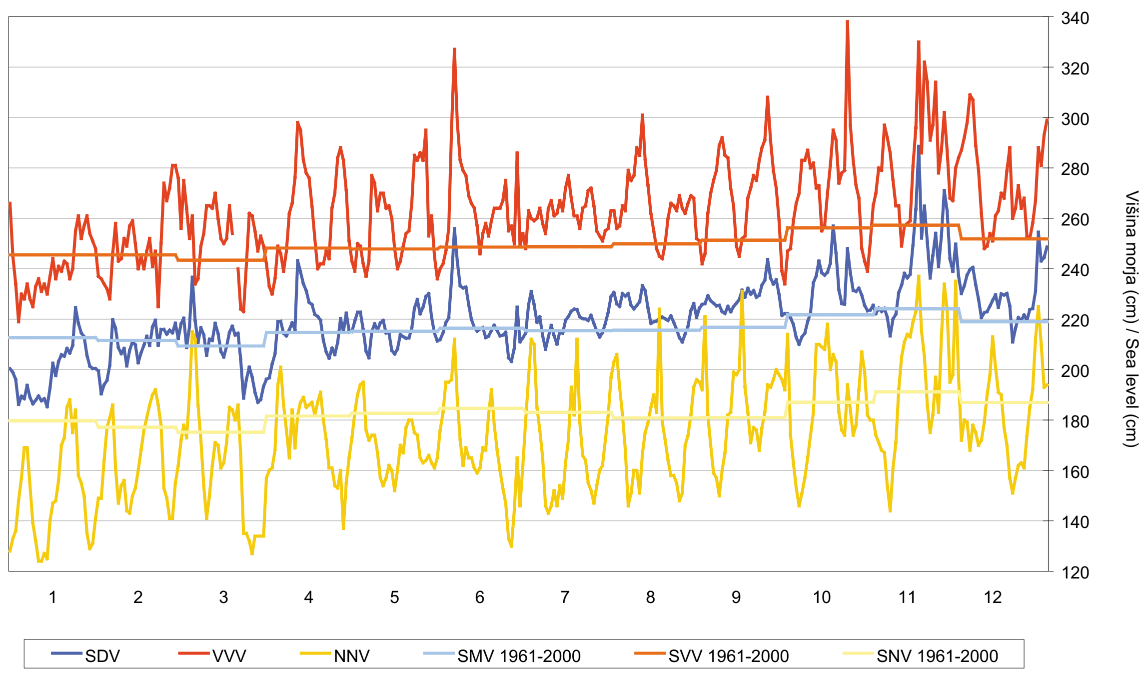
cantly above the mean for this period of year. The mean monthly sea level was only 3 cm lower than the highest sea level in the comparative period. The lowest monthly sea level was also above average.

Throughout the **September** the sea level was higher than the forecast level. Deviation was highest in the last third of the month (Graph 30). The highest sea level, at 307 cm, was registered on the 24th September. Compared to the period, all the characteristic values were considerably above average.

In **October** the sea level was high as well. In the morning of the 22nd October, the sea overflowed into the low-lying coastal areas for several hours. The highest sea level (338 cm) was reached on that morning. During that night, from the 21st to the 22nd October, a weather front passed across Slovenia. There were local storms and heavy showers of rain. In the morning of the 22nd October one of the storms developed above the Trieste Gulf and moved towards the Slovenian coast. It caused a heavy sea, pushing water masses onto the coast. Due to such effects, the sea increased and decreased quickly and heavily. The monthly maximum was reached at 6:25, four hours before the forecasted astronomic high water (Graph 31). With the exception of the lowest water in the month, which was somewhat below the average, the other measurements (mean monthly, mean high, mean low and the highest water) were above average.



Graf 32: Višina gladine morja v novembru ob posebnih meteoroloških razmerah.
Legenda: Vv = hitrost vetra, dP = razlika zračnega pritiska do srednje vrednosti 1016 mb, Vs = smer vetra v stopinjah, Hmer = izmerjena višina morja, Ha = astronomska višina morja, Hres = residualna višina je razlika med napovedano in izmerjeno višino morja.
Graph 32: The sea level in November during special meteorological conditions.
Legend: Vv = wind speed, dP = deviation of air pressure from the mean value of 1016 mb, Vs = wind direction in degrees, Hmer = measured sea level, Ha = astronomic sea level, Hres = residual sea level (the difference between the forecasted and the measured sea level).



Graf 33: Povprečne dnevne višine morja, povprečne dnevne plime in oseke v letu 2002 in pripadajoče povprečne mesečne vrednosti iz obdobja 1961-2000.
Graph 33: Mean, high and low waters in 2001 and mean monthly values from 1961-2000 period.

Z izjemo prvih dni v mesecu je bilo morje v **novembru** občutno višje od napovedanega. Morje je večkrat poplavilo dele obale, 16.in 25. novembra celo po dvakrat. Posebej za drugo polovico novembra je bilo značilno izrazito povišano plimovanje. Meteorološke razmere, ki so trajale več dni: nizek zračni pritisk in močan južni veter, so močno vplivale na gladino morja. Residualne višine so bile zelo visoke, celo do +98 cm (graf 32). Dne 16. novembra je bila srednja dnevna višina morja najvišja v vsem letu, 287,1 cm. Najvišja (330 cm) in najnižja (144 cm) gladina v mesecu sta bili sicer nadpovprečni v primerjavi s 40-letnim obdobjem, ne pa izjemni. Izjemno visoke pa so bile srednje vrednosti: srednja mesečna, srednja nizka in srednja visoka voda. Te so bile višje od najvišjih obdobnih vrednosti. Srednja mesečna vrednost je bila najvišja v letu, 241 cm.

V **decembru** je bilo morje nadpovprečno visoko. Največja odstopanja od napovedanih vrednosti so bila predvsem v začetku in ob koncu meseca. Morje je v začetku meseca dvakrat preseglo kritično vrednost 300 cm, ob koncu decembra pa se je tej vrednosti nekajkrat približalo. Vse značilne vrednosti so bile med srednjimi in najvišjimi primerljivimi obdobnimi vrednostmi.

With the exception of the first days in the month, the sea level in **November** was substantially higher than the forecasted level. On several occasions the sea overflowed parts of the coast, two times a day even on the 16th and the 25th November. A pronounced increase to the tide was especially characteristic of the second half of November. The meteorological conditions, low air pressure and strong southerly wind, lasted for several days and heavily influenced the sea level. The residual sea levels were very high, even up to +98 cm (Graph 32). On the 16th November, the mean daily sea level was the highest in the year, at 287.1 cm. The highest (330 cm) and the lowest (144 cm) sea level in the month were all above-average compared to the 40-year period, yet they were not outstanding. All the mean values however, the mean monthly, mean low and mean high water, were exceptionally high. These were higher than the highest values in the comparative period. The mean monthly value was the highest of the year at 241 cm.

In **December** the sea level was considerably above average. The highest deviations from the forecast values occurred mainly at the beginning and the end of the month. In the first part of the month the sea level twice exceeded the critical value of 300 cm, while at the end of the month, it came close to this value several times. All the characteristic values were between the mean and the highest values from the comparative period.

Strunjanski klif (foto: Jože Uhan).
The cliff of Strunjan (photo: Jože Uhan).

E. VODNA BILANCA

VODNA BILANCA

Peter Frantar

Vodna bilanca je razdelitev vodnega kroga na določenem območju na njegove sestavne člene. Izračun temelji na primerjavi vtokov (Q_v) in padavin (P) z odtoki (Q_i), evapotranspiracijo (ET) ter spremembo vodnih zalog (A). Pri izračunu bilance leta 2002 za območje Slovenije nismo upoštevali sprememb vodnih zalog. Predpostavili smo, da je ta člen bilance po količini zanemarljiv. To je potrebno upoštevati pri interpretaciji rezultatov. Uporabili smo enačbo vodne bilance, ki predpostavlja ravnovesje padavin z odtokom in evapotranspiracijo:

Padavine (P) = Odtok (Q) + Evapotranspiracija (ET)

Bilanco smo izdelali za osnovno hidrogeografsko razdelitev Slovenije na dve povodji: Jadransko in Črnomorsko, ki smo ju pri računanju odtokov še notranje razdelili. Jadransko povodje smo razdelili na porečje Soče, ki zajema pritoke Soče in Vipave, ter na povodje Jadranskih rek, ki zajema preostanek povodja Jadranskega morja. Črnomorsko povodje pa smo razdelili na Pomurje, Podravje in Posavje. Izračunane količine padavin in evapotranspiracije temeljijo na GIS analizi posameznih enot glavnih povodij.

Členi vodne bilance

Letno količino **padavin in evapotranspiracije** smo pridobili z metodo seštevanja v rastru z velikostjo celice 100 m x 100 m. Za raster padavin so bile uporabljene nekorigirane padavine za leto 2002, za raster evapotranspiracije pa izračunana potencialna evapotranspiracija za leto 2002. S prekrivanjem poligonov smo tako dobili skupno količino padavin in evapotranspiracije v posameznem porečju. Tako določeno evapotranspiracijo smo primerjali z vrednostjo, izračunano po enačbi P – Q = ET in ugotovili, da so rezultati podobni. Upoštevati moramo tudi dejstvo, da so dejanske količine padavin zlasti v gorskem svetu lahko celo nekaj deset odstotkov večje od upoštevanih, žal pa jih zaradi pomanjkanja podatkov nismo mogli korigirati.

Odtoki so praviloma najzanesljivejši člen vodne bilance. V reprezentančnih vodomernih postajah se namreč ves odtok določenega območja zbere na enem vodomernem profilu. Pri izračunavanju smo upoštevali pretoke glavnih vodomernih postaj

E. WATER BALANCE

WATER BALANCE

Peter Frantar

Water balance is the separation of the hydrologic cycle at a certain area into its constituent components. The calculation is based on the comparison of inflows (Q_i) and precipitation (P) with the outflows (Q_o), the evapotranspiration (ET) and the change of water reserves (A). In the calculation of balance for the area of Slovenia in the year 2002 the changes of water reserves were not considered. It was assumed that the amount of this balance component is negligible and this should be considered at the interpretation of the results. We used the water balance equation, which assumes equilibrium between precipitation and the outflow and the evapotranspiration:

Precipitation (P) = Outflow (Q) + Evapotranspiration (ET)

The balance was made for the basic hydrogeographic division of Slovenia into two basins, the Adriatic basin and the Black Sea basin, which were subdivided also internally for the calculation of the outflows. The Adriatic basin was divided into the catchment of the Soča River, capturing the tributaries of the Soča and Vipava rivers, and the so-called catchment of the Adriatic rivers, which captures the rest of the Adriatic Sea catchment. The Black Sea basin was divided into the river catchments of the Mura (Pomurje), Drava (Podravje) and Sava (Posavje) rivers. The calculated amounts of precipitation and evapotranspiration are based on the GIS analysis of the individual units of the main catchments.

Components of Water Balance

The yearly amounts of **precipitation and evapotranspiration** were obtained by the method of addition in a raster with the size of a cell 100 m x 100 m. For the precipitation raster the uncorrected amount of precipitation for the year 2002 was used, while the calculated potential evapotranspiration for the year 2002 was used for the evapotranspiration raster. By covering the polygons, the total amount of precipitation and evapotranspiration in the individual area was obtained. Thus the measured evapotranspiration was compared to the value calculated according to the equation P – Q = ET, which showed that the results were similar. We must consider the fact that the actual amounts of precipitation, espena vtokih in iztokih iz države ter ocene pretokov za vodotoke, ki imajo v Sloveniji le povirja. Za hidrometrično nepokrita območja smo pretoke določili z upoštevanjem specifičnih odtokov (l / km^2 / s) hidrološko primerljivih vodomernih postaj.

Vodna bilanca po glavnih slovenskih porečjih

Pomurje je hidrogeografska regija s površino vsega 1.390 km² in z najmanjšo povprečno količino padavin v Sloveniji. Leta 2002 je v Pomurju padlo v povprečju 780 mm padavin, kar je 34,3 m³/s. Količina izhlapele vode je bila po izračunu potencialne evapotranspiracije skoraj enaka računani ET po enačbi vodne bilance. Domnevna vzroka sta vegetacija, ki je večinoma negozdna (travniki, njive), pa tudi majhna količina padavin. Izhlapelo je 735 mm oz. 32,6 m³/s. Najmanj padavin je leta 2002 padlo na skrajnem severovzhodu, pri Hodošu, dobrih 650 mm, največ pa jih je padlo na severozahodnem delu, v Slovenskih goricah, in sicer nekaj nad 950 mm. Količine tekoče vode v tej pokrajini so močno odvisne od dotokov iz sosednjih območij. Pri vtoku v Slovenijo smo upoštevali Muro, del porečja Kučnice in Ledave izven Slovenije. Pri odtoku iz države pa smo upoštevali Muro, Veliko Krko, Ledavo ter odtok s preostalega območja, ki ga ne zajamemo z vodomernimi postajami. Vsi dotoki v Pomurje so leta 2002 doprinesli 136,3 m³/s, iz območja Pomurja pa je odteklo skupaj 138,0 m³/s. Količina vode, ki je leta 2002 odtekla iz Pomurja, je v povprečju 1,7 m³/s.

Podravje meri 3.265 km² in skozenj teče naša največja prehodna reka – Drava. Leta 2002 je bilo tu v povprečju 1040 mm padavin, kar je skoraj 108 m³/s. Najmanj padavin v Podravju je bilo leta 2002 na vzhodnem delu – v osrednjem delu Slovenskih goric (pod 800 mm), največ jih je bilo na zahodnem delu Podravja – na severnih pobočjih Olševe, kjer je padlo 1500 mm. Količino pritekle vode iz Avstrije smo določili s pretoki na Dravi v Dravogradu, na Bistrici v Muti ter na povirju Pesnice. Skupni odtok vsega Podravja je Drava na iztoku iz Slovenije. V Podravje je leta 2002 v povprečju priteklo dobrih 226 m³/s vode, odteklo pa jo je 272,3 m³/s. Neto prispevek Podravja k odtoku Drave je bil torej skoraj 46 m³/s. Z upoštevanjem padavin ter neto odtoka dobimo podatek, da je iz Podravja izhlapelo vsako sekundo 62 m³/s vode.

Posavje zajema 11.750 km^2 površine Slovenije. Leta 2002 je bilo na območju slovenskega Posavja v povprečju 1390 mm padavin oz. 518,6 m³/s. Porečje ima velik razpon količine padavin – od slabih 1000 mm v Posotelju do 2900 mm v ožjem območju zahodno od Bohinja. Pritoki v slovensko Posavje iz Hrvaškega dela porečja Ljubljanice, Kolpe, Krke in Sotle so bili slabih 36 m³/s, skupen iz-

cially in the highlands, can be also up to several tens of percent higher than the considered amounts. Unfortunately we were not able to correct them due to the lack of data.

Outflows are usually the most reliable element of water balance. Specifically, at the representative water gauging stations the total outflow of a certain area is assembled at one water gauging profile. In calculation, we considered the discharges of the main water gauging stations at inflows and outflows across the country, as well as the estimations of the discharges for water courses that only have headwaters in Slovenia. The discharges for the areas that were not hydrometrically covered were determined by considering the specific outflows (l / km^2 / s) of hydrologically comparative water gauging stations.

Water Balance of the Main Slovenian River Catchments

Pomurje (the catchment of the Mura River) is a hydro-geographic region with an area of only 1,390 km^2 and has the lowest average amount of precipitation in Slovenia. In 2002 an average amount of 780 mm of rainfall fell in Pomurje, which is 34.3 m^3/s. According to the calculation of the potential evapotranspiration, the amount of the evaporated water was almost the same as the calculated ET according to the water balance equation. The supposed reasons are the vegetation, which is mainly non-forest (grasslands, fields) and the low amount of rainfall. Evaporation there amounted to 735 mm or 32.6 m^3/s. The lowest amount of rainfall in the year 2002 fell in the most distant north-eastern part, at Hodoš, which recorded 650 mm, while the highest amount of rainfall fell in the north-western part in Slovenske gorice, recording over 950 mm. The amounts of running water in this region are heavily dependant on the inflows from the neighbouring areas. With the inflow into Slovenia we considered the Mura River, as well as a part of the river basins of the Kučnica and Ledava rivers outside Slovenia. With the outflow from the country we considered the Mura, Velika Krka and Ledava Rivers, as well as the outflow from the rest of the area, which is not captured by the water gauging stations. In 2002 all the inflows into Pomurje contributed 136.3 m^3/s, while a total amount of 138.0 m^3/s flowed out of the Pomurje region. Therefore the amount of water that flowed out of Pomurje in 2002 was 1.7 m^3/s on average.

Podravje (the catchment of the Drava River) measures 3,625 km^2 and contains the largest Slovenian transit river – the Drava. In 2002 there was 1040 mm of precipitation on average, which is almost 108 m^3/s. In Podravje, the lowest amount of rainfall in 2002 fell in the eastern part – the central tok iz Slovenije pa je bil 312 m³/s. Iz slovenskega Posavja je odteklo 276,2 m³/s. Po bilančni enačbi izračunana evapotranspiracija je bila 242,5 m³/s.

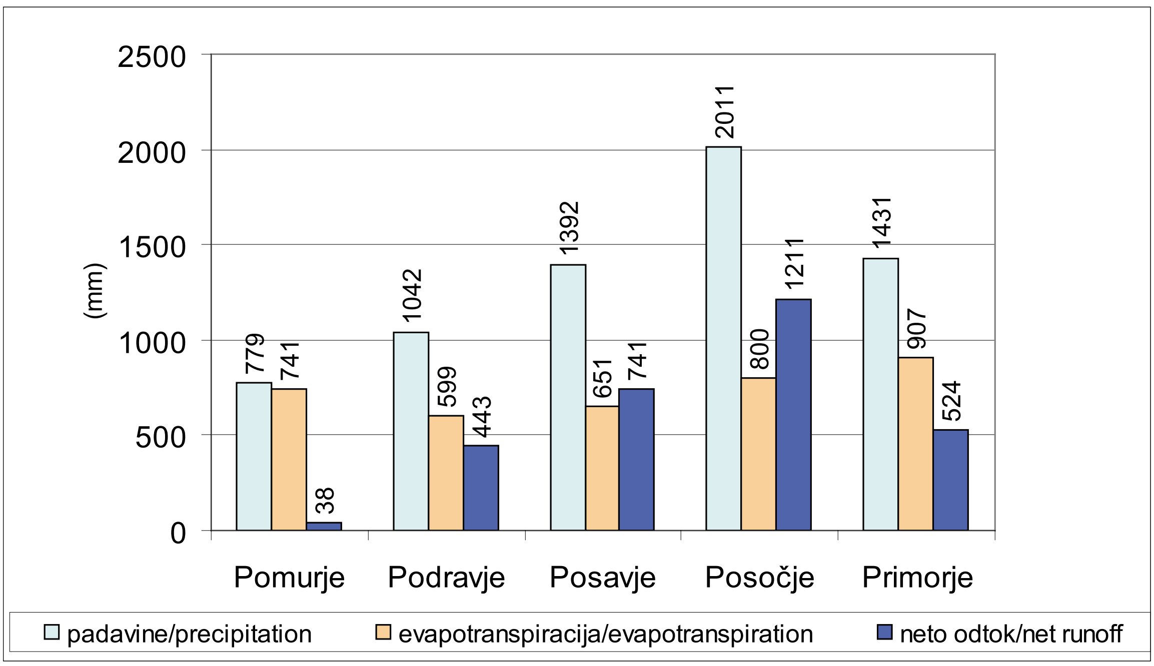
Posočje meri 2.320 km² in je najbolj vodnato porečje. Tudi leta 2002 je tu padlo največ padavin, v povprečju preko 2000 litrov na kvadratni meter v celem letu oz. slabih 150 m³/s. Preko 2000 mm padavin je padlo na območju Idrijsko-Cerkljanskega hribovja ter Julijskih Alp, največ, preko 3000 mm, v Krnskem pogorju. Najmanjša količina padavin v Posočju je bila leta 2002 v Vipavski dolini – nekaj nad 1350 mm. Skoraj vse povirje Posočja pripada Sloveniji. Izjeme so povirja Učje, Nadiže ter deloma Idrije, upoštevati pa moramo tudi vodo, ki se iz rudniškega rova v Logu pod Mangartom pretoči iz Podonavja v Posočje. Vsi ti dotoki vode prinesejo 5,22 m³/s. Iz slovenskega ozemlja Posočja pa voda odteka v največji meri preko Soče, Vipave in Nadiže, pa tudi preko Idrije, Reke, Korena in nekaj manjših izvirov. Tako je leta 2002 odteklo okrog 95 m³/s, količina izhlapevanja pa je bila v Posočju leta 2002 skoraj 60 m³/s.

part of Slovenske gorice (below 800 mm), while the highest amount fell in the western part of Podravje, on the northern hillsides of the Olševa Mountain, where 1500 mm fell. The amount of the water that flowed in from Austria was determined by the discharges recorded on the Drava River at Dravograd, on the Bistrica River at Muta and on the headwater of the Pesnica River. The Drava River at the outflow from Slovenia represents the total outflow from the entire region of Podravje. On average over 226 m³/s of water flowed into Podravje in 2002, while 272.3 m³/s of water flowed out. The net contribution of Podravje to the outflow of the Drava River was therefore nearly 46 m³/s. Considering the rainfall and the net outflow, the data shows that 62 m³/s of water evaporated from Podravje each second.

Posavje (the catchment of the Sava River) covers and area of 11,750 km². In 2002 there was on average, a precipitation of 1390 mm, or 518.6 m³/s, in the area of Slovenian Posavje. The river basin has a large range of rainfall – from less than 1000 mm in the river basin of the Sotla River up to 2900 mm

Preglednica 17: Členi vodne bilance po hidrogeografskih enotah Slovenije leta 2002.
Table 17: Components of the water balance by the hydrogeographic units of Slovenia in 2002.

(mm)	Pomurje	Podravje	Posavje	Posočje	Primorje
padavine / precipitation	779	1042	1392	2011	1431
evapotranspiracija / evapotranspiration	741	599	651	800	907
neto odtok / net runoff	38	443	741	1211	524
odtočni količnik / runoff coeficient	0,05	0,43	0,53	0,60	0,37



Graf 34: Elementi vodne bilance leta 2002 po hidrogeografskih enotah Slovenije.
Graph 34: Components of the water balance by the hydrogeographic units of Slovenia in 2002.

Vodomerna postaja Šalara na Badaševici 12. julija 2002.
(foto: Bogomir Štolcar)
The Badaševica river at Šalara on the 12th July 2002.
(photo: Bogomir Štolcar)

Povodje preostalih Jadranskih rek zajema 1.530 km², največji vodotok pa je Reka. Tu je padlo leta 2002 v povprečju 1430 mm padavin, to je slabih 70 m^3/s. V nekajkilometrskem obalnem pasu je padlo le nekaj nad 1000 mm, na ožjem območju Snežnika pa skoraj 2000 mm. Dotoki v Slovenijo so tu samo v povirju Rižane in Reke ter v zaledju Dragonje. Skupaj priteče v Slovenijo manj kot 1 m^3/s vode. Iztokov je več – poleg večine Krasa ter obale se v Italijo odtaka tudi Osapska reka, na Hrvaško pa teče voda iz povirja porečja reke Mirne. Skupni odtok je iz tega povodja 25,4 m^3/s, neto odtok pa je za 1 m^3/s manjši. Leta 2002 je izhlapelo preko 24 m^3/s.

Primerjava z obdobno vodno bilanco

Leta 1998 sta Kolbezen in Pristov izdelala pregled členov vodne bilance Slovenije za obdobje 1961-1990. Uporabila sta korigirane vrednosti padavin. Kljub različni metodologiji določitve padavin smo primerjali korigirane obdobne in nekorigirane vrednosti za leto 2002. Vse člene vodne bilance leta 2002 smo primerjali z referenčno obdobno vodno bilanco 1961-1990.

V **Podonavju** je leta 2002 padlo manj padavin, kot je obdobno povprečje. Med leti 1961-1990 je bila povprečna količina padavin Podonavja 1445 mm, leta 2002 pa le 1270 mm, kar je 12 odstotkov manj. Evapotranspiracija pa je bila leta 2002 praktič-

in a narrow area west of Bohinj. The inflow into the Slovenian Posavje from the Croatian part of the river basins of the Ljubljanica, Krka and Sotla rivers was only 36 m^3/s, while the total outflow from Slovenia was 312 m^3/s. From Slovenian Posavje, 276.2 m^3/s flowed out. The evapotranspiration calculated according to the balance equation was 242.5 m^3/s.

Posočje (the catchment of the Soča River) measures 2,320 km^2 and is the catchment with the largest amount of water in Slovenia. Also in 2002, the highest amount of precipitation was registered, over 2000 liters per square meter or almost 150 m^3/s on average throughout the year. Over 2000 mm of rainfall fell in the area of the Idrija-Cerklje Hills and in the Julian Alps, the highest being 3000 mm in the mountain chain in the area of Krn Mountain. In 2002 the lowest amount of rainfall in Posočje was in the Vipava Valley – something over 1350 mm. Almost the entire region of Posočje belongs to Slovenia, the exceptions being the headwaters of the rivers Učja, Nadiža and partially the Idrija River. We must also consider the water that is discharged from the Danube River basin through a mine tunnel at Log pod Mangartom into the catchment of the Soča River. All these inflows bring in 5.22 m^3/s of water. From the Slovenian area of Posočje the water flows out to the greatest extent via the Soča, Vipava and Nadiža Rivers, as well as via the Idrija, Reka and Koren Rivers and some small springs. Thus, in the year 2002 around 95 m^3/s of water flowed out of Posočje, while the amount of evaporation in 2002 was almost 60 m^3/s.

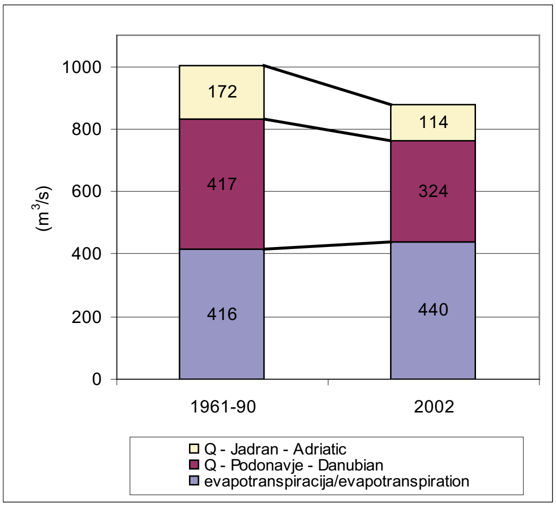
The catchment of the rest of the Adriatic rivers captures 1,530 km^2, the largest water course being the Reka River. In 2002 an average of 1430 mm of precipitation was registered, which is almost 70 m^3/s. Only something above 1000 mm of rain fell in the several kilometres of the coastal area, while in the narrow area of Snežnik Mountain almost 2000 mm fell. Here, inflows into Slovenia are only through the headwaters of the Rižana and Reka Rivers, and also in the hinterland of the Dragonja River. In total, there is less than 1 m^3/s of water flowing into Slovenia. There are several outflows – in addition to most of the Karst region and the coast, the Osapska reka River also flows out to Italy, while the water from the headwaters of the river basin of the Mirna River flow out to Croatia. The total outflow from this catchment is 25.4 m^3/s, while the net outflow is lower than 1 m^3/s. In 2002 over 24 m^3/s of water evaporated.

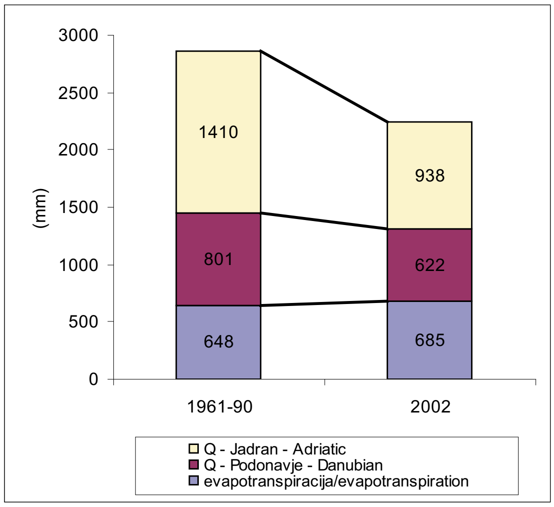
Comparison with the Multiannual Period Water Balance

In 1998 Kolbezen and Pristov made a survey of the components of the water balance of Slov-

Preglednica 18: Primerjava členov vodne bilance 2002 z dolgoletnim obdobjem 1961-1990.
Table 18: Comparison of the components of the 2002 water balance with the multi-annual period 1961-1990.

(mm)	Podonavje		Jadran		Slovenija	
	1961-90	2002	1961-90	2002	1961-90	2002
padavine / precipitation	1445	1270	2073	1781	1565	1367
evapotranspiracija / evapotranspiration	644	648	664	842	648	685
neto odtok / net runoff	801	622	1410	938	917	682
odtočni količnik / runoff coeficient	0,55	0,49	0,68	0,53	0,59	0,50





Graf 35: Členi vodne bilance v referenčnem obdobju 1961-1990 ter letu 2002. Povprečna količina odtoka v glavnih povodjih in skupnega izhlapevanja.
Graph 35: The components of the water balance in the reference period 1961-1990 and in the year 2002. The average amount of outflow from the main catchments and the amount of total evaporation.

no enaka povprečju obdobja 1961-1990. Leta 2002 je v Podonavju izhlapelo skoraj 650 mm vode V obdobju 1961-1990 smo iz Slovenije v Podonavje prispevali skoraj 420 m^3/s vode oz. 800 mm. Leta 2002 je bil odtok manjši za več kot petino: v Podonavje smo prispevali dobrih 320 m^3/s oz. 620 mm.

V primerjavi z dolgoletnim obdobjem je bil leta 2002 v Podonavju zaradi manjše količine padavin in skoraj enake evapotranspiracije, odtok precej manjši.

V slovenskem delu **Jadranskega povodja** je v letu 2002 padlo skoraj 15 odstotkov manj padavin kot v dolgoletnem obdobju. V tem letu je bila količina padavin 1780 mm, obdobno povprečje pa je 2070 mm. Evapotranspiracija je bila po letnih vodnobilančnih izračunih večja za dobrih 25 odstotkov – v letu 2002 skoraj 850 mm. V letu 2002 je bil povprečni odtok v Jadran samo 114 m^3/s (938 mm), medtem ko je dolgoletni povprečni odtok preko 170 m^3/s (1410 mm). Odtok v letu 2002 je bil manj kot 2/3 povprečnega obdobnega odtoka.

enia for the period 1961-1990. They used corrected rainfall values. Despite the different methodology used in determining the precipitation, we compared the corrected period and the uncorrected values for the year 2002. All the elements of the 2002 water balance were compared to the reference period water balance in the period 1961-1990.

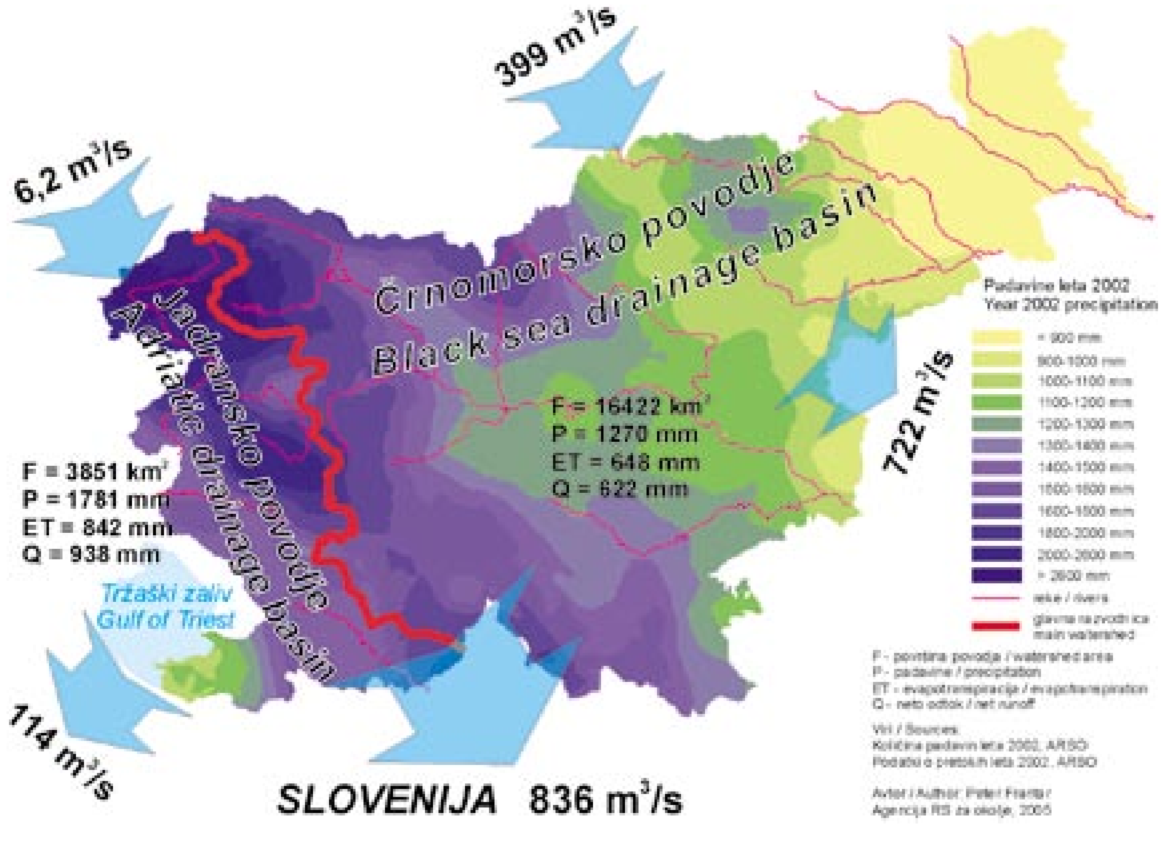
In **Podonavje**, the river basin of the Danube River, the amount of precipitation in 2002 was lower than the period mean. During the years 1961-1990, the average amount of rainfall in Podonavje was 1445 mm, while in 2002 it was only 1270 mm, which is 12 percent less. The evapotranspiration in 2002 however, was practically the same as the mean for the period 1961-1990. In 2002 almost 650 mm of water evaporated in Podonavje. In the period of 1961-1990 the water from Slovenia contributed almost 420 m^3/s, or 800 mm, to the Danube River basin. In 2002 the outflow was lower by more than a fifth with only 320 m^3/s, or 620 mm contributed.

Compared to the multi-annual period, the outflow from Podonavje in 2002 was considerably lower due to the lower amount of rainfall and the almost unchanged amount of evapotranspiration.

Leta 2002 je bilo v **Sloveniji** v primerjavi z referenčnim obdobjem manj padavin, nekoliko se je povečala evapotranspiracija, zato so bili odtoki precej manjši. Padavin je bilo v primerjavi z dolgoletnimi obdobnimi povprečji manj za 12 odstotkov, izhlapevanja je bilo več za 6 odstotkov, lastni odtok iz Slovenije pa je bil manjši za 25 odstotkov. Izračun členov vodne bilance je pokazal, da je bilo leto 2002 podpovprečno vodnato.

In the Slovenian part of **the Adriatic basin**, almost 15 percent less precipitation was measured in 2002 than in the multi-annual period. In that year the amount of rainfall was 1780 mm, while the period mean was 2070 mm. According to the yearly calculations of water balance, the evapotranspiration was higher by over 25 percent – almost 850 mm in 2002. In 2002 the average outflow into the Adriatic Sea was only 114 m^3/s (938 mm), while the multi-annual mean outflow was 170 m^3/s (1410 mm). The outflow in 2002 was less than 2/3 of the mean period outflow.

In 2002 the amount of precipitation in **Slovenia** was lower in comparison with the reference period, while the evapotranspiration had somewhat increased. This is why the outflows were considerably lower. The amount of rainfall compared to the multi-annual period means was 12 percent lower, the evaporation was 6 percent higher, while Slovenia's own outflow was 25 percent lower. The calculation of the water balance components showed that in 2002 the amount of water was below average.



Karta 7: Karta vodnobilančnih členov v Sloveniji leta 2002.
Map 7: Map of the water balance components in Slovenia in the year 2002.