I. DEL: PREGLED HIDROLOŠKIH RAZMER V LETU 2000

PART I: A REVIEW OF HYDROLOGICAL CONDITIONS IN THE YEAR 2000

A. POVRŠINSKE VODE

VODOSTAJI IN PRETOKI REK

Igor Strojan

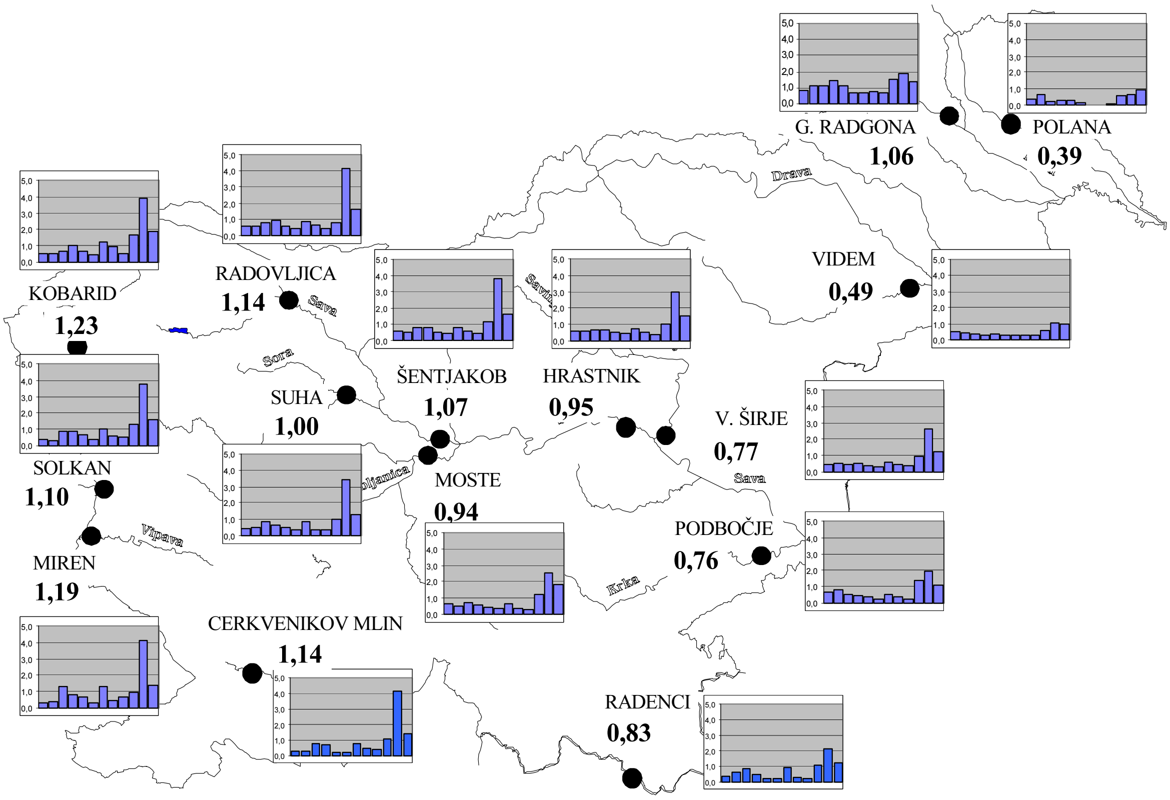
V celoti je po slovenskih rekah v letu 2000 preteklo šest odstotkov manj vode kot običajno. Značilno za hidrološke razmere v tem letu je podpovprečna vodnatost rek od začetka leta do jesenskih mesecev ter izredno velika vodnatost novembra in deloma decembra (graf 1 in 2).
Odstopanja od povprečnih pretokov so bila prostorsko dokaj neenakomerno porazdeljena (karta 1). Pretoki so bili večji od povprečnih v zahodnem, severnem in osrednjem delu, manjši v vzhodnem, ter najmanjši v severovzhodnem delu države. Izjema so pretoki na Muri, ki se zaradi napajanja v avstrijskem visokogorju že običajno razlikujejo od pretokov rek s povodji v severovzhodni Sloveniji.
Časovna razporeditev pretokov je bila dokaj nenavadna. Pretoki se preko leta niso spreminjali skladno z ustaljenimi pretočnimi režimi rek. Običajnih pomladanskih visokih voda ni bilo. Pretoki so bili majhni do srednji vse od januarja do oktobra. Najmanjši so bili junija, avgusta ali septembra. V zadnjih treh mesecih leta je po rekah odtekla polovica celoletne količine vode. Samo novembra je odteklo po rekah skoraj tri krat več vode kot navadno (graf 1).
Sušna obdobja so bila najbolj izrazita v severovzhodni Sloveniji. Na vodomerni postaji Polana na Ledavi je bil srednji dnevni pretok 100 dni zaporedoma (s prekinitvijo enega dne) manjši od obdobnega srednjega pretoka. Še daljše in izrazitejše sušno obdobje so preprečile padavine v juliju, ki so prehodno povečale pretoke tudi preko srednjih vrednosti (graf 2). V zahodnem delu Slovenije so bile hidrološke sušne razmere nekoliko milejše. Pretoki manjši od povprečnih obdobnih malih pretokov so bili zelo redki.
Najvišje letne visokovodne konice novembra so bile v povprečju le nekoliko večje kot navadno, v nekaterih primerih pa podobne najvišjim visokovodnim konicam iz primerjalnega obdobja 1961–1990 (graf 3). Reke so poplavljale večje površine kot običajno. Podrobneje so visokovodne in sušne razmere v letu 2000 opisane v poglavjih Visoke vode in poplave ter Hidrološka suša rek.

A. SURFACE WATERS

WATER LEVEL AND RIVER DISCHARGE

Igor Strojan

On the whole, river discharge in Slovenia in the year 2000 was 6 % lower than usual. It was typical for the hydrological situation that the quantity of water in the rivers was below average from the beginning of the year until autumn, but it was exceptionally high in November and partly in December (Graphs 1 and 2).
Deviations from average discharge values were spatially, rather than unequally distributed (Map 1). Discharges were higher than the average in the western, northern and central part, but lower in the eastern, and the lowest in the northeastern part of the country. An exception was the river Mura, the discharges of which are usually different from those of the rivers with catchments in northeastern Slovenia, because they are recharged in the Austrian mountains.
Temporal distribution of discharges was rather unusual. They did not change over the year in accordance with established discharge regimes. High spring waters, which normally occur at that time of the year, were not observed in the year 2000. Discharges were low to medium from January to October, and in June, August and September, they were the lowest. Half of the total annual water runoff occurred in the last three months of the year. The November runoff was almost three times higher than usual. (Graph 1).
Dry periods were the most explicit in northeastern Slovenia. At the gauging station Polana on the Ledava, the mean daily discharge was, for 100 consecutive days (with a one-day interruption), lower than the mean discharge of the period. Precipitations in July prevented an even longer and more severe dry period. They temporarily increased discharges even above the mean values (Graph 2). In western part of Slovenia hydrological conditions in the dry period were somewhat milder. Discharges that were lower than the average low discharges of the period, were very rare.
Maximum annual high-water peaks in November were on average only a little higher than usual, and in some cases they were similar to the maximum high-water peaks from the comparative period 1961–1990 (Graph 3). The rivers



Karta 1: Razmerja med srednjimi letnimi pretoki leta 2000 in obdobja 1961–1990 ter grafični prikazi razmerij med srednjimi mesečnimi pretoki leta 2000 in obdobja 1961—1990. Vrednost razmerja 1 pomeni enak pretok leta 2000 kot v povprečju dolgoletnega obdobja.

Map 1: Ratios between the mean annual discharges of the year 2000 and of the period 1961–1990 and graphic presentation of the ratios between the mean monthly discharges of the year 2000 and of the period 1961—1990. Ratio value 1 means the same discharge in the year 2000 as multiannual mean.

Pregled po mesecih. Januar in februar sta bila hidrološko izrazito suha meseca. Pretoki so bili v povprečju polovico manjši kot navadno v tem obdobju. Samo pretok Mure je bil večji kot na ostalih rekah in le nekoliko manjši od dolgoletnega povprečja v tem obdobju.

Srednje veliki pretoki rek iz prvih januarskih dni so se zmanjševali vse do zadnjih dni v mesecu, ko so se zaradi otoplitve in taljenja snega takrat mali pretoki ponovno povečali do srednjih vrednosti. Pretoki so se nato prvo februarsko dekado zmanjševali, kasneje pa ponekod ponovno bolj izrazito povečali, na Krki in Kolpi do srednjih vrednosti. Zaradi padavin in taljenja snega so se pretoki povečali tudi 17. februarja. Pretoki so bili v naslednjih dneh in vse do konca meseca mali.

Marca in aprila se je vodnatost večine rek glede na januar in februar nekoliko povečala, vendar so se hidrološko sušne razmere nadaljevale. Pretoki so bili v povprečju trideset odstotkov manjši kot navadno v tem času. V vzhodni Sloveniji se je vodnatost glede na predhodna me-

flooded larger areas than usual. The conditions of high-water and dry period in the year 2000 are described in more detail in the following chapters High waters and Floods and hydrologies droughts of rivers.

A review by months. January and February were hydrologically very dry months. Discharges were on average half as low than they usually are in this period. Only the discharge of the Mura river was higher than those on other rivers and only somewhat lower than the multiannual mean.

River discharges of medium values from the first days of January were decreasing until the last days of the month. At that time, due to warming and melting of the snow, these discharges, which were than low, increased to medium values again. Discharges were decreasing in the first decade of February, and later they markedly increased at some places, on the rivers Krka and Kolpa up to medium values. Due to precipitations and melting of snow, the discharges increased on the 17th of February as well, but in the following days and until the end of the month, the discharges were low.

seca celo zmanjšala. Pretok Mure je bil še vedno večji kot pretoki ostalih rek in celo nekoliko večji kot navadno v tem obdobju.
V začetku marca so se najbolj povečali pretoki v zahodni Sloveniji, kjer so bili veliki, in manj v osrednji Sloveniji, kjer so dosegli srednje vrednosti. V naslednjih dneh so se pretoki večinoma zmanjševali do zadnjih dni marca, ko so jih nekajdnevne padavine povečale do velikih vrednosti. Padavine v prvem tednu aprila in občasno tudi v naslednjih aprilskih dneh so upočasnjevale zmanjševanje pretokov. V tem času je bil pretok največji na Muri. Pretoki so se do konca aprila zmanjšali do malih oz. srednjih vrednosti.
Maja in junija se je vodnatost rek glede na predhodna meseca ponovno močno zmanjšala. Povprečni pretoki v juniju so bili samo nekaj večji od tretjine običajnih pretokov v tem času. Prostorska porazdelitev vodnatosti se je ohranjala. Najbolj vodnata je bila Mura, nekoliko manjša je bila vodnatost v zahodni in osrednji Sloveniji, najmanjša pa v vzhodnem delu države. Maja so občasne padavine nekoliko upočasnjevale že tako hitro zmanjševanje večinoma malih do srednjih pretokov. Celoten junij so bili pretoki z redkimi izjemami (Mura in Drava) mali.

In **March and April** the quantity of water in most rivers increased, compared to January and February, but the hydrologically dry conditions continued. The discharges were on average 30 % lower than they usually are at this time of year. The quantity of water even decreased in eastern Slovenia, compared to the previous two months. The discharge of the Mura river was still higher than the discharge of other rivers, and even somewhat higher than it usually is in this period.
At the beginning of March, the discharges in the western part of Slovenia, where they had already been high, increased the most, but less in central Slovenia where they reached medium values. In the following days the discharges were mainly decreasing, until the last days of March, when precipitation, lasting for a few days, caused an increase to high values. Precipitation in the first week of April, and occasionally also in the following days of April, were slowing down the decrease of discharges. The Mura river had the highest discharge in this period. By the end of April the discharges decreased to low or medium values.
In **May and June** the quantity of water in the rivers decreased substantially, compared to the previous two months. Average discharges in June were only somewhat higher than one third of normal discharges at this time of the year. Spatial dis-

Vodomerna postaja ob reki Učja v kraju Žaga. (foto: Peter Frantar)
Surface water gauging station on the river Učja in Žaga. (photo: Peter Frantar)

V naslednjih treh mesecih, **juliju, avgustu in septembru** so se ponovile razmere iz prejšnjih treh mesecev. Pretoki so se v juliju, podobno kot v aprilu, povečali in glede na junij večinoma podvojili. Kljub dotedanjim splošnim sušnim razmeram so se predvsem v drugem tednu julija povečali do velikih pretokov. Visokovodne konice so bile največje na zahodu države. Pretok Mure se je povečal v manjši meri. Vodnatost v severovzhodni Sloveniji se je le malo povečala. Avgusta in septembra so se pretoki zmanjšali do vrednosti, ki so jih imeli v juniju. Hidrološka suša je bila v tem obdobju najbolj izrazita.

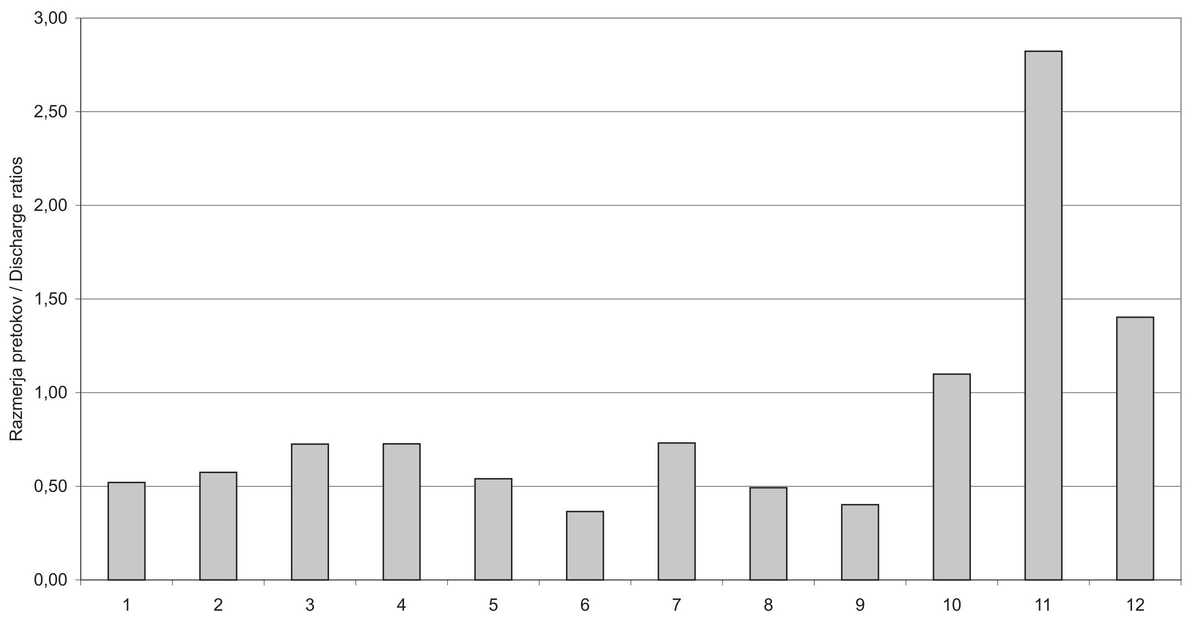
Oktober, november in december so bili hidrološko mokri meseci. Izrazito moker je bil november, v katerem je po večini rek preteklo nekajkrat več vode kot povprečno v tem času. Pretoki so bili novembra le v redkih primerih manjši od velikih pretokov. Reke so poplavljale. Decembra je bilo padavin manj, pretoki so se zmanjšali, a so bili še vedno večji kot običajno v tem času.

Dnevno spreminjanje pretokov na slovenskih rekah leta 2000 je predstavljeno s srednjimi dnevnimi pretoki Save na vodomerni postaji v Hrastniku (graf 2). Odstopanja od prikazanih pretokov so se tudi v letu 2000 pojavljala predvsem na rekah z drugačnim pretočnim režimom, od katerih je najbolj izrazit primer Mure, ki ima t.i.

tribution of water quantity remained the same. In this period the Mura river had the highest quantity of water, while water quantity was a little lower in western and central Slovenia, and the lowest in the eastern part of the country. Occasional precipitations in May were somewhat slowing down the fast decrease of low to medium discharges. In June the discharges were low, with a few exceptions (the rivers Mura and Drava).

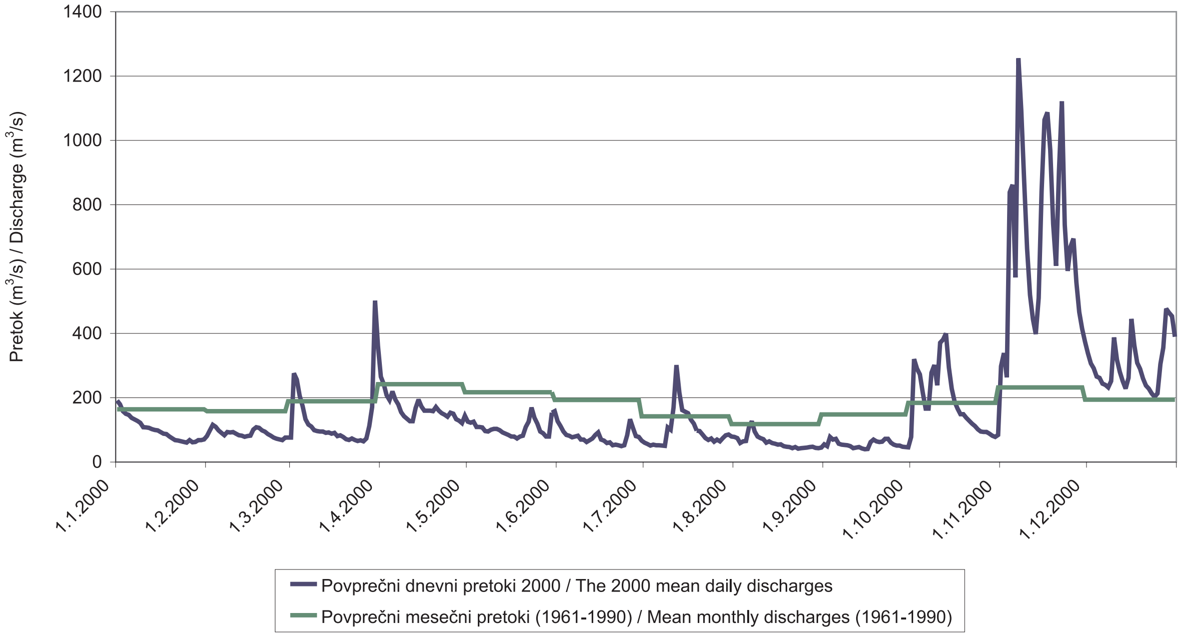
In the next three months, in **July, August and September**, the situation of the previous three months repeated itself. Similar to April, the discharges in July increased, and with respect to June, most of them doubled. In spite of the generally dry conditions thus far, they increased to high values, mainly in the second week of July. High-water peaks were the greatest in the western part of the country. The discharge of the Mura did not increase to a great extent. Water quantity in north-eastern Slovenia increased only a little. In August and September the discharges decreased to the same value they had in June. Hydrological drought was the most explicit at this time of the year.

October, November and December were hydrologically wet months. A markedly wet month was November, when several times more water than the average for this period flowed in most of the rivers. Discharges in November were rarely lower than the high values. The rivers flooded. There



Graf 1: Razmerja med srednjimi mesečnimi pretoki v letu 2000 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 the year 2000 and between the mean monthly discharges of the period. The ratios are calculated as average values of ratios on the selected stations (see Map 1).



Graf 2: Srednji dnevni pretoki v letu 2000 in srednji mesečni pretoki v dolgoletnem obdobju 1961 – 1990 na reki Savi v Hrastniku.
Graph 2: Mean daily discharges in the year 2000 and mean monthly discharges in a longer period 1961 – 1990 on the Sava in Hrastnik.

snežni pretočni režim z obilnimi pretoki pomladi in poleti.

Značilni pretoki. Mura, Sava v zgornjem toku ter Soča so imele v letu 2000 **najmanjši pretok** januarja in februarja, kar je skladno z njihovimi običajnimi pretočnimi režimi. Dravinja in Vipava sta imeli najmanjši pretok pred prekinitvijo suše v juniju. Na večini rek so bili pretoki najmanjši avgusta in septembra (graf 3 in preglednica 1). V povprečju so bili najmanjši pretoki 23 odstotkov manjši kot v primerjalnem obdobju. Najbolj je izstopal izredno majhen pretok na Ledavi v Polani 0,01 m^3/s 12. avgusta.

Srednji letni pretoki rek, ki so prikazani na karti 1, grafu 3 in v preglednici 1, so bili v povprečju nekoliko manjši kot v dolgoletnem primerjalnem obdobju. Pretoki v severovzhodni Sloveniji so bili med najmanjšimi v primerjalnem obdobju (graf 3 in preglednica 1).

V letu 2000 so se **največji pretoki** v povprečju le malo razlikovali od običajnih največjih pretokov v primerjalnem obdobju, vendar so bili glede na velikosti prostorsko dokaj neenakomerno porazdeljeni. Nadpovprečne so bile visokovodne konice na Savi, Soči, Vipavi in Savinji. Le nekoliko večje od najmanjših v primerjalnem obdobju so bile visokovodne konice na Muri in v severovzhodni Sloveniji. Na ostalih rekah so

was less precipitation in December and the discharges decreased, but they were still higher than they usually are at this time of the year.

Daily discharge changes on the Slovene rivers in the year 2000 are presented with mean daily discharges of the Sava river on the water gauge station in Hrastnik (Graph 2). Deviations from the presented discharges appeared in the year 2000 mainly on the rivers with a different discharge regime. The most explicit example is the river Mura with a snow discharge regime with high discharges in spring and summer.

Characteristical discharges. The **lowest discharges** of the Mura, of the upper reach of the Sava and of the river Soča in the year 2000 were in January and February, which is in accordance with their common discharge regimes. The Dravinja and the Vipava had the lowest discharges before the precipitation occurred in June and interrupted the dry period. On most rivers the discharges were the lowest in August and September (Graph 3 and Table 1). The lowest discharges were on average 23 % lower than in the comparative period. The most outstanding was a very low discharge on the Ledava in Polana, 0.01 m^3/s on the 12th of August.

Mean annual discharges of rivers, which are shown on Map 1, in Graph 3 and in Table 1, were

Preglednica 1: Značilni pretoki v letu 2000 in obdobju 1961-1990.
Table 1: Characteristic discharges in the year 2000 and in the period 1961-1990

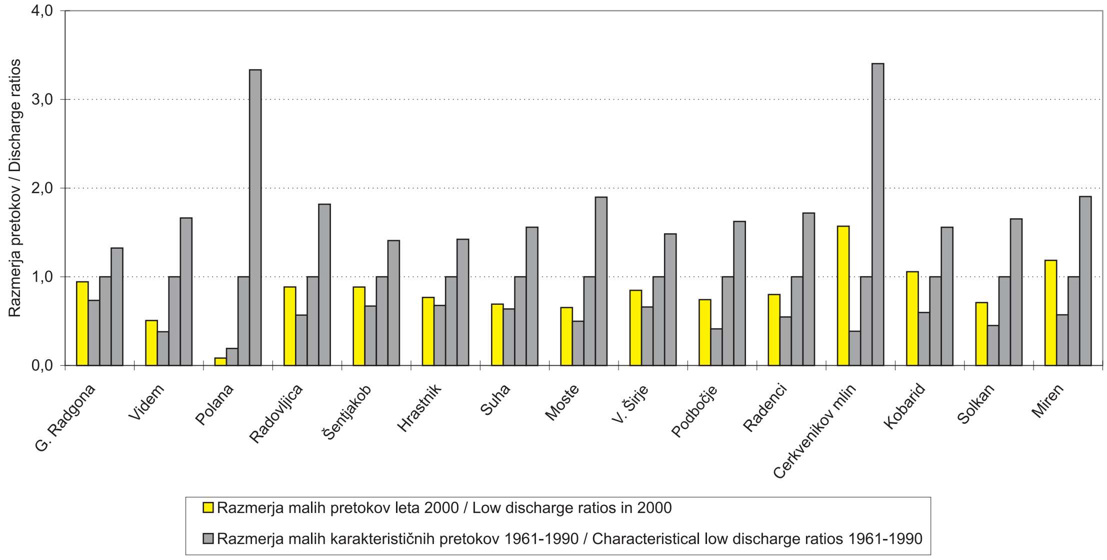
VODOTOK STREAM	POSTAJA GAUGING STATION	**Qnp**		nQnp	sQnp	vQnp
		2000		1961-1990		
		m^3/s	dan/day	m^3/s	m^3/s	m^3/s
MURA	G. RADGONA	58,2	27. 1.	45,3	61,7	81,7
DRAVINJA	VIDEM	1,0	23. 6.	0,78	2,05	3,41
LEDAVA	POLANA	0,01	12. 8.	0,03	0,15	0,52
SAVA	RADOVLJICA	7,8	24. 2.	5	8,8	16
SAVA	ŠENTJAKOB	26,0	25. 2.	19,7	29,4	41,4
SAVA	HRASTNIK	39,9	15. 9.	35,2	52,0	74,0
SORA	SUHA	2,7	23. 8.	2,44	3,83	5,97
LJUBLJANICA	MOSTE	5,4	15. 9.	4,1	8,22	15,6
SAVINJA	V. ŠIRJE	7,7	31. 8.	6,0	9,1	13,5
KRKA	PODBOČJE	8,1	13. 9.	4,5	10,9	17,7
KOLPA	RADENCI	5,1	5.7.	3,5	6,4	11
REKA	CERKVENIKOV MLIN	0,9	6.6.	0,22	0,57	1,94
SOČA	KOBARID	8,1	21. 2.	4,6	7,7	12,0
SOČA	SOLKAN	15,1	27. 2.	9,6	21,3	35,2
VIPAVA	MIREN	2,5	20. 6.	1,2	2,1	4,0

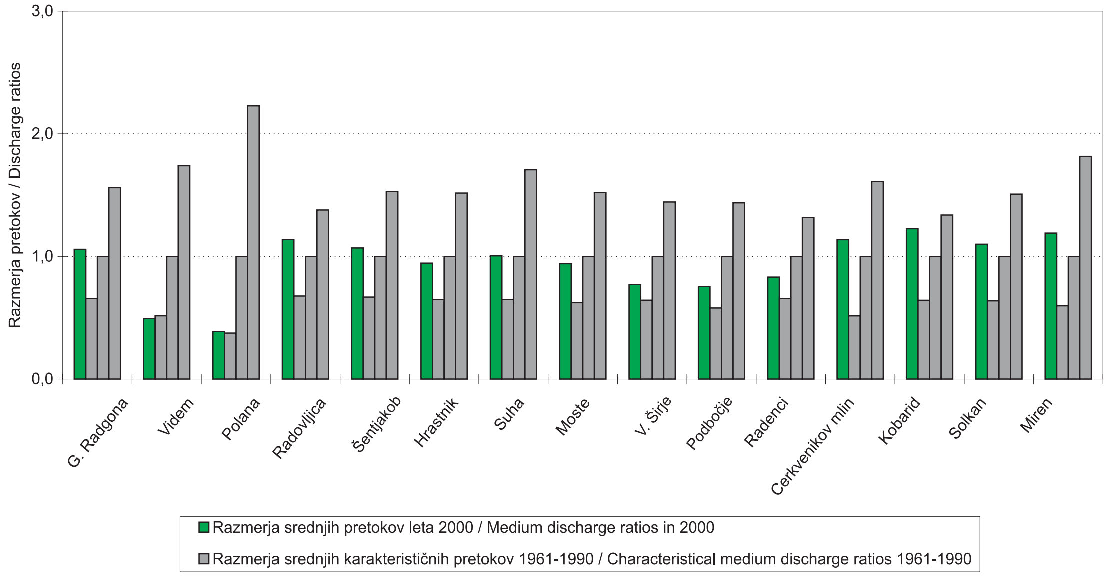
VODOTOK STREAM	POSTAJA GAUGING STATION	**Qs**	nQs	sQs	vQs
		2000	1961-1990		
		m^3/s	m^3/s	m^3/s	m^3/s
MURA	G. RADGONA	166,0	103	157	245
DRAVINJA	VIDEM	5,9	6,14	11,9	20,7
LEDAVA	POLANA	0,5	0,51	1,36	3,03
SAVA	RADOVLJICA	51,1	30,4	44,9	61,9
SAVA	ŠENTJAKOB	97,9	61,2	91,6	140
SAVA	HRASTNIK	172,0	118	182	276
SORA	SUHA	20,9	13,5	20,8	35,5
LJUBLJANICA	MOSTE	53,9	35,7	57,3	87,1
SAVINJA	V. ŠIRJE	35,6	29,7	46,2	66,7
KRKA	PODBOČJE	41,3	31,7	54,7	78,6
KOLPA	RADENCI	44,4	35,1	53,4	70,3
REKA	CERKVENIKOV MLIN	9,4	4,26	8,26	13,3
SOČA	KOBARID	41,8	21,9	34,1	45,6
SOČA	SOLKAN	105	60,9	95,5	144
VIPAVA	MIREN	21,3	10,7	17,9	32,5

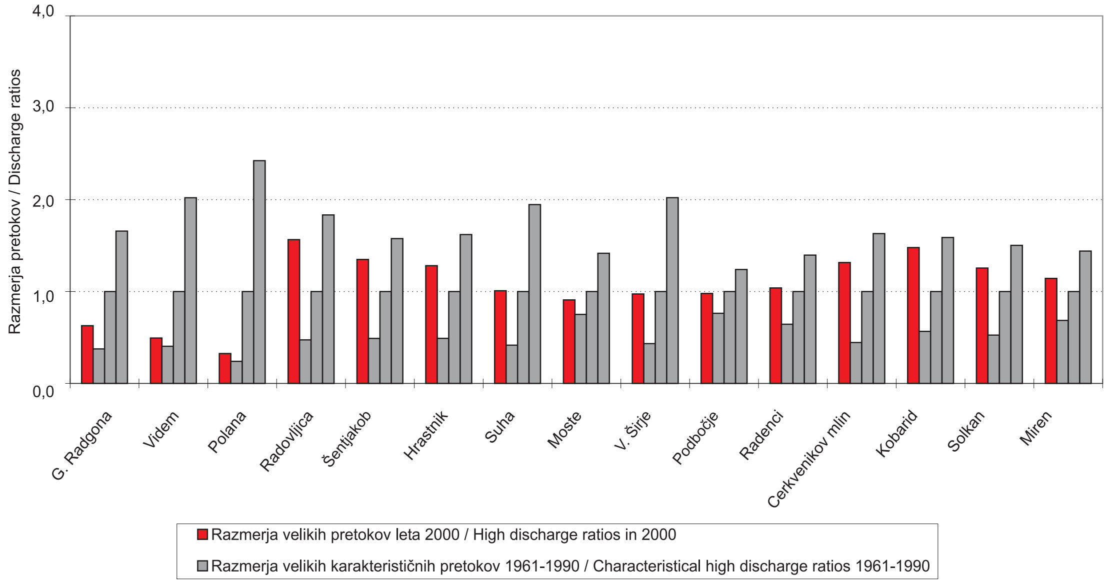
VODOTOK STREAM	POSTAJA GAUGING STATION	**Qvk**		nQvk	sQvk	vQvk
		2000		1961-1990		
		m^3/s	dan/day	m^3/s	m^3/s	m^3/s
MURA	G. RADGONA	457	25. 4.	273	727	1205
DRAVINJA	VIDEM	71,0	18. 11.	58,2	144	291
LEDAVA	POLANA	10,8	28. 12.	8,0	33,2	80,5
SAVA	RADOVLJICA	687	7. 11.	208	439	805
SAVA	ŠENTJAKOB	1217	7. 11.	442	902	1422
SAVA	HRASTNIK	1668	7. 11.	639	1302	2110
SORA	SUHA	356	7. 11.	147	353	687
LJUBLJANICA	MOSTE	260	9. 11.	215	286	405
SAVINJA	V. ŠIRJE	711	7. 11.	316	730	1476
KRKA	PODBOČJE	286	9. 10.	223	292	362
SOČA	KOBARID	618	7. 11.	237	418	664
KOLPA	RADENCI	739	7.11.	458	711	993
REKA	CERKVENIKOV MLIN	246	7.11.	83,3	187	305
SOČA	SOLKAN	1783	4. 11.	747	1420	2134
VIPAVA	MIREN	280	21. 11.	168	245	353

Qnp .... najmanjši pretok v letu – dnevno povp.
nQnp ... najmanjši mali pretok v obdobju
sQnp ... srednji mali pretok v obdobju
vQnp ... največji mali pretok v obdobju
Qs .... srednji pretok v letu – dnevno povprečje
nQs ..... najmanjši srednji pretok v obdobju
sQs ...... srednji pretok v obdobju
vQs ..... največji srednji pretok v obdobju
Qvk .... največji pretok v letu – konica
nQvk ... najmanjši veliki pretok v obdobju
sQvk ... srednje veliki pretok v obdobju
vQvk ... največji veliki pretok v obdobju

Qnp .... minimum discharge in the year – daily average
nQnp ... minimum low discharge in the period
sQnp ... mean low discharge in the period
vQnp ... maximum low discharge in the period
Qs .... mean discharge in the year – daily average
nQs ..... minimum mean discharge in the period
sQs ...... mean discharge in the period
vQs ..... maximum mean discharge in the period
Qvk .... maximum discharge in the year – peak
nQvk ... minimum high discharge in the period
sQvk ... mean high discharge in the period
vQvk ... maximum high discharge in the period







Graf 3: Razmerja malih, srednjih in velikih pretokov v letu 2000 ter razmerja karakterističnih pretokov obdobja 1961-1990. Vrednosti so podane relativno glede na srednje vrednosti malih, srednjih in velikih obdobnih pretokov.
Graph 3: Ratios of low, medium and high discharges in the year 2000 and ratios of characteristic discharges in the period 1961-1990. The values are relative, regarding the mean values of low, medium and high discharges of the period.

bile visokovodne konice povprečno velike. Pretoki so bili v veliki večini primerov največji od 4. do 9. novembra. Pretok Mure je bil največji spomladi (graf 3 in preglednica 1).

on average somewhat lower than in the long comparative period. Discharges in northeastern Slovenia were among the lowest in the comparative period (Graph 3 and Table 1).

In the year 2000 the **maximum discharges** were on average only slightly different than the characteristic maximum discharges in the comparative period, but they were, considering their levels, spatially rather unequally distributed. High-water peaks on the rivers Sava, Soča, Vipava and Savinja were above average. High-water peaks on the Mura and in northeastern Slovenia were only slightly higher than the minimum values in the comparative period. High-water peaks on other rivers were of average values. In most cases the discharges were the highest between the 4th and 9th of November. The discharge on the Mura river was the highest in spring (Graph 3 and Table 1).

Narasla Koritnica v Logu pod Mangrtom, dne 13.12.2000. Velika prodonosnost močno otežuje hidrološke meritve. (foto: Marjan Bat)
Stream Koritnica high waters in Log pod Mangrtom on 13th December 2000. High carying power of water makes hydrological surveying aggrevated. (photo: Marjan Bat)

TEMPERATURE REK IN JEZER

Igor Strojan

Leta 2000 so bile temperature rek in Blejskega ter Bohinjskega jezera v povprečju nekaj več kot eno stopinjo Celzija (°C) višje kot v večletnem primerjalnem obdobju. Tako visoko odstopanje se je v primerjalnem obdobju pojavljalo redko. Običajne temperature so bile presežene večji del leta, najbolj spomladi, v začetku poletja ter jeseni in v decembru. Nekoliko nižje kot navadno so bile temperature voda le januarja in julija.

Običajne januarske temperature rek so se v zadnjem delu meseca znižale. V naslednjih mesecih so se temperature rek, ob manjših nihanjih, postopno zviševale vse do junija. Z izjemo močnejše ohladitve sredi julija so se temperature, kakršne so bile zabeležene junija, obdržale večinoma do konca avgusta. Takrat so se reke pričele postopoma ohlajati. Trend ohlajanja so spremljala dokaj periodična temperaturna nihanja (graf 4).

V grafičnem prikazu temperaturnih sprememb preko leta (graf 4) izstopata Krka (vodomerna postaja Podbočje) kot najtoplejša in Kamniška Bistrica (vodomerna postaja Kamnik) kot najbolj hladna reka. Krka se je, za razliko od Kamniške Bistrice, hitro ogrevala in dosegla najvišjo temperaturo v letu 25,7 °C že junija. Kamniška Bistrica se je ogrevala

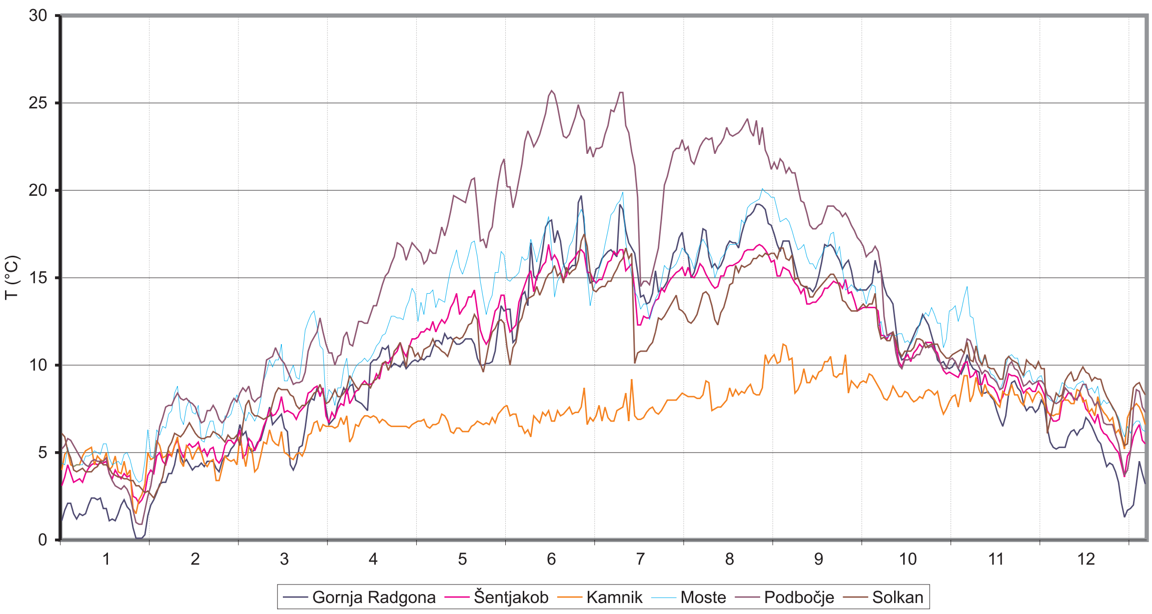
TEMPERATURES OF RIVERS AND LAKES

Igor Strojan

In the year 2000 the temperatures of rivers and of the lakes Bled and Bohinj were on average somewhat more than 1 °C higher than in the comparative period of several years. Deviations of this extent rarely occurred in the comparative period. Normal temperatures were exceeded almost throughout the year; the most in spring, at the beginning of the summer, in autumn and in December. Water temperatures were somewhat lower than usual only in January and July.

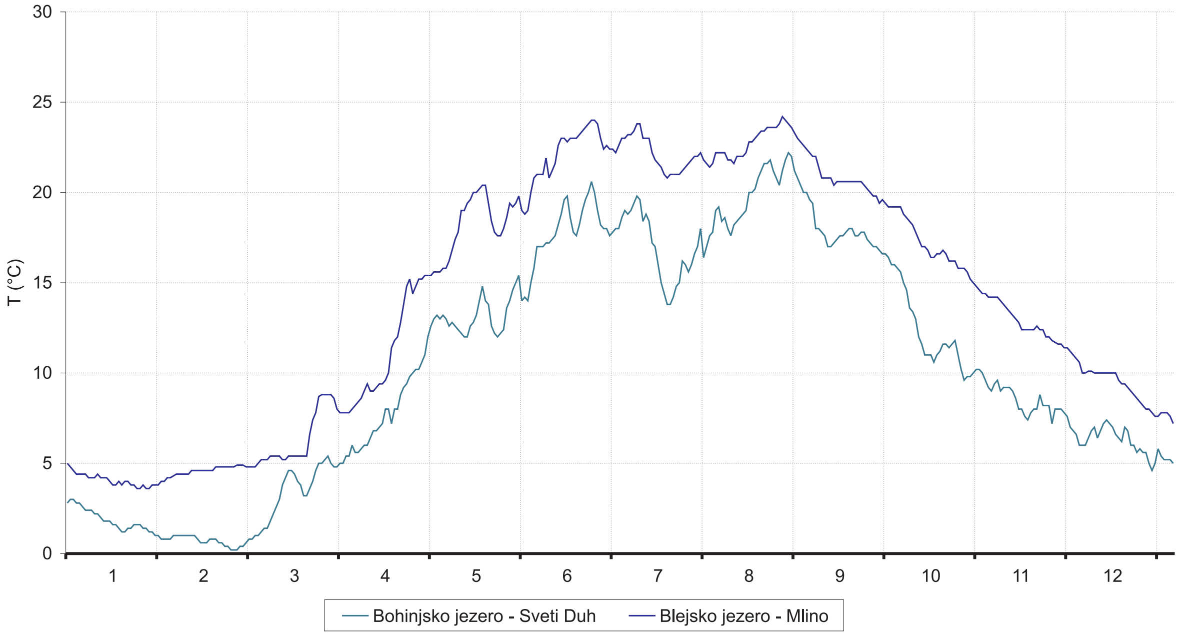
The usual January river temperatures decreased in the last part of the month. In the following months the river temperatures were gradually increasing, which was accompanied with minor temperature fluctuations. Temperatures recorded in June remained practically the same until the end of August, when the rivers gradually started to cool down. An exception was a period in the middle of July, when the temperatures substantially decreased. The course of cooling down was accompanied with rather periodical temperature fluctuations (Graph 4).

The two most noticeable rivers in the graphic presentation (Graph 4) are the Krka (water gauge station Podbočje), as the warmest, and the Kam-



Graf 4: Srednje dnevne temperature Mure, Save, Kamniške Bistrice, Ljubljanice, Krke in Soče na izbranih vodomernih postajah leta 2000 (po mesecih).

Graph 4: Mean daily temperatures of the rivers Mura, Sava, Kamniška Bistrica, Ljubljanica, Krka and Soča on the selected water gauge stations in the year 2000 (by months).



Graf 5: Temperaturna nihanja Blejskega jezera (Mlino) in Bohinjskega jezera (Sveti Duh) leta 2000 (po mesecih).
Graph 5: Temperature fluctuations of lakes Bled (Mlino) and Bohinj (Sveti Duh) in the year 2000 (by months).

bolj postopoma in dosegla najvišjo letno temperaturo 11,2 °C zadnji dan v avgustu.
Na Blejskem in Bohinjskem jezeru je bil potek temperaturnih sprememb podoben kot na rekah,

Zaledenelo Bohinjsko jezero 1. 2. 2000. (foto: Mojca Robič)
Lake Bohinj frozen over on the 1st of February 2000. (photo: Mojca Robič)

niška Bistrica (water gauge station Kamnik), as the coldest river. Unlike the Kamniška Bistrica, the Krka warmed up fast, reaching the maximum annual temperature (25.7 °C) already in June. The Kamniška Bistrica was warming up gradually, reaching its maximum temperature of the year (11.2 °C) in the last day of August.
The course of temperature changes was similar to the one in rivers and also in the lakes Bled and Bohinj, but the substantial warming up in the lakes began a little later than in the rivers (Graph 5). Minor temperature fluctuations are less noticeable in the two lakes than in the rivers. As is the case with rivers, the temperature course in the year 2000 for both lakes also shows the characteristic temperature drop in the middle of July. Lake Bohinj was, as usual, colder than Lake Bled, by less than 4 °C on yearly average.
The rivers were, in accordance with the characteristic temperature regime of river waters, the coldest in January, most of them from the 24th to 28th of January. The temperatures of the two lakes are usually the lowest a little later than in the rivers and the situation was similar in the year 2000 as well. Lake Bled was the coldest on the 24th of January at the water gauge station Mlino (3.6 °C), and Lake Bohinj was the coldest on the 24th of February at the water gauge station Sveti Duh (0.2 °C).
Mean temperatures of rivers and of both lakes were substantially higher than they usually are. Mean annual temperature of rivers on the selected sta-

le da sta se jezeri pričeli bolj izrazito ogrevati nekoliko kasneje kot reke (graf 5). Manjša temperaturna nihanja so na obeh jezerih večinoma manj izrazita kot na rekah. Tako kot v primeru rek, je tudi pri temperaturnem poteku na obeh jezerih za leto 2000 opazen značilen padec temperature sredi julija. Bohinjsko jezero je bilo sicer kot običajno vse leto hladnejše od Blejskega, v povprečju celega leta nekaj manj kot 4 °C.

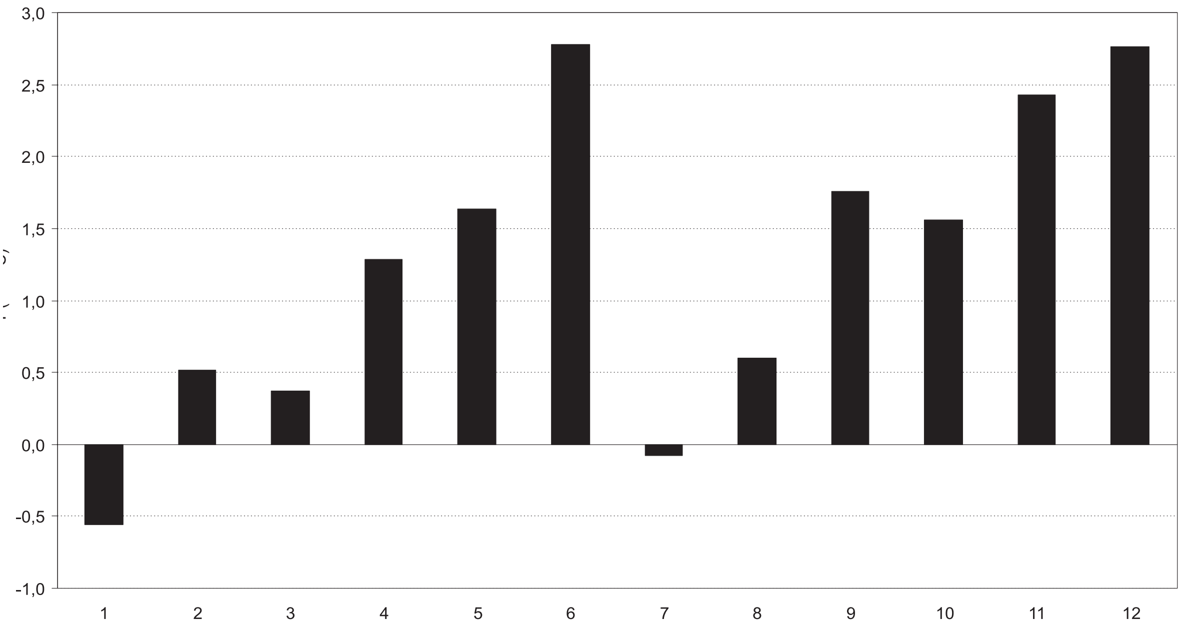
Reke so bile, skladno z običajnim temperaturnim režimom rečnih voda, najbolj hladne januarja, večinoma od 24. do 28. januarja. Jezeri se navadno najbolj ohladita nekaj kasneje kot reke. Podobno je bilo v letu 2000, ko je bilo Blejsko jezero na vodomerni postaji Mlino najbolj hladno 24. januarja (3,6 °C), Bohinjsko jezero na vodomerni postaji Sveti Duh pa 24. februarja (0,2 °C).

Srednje temperature rek in obeh jezer so bile občutno višje kot navadno. Srednja letna temperatura rek na izbranih postajah je bila 10,6 °C, jezer pa 12,3 °C. Srednje mesečne temperature so bile najvišje junija, novembra in decembra, ko so bile na rekah in obeh jezerih dve stopinji višje kot običajno.

Najvišje temperature rek in obeh jezer so bile višje kot navadno. Vode so bile najbolj tople junija, julija in konec avgusta. Najbolj topla je bila Krka v Podbočju 14. junija (25,7 °C).

tions was 10.6 °C, and of the lakes 12.3 °C. Mean monthly temperatures were the highest in June, November and December, when they were in rivers and in both lakes 2 °C higher than usual.

Maximum temperatures of rivers and of the two lakes were higher than usual. Water temperatures were the highest in June, July and at the end of August. The warmest was the Krka in Podbočje on the 14th of June (25.7 °C).



Graf 6: Temperaturna odstopanja srednjih mesečnih temperatur od večletnih srednjih mesečnih temperatur na rekah in obeh jezerih leta 2000. Odstopanja so izračunana kot povprečja odstopanj na šestih rečnih in dveh jezerskih merilnih postajah (glej graf 4 in 5).

Graph 6: Temperature deviations of mean monthly temperatures from the monthly temperatures of many years on rivers and both lakes in the year 2000. The deviations are calculated as average values of deviations on six water gauge stations on the rivers and on two stations on the lakes (see Graphs 4 and 5).

VISOKE VODE IN POPLAVE

Janez Polajnar

Leta 2000 do novembra ni bilo obsežnejših poplav. Prve visoke vode so se pojavile marca, sledile so oktobra, vendar v tem času ni bil presežen obseg vsakoletnih poplav. V novembru so reke poplavile večkrat, ponekod bolj obsežno kot običajno. Visokovodne razmere so bile dolgotrajne. Največji pretoki rek v nekaterih povirnih delih porečij na območju Julijskih in Kamniško Savinjskih Alp ter višine poplavne vode na kraških poljih so ponekod dosegli rekordne vrednosti opazovalnega obdobja. Poplave na teh območjih so bile obsežnejše od vsakoletnih, izdatne padavine v Posočju so povzročile naravno katastrofo. V dolini Koritnice sta se sprožila zemeljski plaz in murasti tok, ki je zahteval smrtne žrtve.

Hidrološka prognostična služba je leta 2000 zaznala 52 dogodkov, ko so reke na vodomernih postajah presegle pogojne vodostaje, ob katerih se začne v hidrološki prognostični službi izredno spremljanje in obveščanje. Največ visokih voda je bilo novembra (42) in marca (7). Junija, oktobra in decembra so bili dogodki te vrste redki, v januarju, februarju, aprilu, maju, juliju, avgustu in septembru jih ni bilo (graf 7).

Leta 2000 so reke in potoki 45-krat prestopili bregove (HMZ RS, CORS). Poplavna voda je predvsem novembra povzročila materialno škodo na stanovanjskih, gospodarskih objektih, promet-

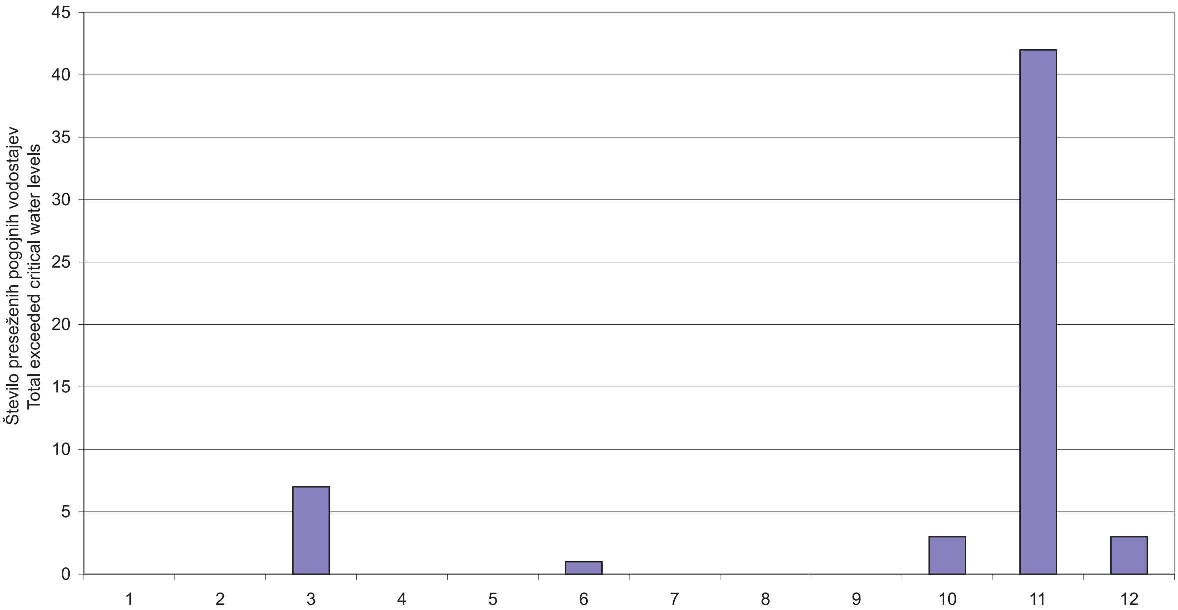
HIGH WATERS AND FLOODS

Janez Polajnar

The year 2000 did not witness any major floods until November. First high waters occurred in March, and then again in October, but they did not exceed the extent of the yearly floods. Rivers flooded several times in November and at some locations the extent of floods was even greater than usual. The high-water situation persisted for a long time. The highest discharges of rivers at the headwaters of their river basins in the Julian and Kamniško-Savinjske Alps and the flood water level on karstic poljes reached at some locations the record values in the observation period. In these areas the floods were more severe than they usually are every year and the abundant precipitation in Posočje caused a natural disaster. In the valley of the Koritnica a landslide and debris flow occurred, which caused some casualties.

In the year 2000 the Hydrologic Prognostic Service perceived 52 cases in which the rivers at the water gauge stations exceeded the conditional gauge heights and that brought about the emergency monitoring and notification at the Hydrological Prognostic Service. High waters were the most common in November (42) and in March (7). They rarely occurred in June, October and December, and were not present at all in January, February, April, May, July, August, and September (Graph 7).

Rivers and streams over flowed forty-five times



Graf 7: Število preseženih pogojnih vodostajev slovenskih rek na opazovanih vodomernih postajah leta 2000 (po mesecih).
Graph 7: The number of exceeded conditional water levels of the Slovene rivers at the monitored water gauge stations in the year 2000 (by months).

nicah ter kmetijskih površinah. Voda se je razlivala tudi na območjih, kjer poplave niso pogoste. Poplavljene površine na kraških poljih Notranjske so v vsem opazovanem obdobju dosegle rekordne vrednosti (preglednica 2).

Visoke vode novembra 2000. Ob izdatni vodnatosti rek na zahodu države v začetku meseca, kjer so največji pretoki nekaterih rek že presegli 5-letno povratno dobo, namočenih tleh in zmanjšani zaščitni vlogi vegetacijskega pokrova, so reke in predvsem hudourniki v goratem območju zahodne in severne Slovenije, ob padavinah med 6. in 8. novembrom, ponovno silovito porasli. Na teh območjih so se na več mestih sprožili tudi zemeljski plazovi. 7. novembra so se visoke vode s povirnih območij razširile do srednjih in spodnjih tokov Save in Drave, ki sta dosegli največje pretoke ob iztoku iz države, v noči na 8. november. Že v pozno popoldanskih urah 6. novembra so izdatno porasli vodotoki v porečju Soče, predvsem

in the year 2000 (HMZ RS, CORS). The floods caused material damage on housing and economic facilities, traffic routes and agricultural areas, most of all in November. The water even flowed over the surfaces where floods do not frequently occur. Flooded areas on the karstic poljes of Notranjska reached record values in the observation period (Table 2).

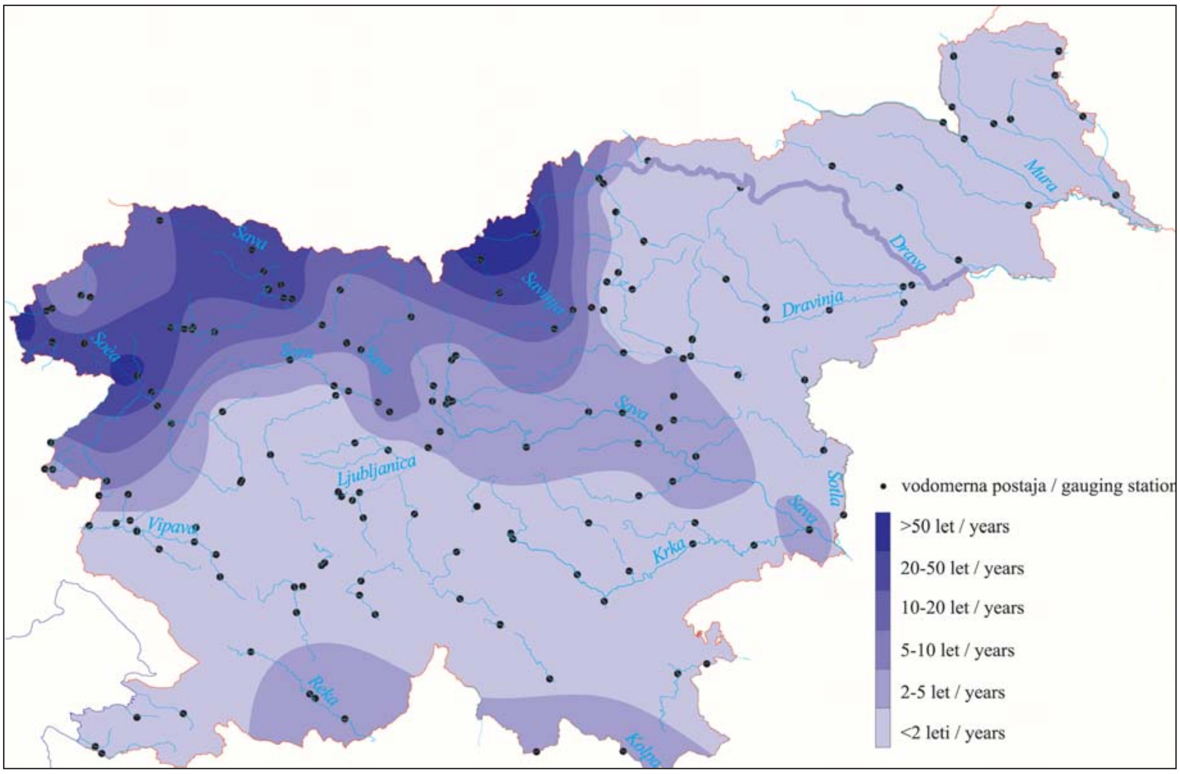
High waters in November 2000. At the beginning of the month the water quantity in the rivers in the west of the country was great and the highest discharges of some rivers had already exceeded the 5-year return period. In addition, the soil was saturated, the protective role of vegetation cover was reduced, and thus the water level in rivers, particularly in the torrents in the mountainous areas of western and northern Slovenia, exceedingly grew during the precipitations between the 6th and 8th of November. Landslides occurred at several locations at the above-mentioned areas. On the 7th of No-

Preglednica 2: Število zabeleženih razlitij leta 2000 (po mesecih), (HMZ, CORS, razlitja manjših hudournikov niso upoštevana).
Table 2: The number of registered overflows in the year 2000 (by months), (HMZ, CORS, overflowing of smaller torrents has not been considered).

	J	F	M	A	M	J	J	A	S	O	N	D
Sava											4	
Ljubljanica			2							1	1	1
Gradaščica			1								1	
Krka										1	1	1
Sava Bohinjka											1	
Tržiška Bistrica											1	
Kokra											1	
Selška Sora											1	
Savinja											1	1
Kolpa			1								1	
Soča											3	
Vipava			1								3	
Reka (Notranjska)											2	
Kamniška Bistrica			1									
Drava										1	1	
Meža											1	
Bolska			1									
Suhadolnica											1	
Temenica											1	
Lepena						1						
Dolenji potok											1	
Pivka											1	
Mali Obrh, Loško polje											1	
Unica, Planinsko polje											1	
Rak, Rakov Škocjan											1	
Stržen, Cerkniško jezero											1	

zgornji tok Soče s pritoki na tem območju. Visokovodni val se je do jutra razširil v spodnji tok Soče z največjim pretokom med 5- in 10-letno povratno dobo. V noči na 7. november so se izdatne padavine razširile nad vzhodne Julijske Alpe, Karavanke in vzhodne Kamniške Alpe. Na tem območju so v jutranjih urah v povirnih delih najmočneje narasle reke Sava Dolinka in Sava v zgornjem toku, kjer je največji pretok dosegel 10 do 20-letno povratno dobo, Tržiška Bistrica ter predvsem Meža in Savinja v zgornjem toku (karta 2), kjer so največji pretoki presegli 50-letno povratno dobo. Savinja je na vodomerni postaji Solčava 7. novembra okoli 2. ure dosegla pretok z obdobno konico. Zabeležen je bil najvišji vodostaj 298 cm in pretok 148 m^3/s. To je najvišja kota vodostaja, izmerjenega v opazovanem obdobju, in je za okoli 62 cm višja kot leta 1980. Savinja v Solčavi je presegla pretok s 100-letno povratno dobo, ki znaša 93 m^3/s (za obdobje 1949–1996). V noči na 7. november so se povečali tudi pretoki rek v predalpskem hribovju Julijskih Alp in na Notranjskem, predvsem v porečjih Selške Sore, v spodnjem toku Poljanske Sore, Gradaščice, Reke (Notranjske), Ljubljanice in Kolpe, kjer pa največji pretoki niso presegli 2-letne povratne dobe (karta 2).

vember, high waters from the headwater areas spread to the central and lower reaches of the Sava and the Drava. The two rivers reached the highest discharges at the point where they flowed out of the country, during the night between the 7th and 8th of November. In the late afternoon of the 6th of November, watercourses in the river basin of the Soča increased substantially, above all the upper reaches of the Soča with tributaries in this area. By the next morning the flood wave had spread into the lower reaches of the Soča, having the highest discharge between the 5-year and 10-year return period. During the night between the 6th and 7th of November the abundant precipitation spread to the eastern Julian Alps, Karavanke and eastern Kamniške Alps. In the morning, the greatest increase of water levels at the headwater parts in the area was observed in the Sava Dolinka and in the upper reach of the Sava, where the highest discharge reached a 10 to 20-year return period, and in the rivers Tržaška Bistrica, Meža and Savinja in their upper reaches (Map 2), where the highest discharges surpassed a 50-year return period. On the 7th of November, around 2 a.m., the Savinja reached the discharge peak of the period at the water gauge station Solčava. The highest water level 298 cm, was recorded, with a discharge of 148 m^3/s. That was the



Karta 2: Povratne dobe največjih pretokov slovenskih rek 7. novembra 2000.
Map 2: Return periods of maximum discharges of the Slovene rivers on the 7th of November 2000.

Manjše reke in hudourniki v goratem svetu zahodne in severne Slovenije so čez dan, 7. novembra 2000, postopno upadale in polnile struge večjih rek. Naraščale so le Sava, Savinja, Drava, Krka in Kolpa v srednjem in spodnjem toku. V dopoldanskih urah se je visokovodni val Save pomikal z Gorenjske vzdolž Ljubljanske kotline, popoldne in zvečer pa je, obogaten z naraslo Savinjo, dosegel Posavje in Krško-Brežiško ravan. V okolici Ljubljane in v Zasavju je Sava preko dneva dosegla največji pretok s 5- do 10-letno povratno dobo. Ob dotoku Savinje, ki v spodnjem toku ni presegla 2-letne vode, je imela Sava ob iztoku iz države, v noči na 8. november, največji pretok okoli, 2300 m^3/s, kar je 2- do 5-letna povratna doba.
Ob izdatnih padavinah in taljenju snega v Karnijskih in Ziljskih Alpah se je ponoči 7. novembra zelo povečal pretok Drave v Avstriji, zjutraj in preko dneva pa tudi v Sloveniji. Velika vodnatost Drave med Dravogradom in Borlom, z največjim pretokom, ki je imel 2- do 5-letno povratno dobo, se je v srednjem in spodnjem delu struge zadržala do noči na 8. november.
Ob izdatni vodnatosti rek po vsej državi, ko so

highest water level measured in the observation period and it was about 62 cm higher than the value measured on the 8th of October 1980. At that time the Savinja in Solčava surpassed the discharge with a 100-year return period, the value of which was 93 m^3/s (for the period 1949–1996). During the night between the 6th and 7th of November the discharges of rivers in the pre-Alpine highlands of the Julian Alps and at Notranjsko increased as well, particularly in the river basins of the Selška Sora, in the lower reaches of the Poljanska Sora, the Gradaščica, the Reka (Notranjska), the Ljubljanica and the Kolpa, but the highest discharges did not surpass the 2-year return period (Map 2).
Water levels of smaller rivers and torrents in the mountainous areas of western and northern Slovenia were gradually decreasing during the day of the 7th of November 2000, and filled the channels of larger rivers. Water level was increasing only in the Sava, Savinja, Drava, Krka and Kolpa in their central and lower reaches. In the morning, the flood wave of the Sava was moving from Gorenjska along the basin Ljubljanska kotlina. In the afternoon and in the evening it was recharged by the high waters of Savinja and it reached Posavje and the Krško-

Posledice poplave Savinje v Zgornji Savinjski dolini novembra 2000. (foto: Gvido Galič)
Consequences of the November 2000 flood of the Savinja river. (photo: Gvido Galič)

največji pretoki nekaterih rek v povirnih delih že presegli 20- do 100-letno povratno dobo, so reke ob novih padavinah v začetku tedna med 13. in 18. novembrom ponovno silovito narasle. Sprva predvsem v goratem območju zahodne Slovenije, kasneje v osrednji Sloveniji in na Notranjskem. Na teh območjih so se na večih mestih prožili tudi zemeljski plazovi, nekatere reke so na izpostavljenih mestih poplavljale. Visokovodne razmere so se iz povirnih delov porečij širile s tokom navzdol, predvsem na Soči, Savi in Dravi. Po krajši prekinitvi 16. novembra so se pretoki rek s povirji v Julijskih in Kamniško-Savinjskih Alpah, v predalpskem hribovju in na Notranjskem, ob koncu tedna ponovno povečali.

Že 13. novembra so se zaradi stalnega dotoka kraških izvirov povečevala poplavna območja na kraških poljih Notranjske in na Ljubljanskem Barju. Od večjih rek so najbolj narasle Soča in Sava v zgornjem toku ter Drava. V noči na 14. november so ponovno najbolj narasle: Soča, Sava, Kamniška Bistrica, Savinja in Drava, pretoki drugih rek, z izjemo Ljubljanice, so se prehodno zmanjševali. Največji pretoki ta dan niso presegli 2-letne povratne dobe.

V noči na 15. november so se ponovno povečevali pretoki rek na zahodu države. Najbolj so narasle Soča, v zgornjem toku v Logu Čezsoškem je s pretokom 440 m^3/s dosegla 5- do 10-letno povratno dobo (karta 3), Sava Bohinjka in Sava v srednjem toku ter Drava. Predvsem v hribovitem svetu zahodne Slovenije so manjši hudourniki in reke v povirnih delih ponekod poplavljali. Čez dan so se pretoki omenjenih rek v zgornjem toku prehodno zmanjševali, visokovodne razmere so se pojavile v spodnjih delih porečij ter ob celotnem toku Drave.

V noči na 16. november so se pretoki rek ponovno povečali v povirjih Julijskih in Kamniško-Savinjskih Alp, ter predvsem v predalpskem hribovju. Pretoki drugih rek so bili veliki in povečini nespremenjeni. V jutranjih in dopoldanskih urah je ponekod ob Savi v Zasavju, ob Vipavi in manjših potokih prišlo do razlitij. Čez dan so reke na zahodu prenehale naraščati.

V noči na 17. november so se pretoki rek s povirji v Julijskih in Kamniško Savinjskih Alpah ter v predalpskem hribovju postopno zmanjševali. Naraščali sta Sava v spodnjem toku in Drava. Pretoki ostalih rek so ostali veliki in so se prehodno postopno zmanjševali. Ta dan največji pretoki niso presegli letne povratne dobe.

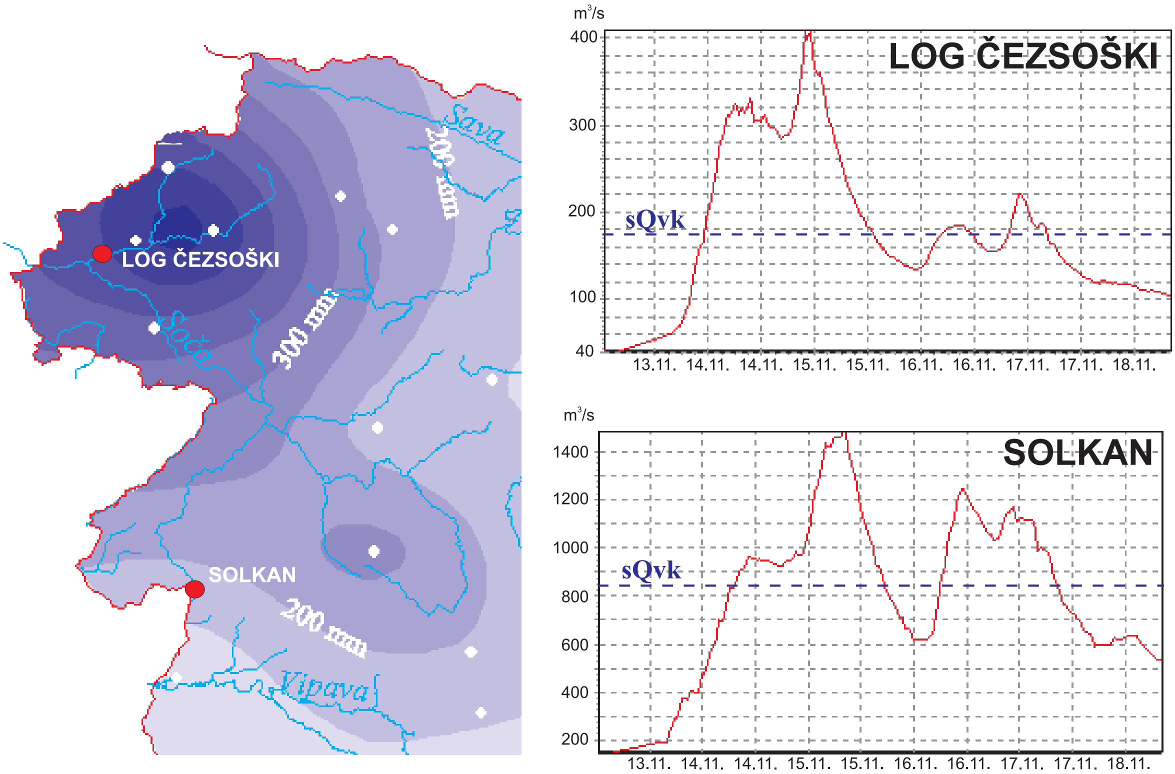
Brežice plateau. In the surroundings of Ljubljana and in Zasavje the Sava reached the maximum discharge during the day, with a 5 to 10-year return period. At the inflow of the Savinja, which did not surpass the 2-year waters in its lower reach, the Sava had, during the night between the 7^{th} and 8^{th} of November, at its outflow from the country, the highest discharge, i.e. about 2300 m^3/s, which is a 2 to 5-year return period.

Due to the high precipitation amount and the melting of snow in the Karnian and Zilja Alps, the discharge of the Drava in Austria increased greatly in the night of the 7^{th} of November, and in the morning and during the day it increased in Slovenia as well. High water quantity in the Drava between Dravograd and Borl, with the highest discharge with a 2 to 5-year return period, persisted in the central and lower reaches of its course until the following night between the 7^{th} and 8^{th} of November.

As water quantity all over the country was great and the highest discharges of some rivers at their headwaters had already exceeded 20 to 100-year return periods, additional precipitation at the beginning of the week between the 13^{th} and 18^{th} of November again caused a substantial rise of the water level. At first, this was the case in the mountainous areas of western Slovenia, and later on in central Slovenia and Notranjsko. Landslides occurred at several places in these areas, and some rivers flooded at the exposed locations. High water waves travelled from the headwater sections of the rivers downstream, especially on the rivers Soča, Sava and Drava. After a short interruption on the 16^{th} of November, the discharges of the rivers with headwaters in the Julian and Kamniško-Savinjske Alps, in the pre-Alpine highlands and at Notranjsko, increased again at the end of the week.

Due to constant inflow of water from karstic springs, the flood areas on the karstic poljes of Notranjska and at Ljubljana Marshes began to expand already on the 13^{th} of November. Among larger rivers, water levels of the Soča and Sava in their upper reaches, and also the Drava, increased the most. During the night between the 13^{th} and 14^{th} of November, the following rivers again rose the most: the Soča, the Sava, the Kamniška Bistrica, the Savinja and the Drava, while the discharges of other rivers, except for the Ljubljanica, were decreasing. The highest discharges that day did not surpass a 2-year return period.

During the night between the 14^{th} and 15^{th} of November, the discharges of the rivers in the west of Slovenia began to increase again. The discharg-



Karta 3: Količina padavin od 14. do 18. novembra in pretok Soče med 13. in 18. novembrom 2000.
Legenda: sQvk – srednja novembrska visoka voda opazovanega obdobja 1950–1996.
Rdeča črta prikazuje povprečni pretok med 13. 11. in 18. 11. 2000.
Map 3: Precipitation quantity between the 14th and 18th of November and the discharge of the Soča river between the 13th and 18th of November 2000.
Key: sQvk – mean quantity of high waters in November in the observation period 1950–1996.
Red line shows, average discharge from 13. 11. and 18. 11. 2000.

Proti večeru in v noči na 18. november so se prehodno ponovno povečali pretoki rek na Primorskem, Notranjskem, v osrednji Sloveniji in v povirju Savinje, vendar največji pretoki tokrat niso presegli 2-letne povratne dobe.

V noči na 21. november so se pretoki rek v zahodni, osrednji in ponekod v vzhodni Sloveniji ponovno povečali. Tam so bili veliki, drugod po državi so ostali srednje veliki. Najbolj so narasle Soča in Vipava v spodnjem toku, Reka (Notranjska), Sava v zgornjem in srednjem toku, Krka v zgornjem toku, Temenica in Drava. Največji pretoki rek so na omenjenih delih dosegli 2- do 5-letno povratno dobo, Krka v zgornjem toku celo večjo od 10-letne povratne dobe. Pretoki ostalih rek niso presegli 2-letne povratne dobe. Izdatno se je povečala vodnatost kraških izvirov na Notranjskem. Poplavljene površine na kraških poljih so se povečevale nad običajne.

22. novembra se je večina pretokov rek po državi zmanjšala, naraščale so Sava v Zasavju in na Krško Breziškem območju, Drava v spodnjem

es increased the most at the Soča, reaching a 5 to 10-year return period in its upper reaches in Log Čezsoški with a discharge of 440 m^3/s (Map 3), at the Sava Bohinjka and at the Sava in their central reaches, and also at the Drava. In the highland areas of western Slovenia, torrents and rivers flooded at some locations at their headwater sections. The discharges of the above-mentioned rivers were slowly decreasing during the day and the high waters occurred in the lower reaches of the river basins and along the entire flow of the Drava river.

During the night between the 15th and 16th of November, the discharges increased again at the headwaters in the Julian and Kamniško-Savinjske Alps, and above all in the pre-Alpine highlands. Discharges of other rivers were high and for the most part they remained the same. In the morning, the water overflowed at some locations along the Sava in Zasavje, along the Vipava and at some smaller streams. The river level in the west of the country stopped rising during the day.

toku in Krka. Največji pretoki omenjenih rek v spodnjem toku niso presegli 2-letne povratne dobe.

Poplavljene površine na kraških poljih Notranjske in Suhe krajine so se v naslednjih dneh, do konca meseca še povečevale. Voda je na Loškem polju, na območju Cerkniškega jezera, v Rakovem Škocjanu in na Planinskem polju poplavila cestne povezave in izpostavljene stanovanjske objekte. Gladina Cerkniškega jezera je 28. novembra dosegla najvišjo točko pri vodomerni postaji Dolenje jezero, 654 cm. Višina jezera je bila rekordna, podobna tisti iz leta 1926, ko je jezero v opazovanem obdobju doseglo najvišjo gladino. Gladina vode na Planinskem polju pri vodomerni postaji Hasberk na Unici je 28. novembra dosegla najvišjo točko 585 cm, kar je nekoliko manj kot leta 1970. Visoka gladina vode se je na omenjenih kraških poljih zadržala do konca meseca.

The discharges of rivers with headwaters in the Julian and Kamniško-Savinjske Alps and in the pre-Alpine highlands were gradually decreasing in the night between the 16th and 17th of November. The Drava and the lower reach of the Sava were increasing and the discharges of other rivers remained high and were transitionally gradually decreasing. The highest discharges that day did not surpass a 2-year return period.

Towards the evening of the 18th of November and at night, the discharges of rivers in Primorska, Notranjska, in the central Slovenia and at the headwaters of Savinja, transitionally increased again, but the highest discharges did not surpass a 2-year return period.

Discharges in western, central and at some locations in eastern Slovenia increased again in the night between the 20th and 21st of November and were high, while elsewhere in the country the river discharges remained at medium level. River levels rose the most at the Soča and Vipava in their lower reaches, the Reka (Notranjska), the Sava in its upper and central reaches, the Krka in its upper reaches, the Temenica and the Drava. The highest river discharges in the above-mentioned areas reached a 2 to 5-year return period, and the Krka in its upper reaches even exceeded a 10-year return period. The discharges of other rivers did not surpass the 2-year return period. Water quantity in the karstic springs in Notranjska increased substantially. Flooded areas of the karstic poljes were larger than usual.

On the 22nd of November most of the river discharges in Slovenia decreased, while the Sava in Zasavje and on the area of Krško and Brežice, the Drava in its lower reach, and the Krka, were increasing. The highest discharges of these rivers in their lower reaches did not exceed the 2-year return period.

Flooded areas on the karstic poljes of Notranjska and Suha krajina were increasing in the following days, until the end of the month. Waters at Loško polje, Cerkniško jezero, in Rakov Škocijan and at Planinsko polje flooded the roads and the more exposed housing facilities. The water level peak of Lake Cerknica on the 28th of November was reached at the water gauge station Dolenje jezero: 654 cm. This was the record gauged height in the lake, similar to the one in 1926, when the lake reached the highest level in the observation period. The water level peak at Planinsko polje on the 28th of November was reached at the water gauge station Hasberk on the Unica: 585 cm, which was somewhat less than in 1970. High water levels persisted at the above-mentioned karstic poljes until the end of the month.

HIDROLOŠKA SUŠA REK

Mira Kobold

Pretoki rek so bili že v začetku leta 2000 pod srednjimi obdobnimi vrednostmi, v mejah srednjih malih in najmanjših malih pretokov. Na to je vplivalo pomanjkanje padavin in temperaturne razmere, ki so se nadaljevale tudi v poletnih mesecih. Odraz tega so bili povečini mali pretoki rek vse do meseca septembra. Nizkovodne razmere so prikazane z mesečnimi pretoki štirih vodomernih postaj (graf 8). Prikazani so srednji (Qs) in najmanjši (Qnp) mesečni pretoki. Za primerjavo so podani značilni obdobni mesečni pretoki, najmanjši mali (nQnp) in srednji mali (sQnp) ter srednji srednji (sQs) pretoki. Hidrološke razmere so odraz količine padavin na povodju, zato je dodana še mesečna količina padavin z reprezentativne padavinske postaje na obravnavanih povodjih.

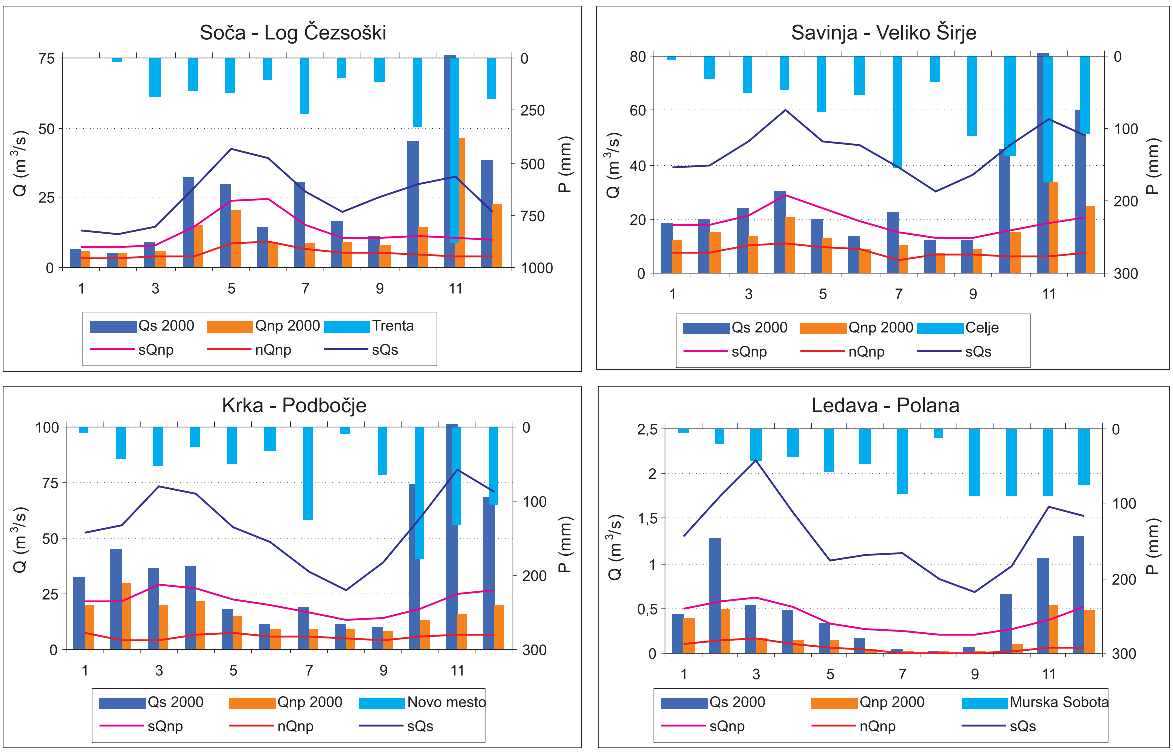
Podrobneje so nizkovodne razmere, za obdobje od junija do oktobra 2000, za tri izbrane vodomerne postaje prikazane na grafu 9. K poteku srednjih dnevnih pretokov smo dodali obdobne pretoke: srednje mesečne (sQs), srednje male

HYDROLOGICAL DROUGHTS OF RIVERS

Mira Kobold

The river discharges were below the mean values of the period from the beginning of the year 2000, within the limits of the mean low and the lowest discharge values. The reason for that was precipitation deficit and high temperatures, which persisted throughout the summer months. As a consequence, the rivers had for the most part low discharges until September. Low water levels are presented with monthly discharges of four gauging stations (Graph 8). The mean (Qs) and the lowest (Qnp) monthly discharges are shown. For comparison, the characteristic monthly discharges of the period are given, the minimum low (nQnp), mean low and mean medium (sQs) discharges the hydrological situation depends upon the precipitation amount at the catchment area, therefore the monthly precipitation amount is stated as well, measured at the representative precipitation station at the relevant catchment areas.

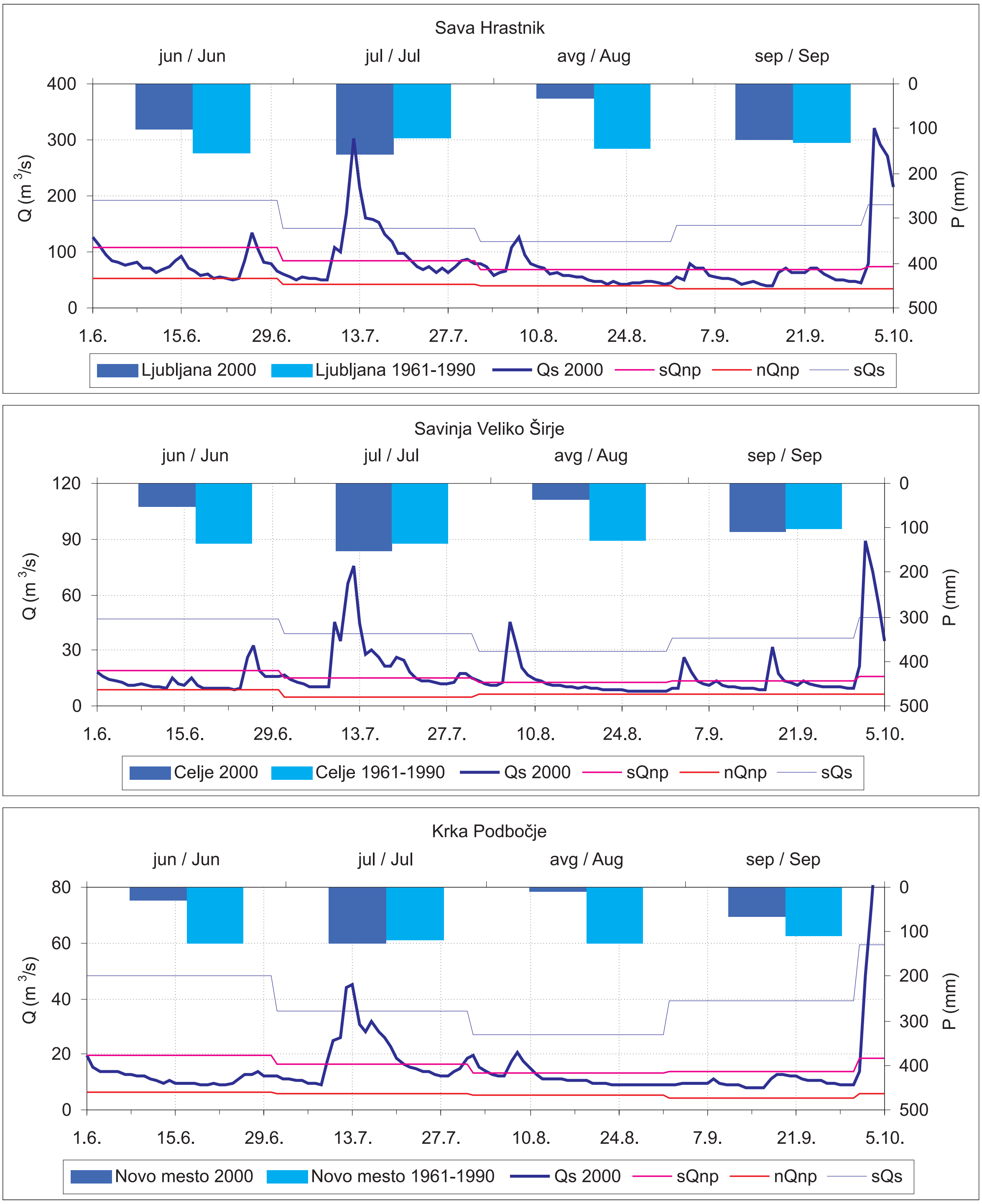
The low flows for the period from June to October 2000 for the 3 selected gauging stations are presented in greater detail in Graph 9. In addition to



Graf 8: Srednji in najmanjši mesečni pretoki v letu 2000, značilni obdobni mesečni pretoki ter mesečna količina padavin.
Graph 8: Mean and minimum monthly discharge values in the year 2000, characteristic monthly discharges of the period and monthly precipitation amount.

(sQnp) in najmanjše male mesečne pretoke (nQnp). Na obravnavanih povodjih so prikazane tudi mesečne količine padavin za reprezentativne padavinske postaje v primerjavi z obdobjem 1961–1990.

mean daily discharges, the monthly discharges of the period were stated as well: mean (sQs), mean low (sQnp) and the minimum low monthly discharges (nQnp). Monthly precipitation amounts from the representative precipitation stations on the



Graf 9: Srednji dnevni pretoki (Qs) za obdobje od junija do oktobra 2000, obdobni mesečni pretoki (sQs, sQnp in nQnp) in mesečna količina padavin.
Graph 9: Mean daily discharges (Qs) for the period from June to October 2000, periodical monthly discharges (sQs, sQnp and nQnp) and monthly precipitation amount.

Zaradi pomanjkanja padavin so se vodne zaloge zmanjševale celo prvo polovico leta 2000. V juniju smo beležili nizkovodno stanje, ki je značilno za hidrološko suhe mesece kot sta avgust in september. Z izjemo Mure in Drave, ki sta zaradi snežnega režima najbolj vodnati v maju, juniju in juliju ter sta imeli takrat povečini srednje pretoke, smo na ostalih vodotokih po vsej državi beležili podpovprečno vodnatost. Pretoki opazovanih rek, razen omenjene Mure in Drave, so se v drugi polovici meseca junija približali in ponekod tudi padli pod obdobno povprečno nizkovodno stanje za mesec junij. Predvsem pretoki večine rek v osrednji, severni in vzhodni Sloveniji so bili junija v mejah najmanjših junijskih obdobnih vrednosti. Povratne dobe malih pretokov na omenjenih območjih so bile med 2- in 5-letnimi.

Padavine proti koncu junija so vplivale na delno izboljšanje hidroloških razmer, predvsem na notranjsko kraškem območju ter na alpskih in predalpskih območjih. V juliju se je vodnatost rek povečala, tudi preko srednjih pretokov, saj je v večjem delu države padla povprečna julijska količina padavin. Vendar so se v južni in vzhodni Sloveniji pretoki rek proti koncu meseca že približali najmanjšim julijskim obdobnim vrednostim. V avgustu je bila hidrološka situacija podobna razmeram iz junija. Pretoki na opazovanih vodotokih so bili nekoliko večji od najmanjših obdobnih vrednosti za avgust. Reke Dragonja, Drnica in Pivka so, kot skoraj vsako leto, presahnile. Povratne dobe malih pretokov so bile v večini primerov od 2- do 5-letne, v severovzhodnem delu Slovenije pa so imeli pretoki 10-letno povratno dobo. Glede na pogostost suš v zadnjih desetih letih to ni tako redek pojav.

Vzroke za nastanek suše gre iskati v primanjkljaju padavin in visokih temperaturah zraka. Časovna in količinska razporeditev padavin po državi je bila zelo različna in v prvih devetih mesecih leta v glavnem pod obdobnimi povprečji (graf 10). Povprečna letna količina padavin se giblje od 750 mm v Prekmurju do 3300 mm na severozahodu v Julijskih Alpah. V letu 2000 je padlo najmanj padavin v Prekmurju, kjer je bil primanjkljaj tudi največji.

Za ovrednotenje malih pretokov oziroma definicijo hidrološke suše vodotokov se uporabljajo različni pristopi kot so krivulja trajanja pretokov, minimalni pretoki različnih trajanj in računanje primanjkljaja odtoka. Vse te metode v glavnem temeljijo na analizah časovnih nizov srednjih

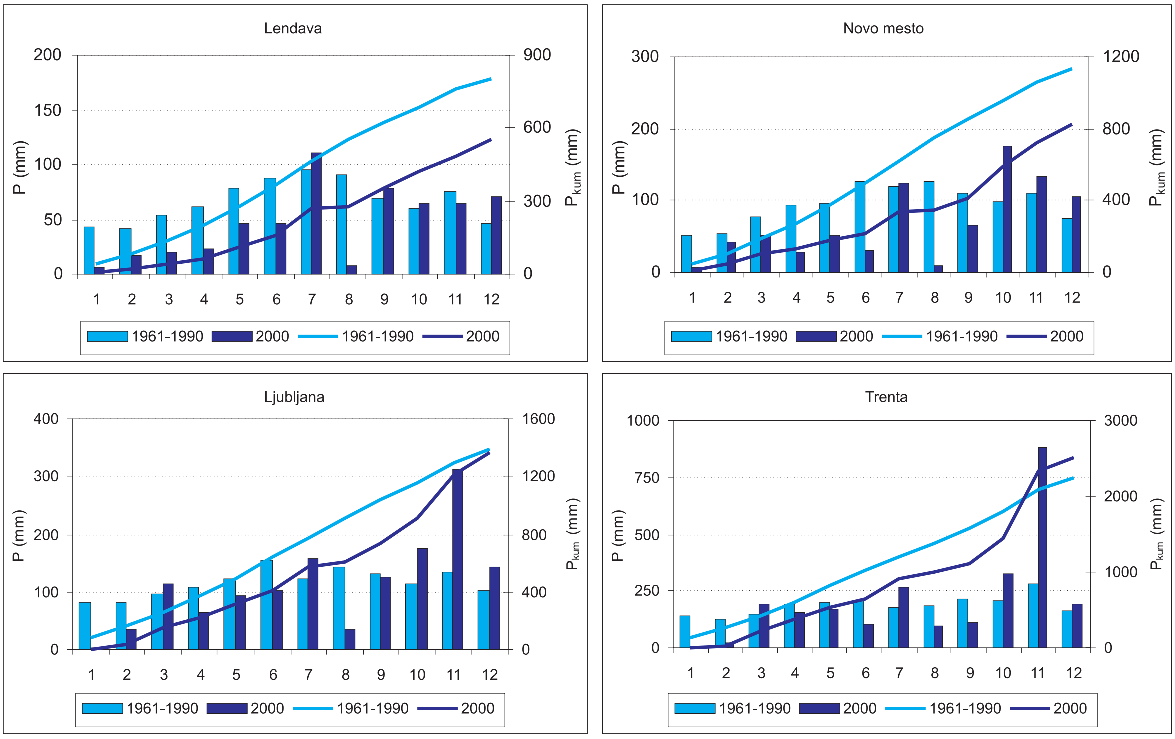
relevant catchment areas are also shown, in comparison with the period 1961–1990.

The amount of water reserves was decreasing throughout the first half of the year 2000 due to precipitation deficit. Low flows, which are characteristic of the hydrologically dry months, such as August and September, were observed in June. With the exception of the rivers Mura and Drava, which have, due to their nival regime, the greatest water quantity in May, June and July, and which at that time had medium discharge levels, the quantity of water in other water courses throughout the country was below average. In the second part of June the discharges of observed rivers, except for the above-mentioned Mura and Drava, within range of multiannual low means of June. Especially the discharges of most rivers in central, northern and eastern Slovenia were in June within the limits of the lowest periodical values for June. The return periods of low discharges at these areas were between the 2- and 5-year return periods.

Precipitation occurring towards the end of June led to partial improvement of the hydrological conditions, above all in the areas of Notranjska and Kras, and also in the Alpine and pre-Alpine areas. In July, the quantity of water in the rivers increased and even exceeded the mean discharges, as most of the country got the average precipitation amount for July. Nevertheless, the discharges of southern and eastern Slovenia came close to the lowest periodical values for July. In August, the hydrological situation was similar to the one in June. Discharges of the observed rivers somewhat exceeded the lowest periodical values for August. The rivers Dragonja, Drnica and Pivka ran dry, like they do practically every year. The return periods of low discharges were in most cases 2 to 5 years, but in the northeastern part of Slovenia the discharges had a 10-year return period. Considering the frequency of droughts in the last ten years, this is not a very rare event.

The reasons for the occurrence of drought are the precipitation deficit and high air temperatures. Temporal and quantitative precipitation distribution in Slovenia was quite diverse and under periodical average from January to September in general (Graph 10). The average annual precipitation quantity varies from 750 mm in Prekmurje to 3300 mm in northwest in the Julian Alps. The lowest precipitation amount in the year 2000 was in Prekmurje, where the deficit was thus the greatest.

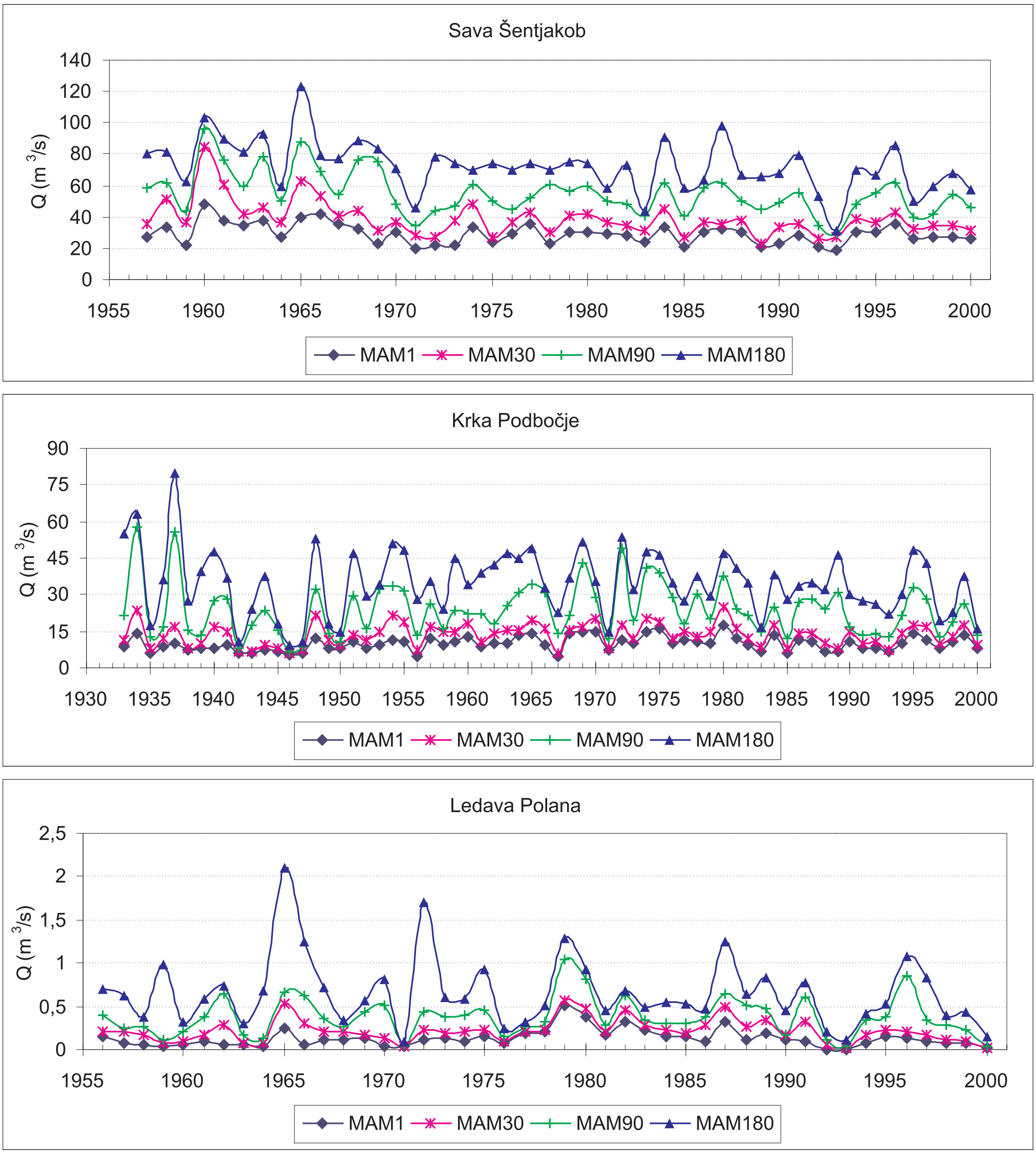
Various approaches are used to evaluate low flows or to define the hydrological drought of rivers, such as flow duration curve, minimum discharg-



Graf 10: Mesečna in kumulativna količina padavin.
Graph 10: Monthly and cumulative precipitation amounts.

dnevnih pretokov. Najenostavnejša je analiza nizkovodnih stanj različnih trajanj (1, 10, 30, 90 dni in več). Pri tem za vsako leto izračunamo najmanjše srednje pretoke različno dolgih neprekinjenih obdobij. Na grafu 11 je za tri vodomerne postaje prikazana analiza nizkovodnih stanj minimalnih letnih povprečnih pretokov (MAM – mean annual minimum) trajanj 1, 30, 90 in 180 dni. Iz diagramov je lahko razbrati najbolj suha leta v analiziranem obdobju. To so leta, pri katerih so vrednosti minimalnih pretokov različnih trajanj blizu vrednosti najmanjšega srednjega dnevnega pretoka MAM1. Iz grafa 11 razberemo, da leto 2000 ni bilo najbolj suho leto v obdobju opazovanj. Za postajo v Šentjakobu je bilo hidrološko najbolj suho leto 1993, v obdobju po letu 1960, sledita pa mu leti 1971 in 1983. Za Krko v Podbočju je bilo v obdobju zadnjih štiridesetih let najbolj suho leto 1971, sledi mu leto 2000. Leta 1971, 1993 in 2000 pa sodijo med najbolj suha tudi v Polani na Ledavi.
Po analizi podatkov mreže državnih vodomernih postaj je bilo za več kot polovico postaj najbolj suho leto 1993, zatem leto 1983 (dobra tretjina vodomernih postaj), na ostalih postajah pa leto 1971. Analiza za leto 2000 kaže, da je bila hidrološka suša v tem letu najbolj izrazita v severovzhodni in južni Sloveniji, še zlasti v Prek-

es of various durations and calculation of the runoff deficit. All these methods are mainly based on the analyses of time series of mean daily discharges. The easiest method is the analysis of low flows of various durations (1, 10, 30, 90 days and more). Here, the lowest mean discharges for continuous periods of various lengths are calculated for each year. Graph 11 shows mean annual minima (MAM) with the durations of 1, 30, 90 and 180 days, for 3 water gauge stations. The driest years of the analysed period can be seen from the diagram, i.e. the years in which the values of minimum discharges of various durations are close to the value of the lowest mean daily discharge MAM1. As we can see in Graph 11, the year 2000 was not the driest year in the observation period. The hydrologically driest year for the water gauge station in Šentjakob in the period after 1960 was 1993, followed by 1971 and 1983. The driest year in the last forty years for the Krka in Podbočje was 1971, followed by the year 2000. The years 1971, 1993 and 2000 were also among the driest in Polana on the Ledava.
According to the data analysis of the public water gauge stations, the driest year for more than half of the stations was 1993, then 1983 (for a good third of the water gauge stations), and 1971 for other stations. The analysis for the year 2000



Graf 11: Analiza povprečnih letnih minimalnih pretokov različnih trajanj.
Graph 11: The analysis of the average annual minimum discharges of various durations.

murju. Analiza tudi kaže, da so za obdobje po letu 1970 značilni dokaj pogosti nizki pretoki. Vendar pa analiza postaj s podatki pred letom 1960 pokaže, da omenjena leta niso bila najbolj suha leta v obdobju opazovanj, ampak so bila to leta v obdobju 1946–1949. Za Krko v Podbočju, ki ima neprekinjen niz podatkov od leta 1933 naprej, je bilo najbolj suho leto 1946.

shows that the hydrological drought in that year was the most severe in northeastern and southern Slovenia, particularly in Prekmurje. The analysis also shows that low discharges were a rather frequent characteristic of the period after 1970. However, the analysis of stations with the available data for the period before 1960 shows that the above-mentioned years were not the driest years in the observation period. The driest were the years in the period 1946–1949. For the Krka in Podbočje with a continuous series of data since 1933, the driest year was 1946.

Savinja v Velikem Širju, 15. 6. 2000 (foto: Marko Burger).
The Savinja river at Veliko Širje on the 15th of June 2000 (photo: Marko Burger).

B. PODZEMNE VODE

PODZEMNA VODA V ALUVIALNIH VODONOSNIKIH

Zlatko Mikulič

Povprečne gladine podzemne vode so bile v letu 2000 pod letnim povprečjem (Hs) dolgoletnega primerjalnega obdobja (graf 12 in preglednica 3). Leto 2000 je zaznamovalo večmesečno zniževanje gladin podzemne vode. V avgustu je hidrološka suša zajela skoraj vse aluvialne vodonosnike Slovenije. V zadnjih dveh mesecih leta je bila za količinsko stanje podzemne vode v aluvialnih vodonosnikih značilna izjemno velika prostorska spremenljivost: od hidrološko sušnih razmer na severovzhodu države, vse do izjemno bogatih zalog podzemne vode na zahodu države. Višine gladin podzemnih vod 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

B. GROUNDWATERS

GROUNDWATER IN THE ALLUVIAL AQUIFERS

Zlatko Mikulič

The mean groundwater levels were in the year 2000 below the multiannual mean (Hs) (Graph 12 and Table 3). The groundwater levels were decreasing for several months. In August, the hydrological drought affected almost all alluvial aquifers of Slovenia. The last two months of the year were characterized by an exceptionally high spatial variability of the groundwater quantity in the alluvial aquifers: from the hydrologically dry situation in the northeast of the country, to the extremely rich groundwater reserves in the west.

Groundwater levels in the alluvial aquifers in Slovenia generally depend on the balance between the inflows on one hand, and outflows, losses and artificial withdrawals of water on the other. Sources of aquifer recharge are precipita-

Aluvialna vodonosnika Kranjskega in Vodiškega polja, kjer je gladina vode ob nizkem vodnem stanju tudi več kot 40 m pod površjem. (foto: Peter Frantar)

On the alluvial aquifers of Kranjsko polje and Vodiško polje the low water levels are more than 40 m below the surface. (photo: Peter Frantar) strani. Viri napajanja vodonosnikov so padavine na samih poljih in v neposrednem padavinskem zaledju na obrobju ravnin, kakor tudi pronicanje iz rek: Ledave, Mure, Drave, Savinje, Kamniške Bistrice, Kokre, Save, Soče itd. Odtoki podzemne vode so posledica pronicanja v vodotoke, izgube pa so posledica evapotranspiracije, ki je

Shema merilnega mesta v Levcu v Spodnji Savinjski dolini.
Observation well at Levec in the Lower Savinja valley.

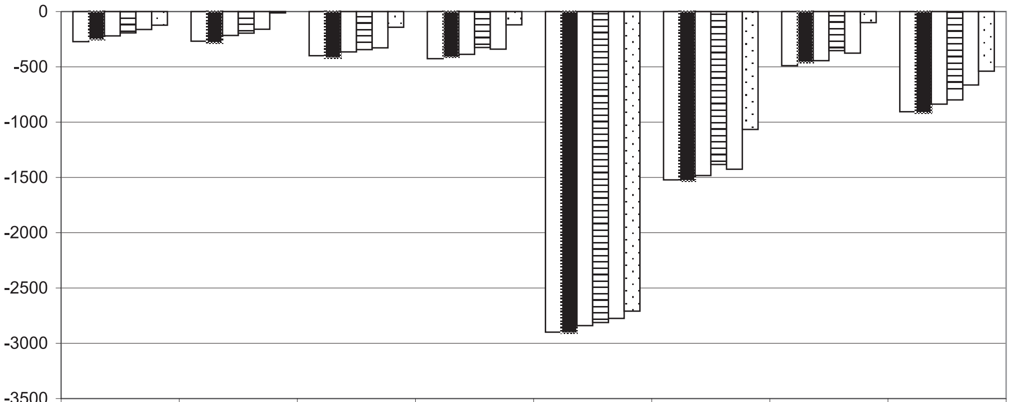
tions, on the fields itself and in the catchment areas bordering the plains, as well as the infiltration from the rivers: Ledava, Mura, Drava, Savinja, Kamniška Bistrica, Kokra, Sava, Soča, etc. The outflows of groundwater are a consequence of drainage into watercourses. The losses are a consequence of evapotranspiration, which is a highly important factor in the shallow aquifers of northeastern Slovenia. Therefore, in order to understand the groundwater regime, we need to consider spatial and temporal variability of precipitation amount, evapotranspiration and water level in the rivers, bordering on aquifers.

Annual precipitation amount at the area of the alluvial aquifers was lower than the multiannual mean in the east of the country, and higher than the multiannual mean in the west. The precipitation amount was lower by one fifth in the area of aquifers in the basins Krško-Brežiška and Celjska kotlina and in northeastern Slovenia. In the central Slovenia, on the aquifers of the basin Ljubljanska kotlina, the annual amount was only slightly different than the multiannual mean. In the west of Slovenia, at the area of aquifers of the valley Vipavsko-Soška dolina, the precipitation amount was higher by one tenth. Even more significant for the groundwater regime was the temporal distribution of precipitation deficit. The deficit was the greatest in January and August, when only one tenth of the usual precipitation fell at the area of aquifers, and the deficits were significant also in the spring. The groundwater regime was greatly influenced also by the very small quantity of snow at the beginning of the year. The snow cover at the area of alluvial aquifers was only about 10 cm thick and no more than 7 cm in Prekmurje. The above-average wet months were at some locations March and July, and the last three months of the year in the entire country.

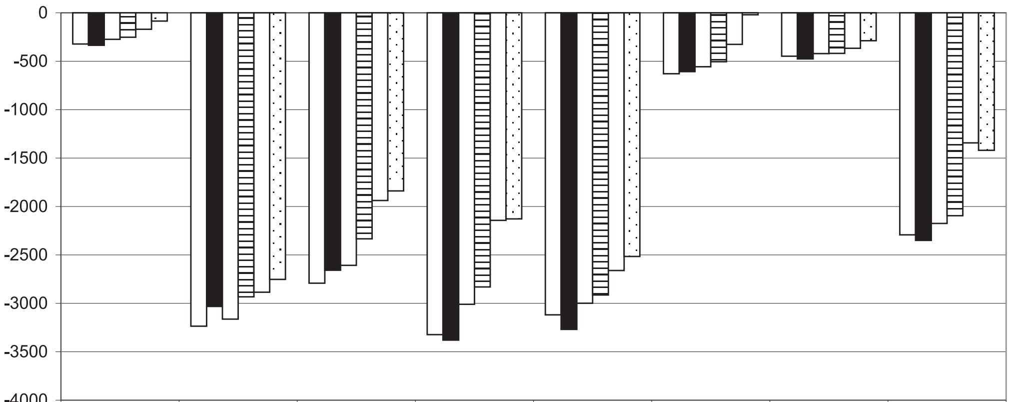
In the area of all alluvial aquifers, the year 2000 was warmer than usual, for the most part by 2.5 °C. The main reasons for that were warm mornings and afternoons, which resulted in the above-average water loss through evapotranspiration in the vegetation period from the spring onwards. The losses were above average in the areas of all alluvial aquifers, particularly in the northeast of Slovenia, in Dolenjska and in the basin Celjska kotlina, where the air temperature exceeded 30 °C in more than thirty hot days.

The described precipitation distribution resulted in distinct spatial and temporal distribution of discharges and water levels in the rivers, which borposebej pomemben dejavnik v plitvih vodonosnikih severovzhodne Slovenije. Za razumevanje vodnih razmer podzemnih voda je torej potrebno upoštevati prostorsko in časovno spremenljivost količine padavin, evapotranspiracijo in višino vode v rekah, ki mejijo na vodonosnike. Celoletna količina padavin na območju aluvialnih vodonosnikov je bila manjša od dolgoletnega povprečja v vzhodnem delu države, večja od povprečja pa v zahodnem delu države. Za petino manj padavin je bilo na območju vodonosnikov Krško-Brežiške kotline, Celjske kotline in severovzhodne Slovenije. V osrednji Sloveniji, na vo-

der on aquifers. Annual discharge average of all rivers in the country was 7 % lower than the multiannual mean, which highlights hydrological low-water situation. On the level of the entire year, water levels were higher in the rivers in the west, and lower in the rivers in the east of the country. Mean annual discharges ranged from one quarter above the long-term average at the utmost western part of the country to merely four tenths of the long-term average in the area of northeastern Slovenia. Irregular temporal distribution of discharges was highly significant for the groundwater regime. From January to October, the river discharges were



	0970 Brezovica	3370 Rankovci	0400 Zg. Krapje	0120 M. Segovci	0080 Kamnica	0721 Tezno	0370 Dornava	0840 Šempeter
Hnk-2000	-272	-268	-399	-426	-2899	-1522	-489	-906
Hnk-obdobje / Hnk-period	-254	-285	-420	-413	-2907	-1534	-461	-918
Hs-2000	-220	-216	-365	-387	-2840	-1483	-444	-837
Hs-obdobje / Hs-period	-193	-195	-344	-325	-2812	-1383	-353	-799
Hvk-2000	-162	-160	-328	-340	-2775	-1426	-376	-664
Hvk-obdobje / Hvk-period	-123	-12	-142	-120	-2709	-1066	-100	-539



	VČ-5072 Latkova vas	0320 Meja	0360 Brnik	MP-0275 Mengeš	0541 Kleče	0152 Skopice	0111 Sp. S. Grad	0220 Šempeter
Hnk-2000	-322	-3236	-2792	-3323	-3119	-629	-448	-2293
Hnk-obdobje / Hnk-period	-335	-3032	-2658	-3380	-3269	-607	-476	-2350
Hs-2000	-274	-3163	-2608	-3010	-2999	-557	-421	-2175
Hs-obdobje / Hs-period	-252	-2933	-2334	-2831	-2914	-505	-419	-2095
Hvk-2000	-170	-2885	-1938	-2143	-2661	-326	-366	-1343
Hvk-obdobje / Hvk-period	-85	-2753	-1839	-2128	-2516	-20	-288	-1420

Graf 12: Primerjava značilnih gladin podzemnih voda v letu 2000 z značilnimi gladinami za primerjalno obdobje 1961–1990.
Graph 12: Characteristic groundwater levels in the year 2000 compared to multiannual characteristic levels 1961–1990.

donosnikih Ljubljanske kotline, je celoletna količina le neznatno odstopala od dolgoletnega povprečja. Za desetino več padavin je bilo na zahodu Slovenije, na območjih vodonosnikov Vipavsko-Soške doline. Za režim podzemnih voda je bila še pomembnejša časovna razporeditev primanjkljajev padavin. Največji primanjkljaji so bili januarja in avgusta, ko je padla na območju vodonosnikov le ena desetina običajnih padavin, znatni primanjkljaji pa so bili tudi v spomladanskem obdobju. Na režim podzemnih voda je pomembno vplivala zelo majhna količina snega na začetku leta. Snežne odeje je bilo na območju aluvialnih vodonosnikov le okoli deset centimetrov. V Prekmurju je bila debela komaj 7 cm. Nadpovprečno namočeni meseci so bili ponekod marec in julij, povsod pa zadnji trije meseci v letu.

Na območju vseh aluvialnih vodonosnikov je bilo leto 2000 toplejše od dolgoletnega povprečja, večinoma za poltretjo stopinjo Celzija. K temu so največ prispevala topla jutra in popoldnevi, kar je imelo za posledico nadpovprečno veliko izgubo vode z evapotranspiracijo v vegetacijskem obdobju od pomladi naprej. Izgube so bile nadpovprečne na območjih vseh aluvialnih vodonosnikov, posebej velike pa v severovzhodni Sloveniji, na Dolenjskem in v Celjski kotlini, kjer je bilo več kot trideset vročih dni s temperaturo zraka nad trideset stopinj Celzija.

Opisana razporeditev padavin se je kazala v prostorski in časovni porazdelitvi pretokov oziroma višine vode rek, ki mejijo na vodonosnike. Letno povprečje pretokov vseh rek v državi je bilo sedem odstotkov manjše od dolgoletnega povprečja, kar kaže na hidrološko nizkovodne razmere. Na celoletni ravni je bila značilna večja vodnatost rek v zahodni in manjša v vzhodni polovici države. Razpon srednjih letnih pretokov je bil od ene četrtine nad dolgoletnim povprečjem, na skrajnem zahodnem robu države, do komaj štiri desetine dolgoletnega povprečja, na območju severovzhodne Slovenije. Za režim podzemnih voda je bila zelo pomembna neenakomerna časovna razporeditev pretokov. Od januarja do oktobra so bili pretoki rek majhni do srednji in je bil takrat dotok iz rek v vodonosnike pod običajnimi za ta letni čas. Hidrološka suša površinskih voda je bila najbolj izrazita v severovzhodni Sloveniji. O nizki vodnatosti v prvih desetih mesecih in namočenosti konec leta priča dejstvo, da je v zadnjih treh mesecih leta pretekla polovica vseh količin vode v letu 2000. Najbolj namočen je bil november, s trikrat večjimi srednjimi pretoki (Qs) low to medium and the inflow of rivers into the aquifers was then lower than it usually is at that time of the year. The hydrological drought of surface waters was the most severe in northeastern Slovenia. Low water quantity in the first ten months of the year and wetness at the end of the year can be inferred from the fact that one half of all water quantities in the year 2000 flew in the last three months of the year. The wettest month was November, having the mean discharges (Qs) three times bigger than the multiannual mean for this month. However, in northeastern Slovenia water levels at the end of the year were below average, with the exception of the Mura having its headwaters in Austria. As the river discharges were below average in the first ten months of the year, the outflows from aquifers into the rivers generally exceeded the inflows and that contributed to the decrease of groundwater storage.

Low water levels on Sorško polje and on a part of Kranjsko polje are not defined as hydrological drought, because the comparison refers to the period of raised groundwater levels after the construction of the hydroelectric power station Mavčiče in 1986. Water levels in this area have been decreasing in the last few years due to the silting-up of the bottom of the dam reservoir of the hydroelectric power station which result in decreased infiltration from the river Sava.

In the year 2000, the regime of fluctuations of water levels, as well as groundwater reserves was not conditioned only by the above-mentioned factors, but also by the regime of the previous year. In the autumn of 1999 water reserves were decreasing from September onwards, reaching the lowest level in November. In Slovenia the precipitation amount in November is usually high, which is crucial for a favourable regime in the following year. In November 1999, the precipitation deficit was so severe that the alluvial aquifers were affected by hydrological drought, which is an extremely rare phenomenon at that time of the year. Due to the abundant precipitation in December, the water reserves temporarily improved, but as January of the year 2000 hardly got any precipitation at all, the improved situation did not last long. At the end of January, water levels in most aquifers were below the values multiannual means. The rate of level decrease was low at the fields Prekmursko, Mursko and Apaško polje and thus the levels there remained above average. Minor temporary improvements were observed at some locations in February, but in spite of that the aquifers of Vrbanski plato and

Preglednica 3: Primerjava značilnih gladin podzemnih voda v letu 2000 z značilnimi gladinami primerjalnega obdobja 1961–1990.
Table 3: Characteristic groundwater levels in the year 2000 and the characteristic levels of the comparative period 1961–1990.

POSTAJA LOCATION	VODONOSNIK AQUIFER	2000			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	272	220	162	1980-1990	254	242	193	138	123
3370 Rankovci	PREKMURSKO POLJE	268	216	160	1961-1990	285	248	195	113	12
0400 Zg. Krapje	MURSKO POLJE	399	365	328	1964-1990	420	385	344	285	142
0120 Mali Segovci	APAŠKO POLJE	426	387	340	1961-1967	413	391	325	239	166
0080 Kamnica	VRBANSKI PLATO	2899	2840	2775	1981-1990	2907	2870	2812	2747	2709
0721 Tezno	DRAVSKO POLJE	1522	1483	1426	1961-1990	1534	1476	1383	1246	1066
0370 Dornava	PTUJSKO POLJE	489	444	376	1961-1990	461	410	353	276	100
0840 Šempeter	SP. SAVINJSKA DOL.	906	837	664	1966-1990*	918	879	799	668	539
VČ-5072 Latkova vas	DOLINA BOLSKE	322	274	170	1975-1990	335	307	252	163	85
0320 Meja	SORŠKO POLJE	3236	3163	2885	1987-1990	3032	3009	2933	2827	2753
0360 Brnik	KRANJSKO POLJE	2792	2608	1938	1987-1990	2658	2559	2334	1980	1839
MP-0275 Mengeš	D. KAMN. BISTRICE	3323	3010	2143	1976-1990	3380	3168	2831	2389	2128
0541 Kleče	LJUBLJANSKO POLJE	3119	2999	2661	1974-1990	3269	3066	2914	2726	2516
0152 Skopice	KRŠKO POLJE	629	557	326	1980-1990	607	579	505	305	20
0111 Sp. Stari grad	BREŽIŠKO POLJE	448	421	366	1971-1990	476	453	419	344	288
0220 Šempeter	VIPAVSKO -SOŠKA D.	2293	2175	1343	1961-1990	2350	2259	2095	1775	1420

* prekinjen časovni niz / interrupted time series

od dolgoletnega povprečja, ki je veljal za ta mesec. Vendar je bil v severovzhodni Sloveniji tudi konec leta pod povprečjem, z izjemo reke Mure s povirjem v sosednji Avstriji. Ob podpovprečnih pretokih rek, v obdobju prvih desetih mesecev, so praviloma odtoki iz vodonosnikov v reke presegali dotoke, kar je prispevalo k zmanjševanju zalog podzemnih voda.

Nizkega stanja na Sorškem polju in na delu Kranjskega polja ne označujemo za hidrološko sušo, saj se primerjava nanaša na obdobje zvišanih gladin podzemne vode po izgradnji HE Mavčiče leta 1986. Na tem območju se gladine zadnjih nekaj let znižujejo zaradi zamuljevanja dna zajezitvenega jezera hidroelektrarne in s tem povezanega zmanjšanja pronicanja vode iz Save v podzemlje. Režim nihanja gladin, oziroma zalog podzemnih voda, je bil v letu 2000 poleg opisanih dejavnikov vodne bilance pogojen tudi z režimom v predhodnem letu. V jeseni 1999 so se vodne zaloge zniževale od septembra naprej in so dosegle najnižjo raven v novembru. V naših klimatskih razmerah je november običajno padavinsko bogat, ključen za ugoden režim naslednjega leta. Novembra 1999 je bil tako velik primanjkljaj padavin, da je takrat aluvialne vodonosnike že zajela hidrološka suša, kar je izjemno redek pojav. Obilne padavine v decembru so prehodno izboljšale stanje vodnih zalog, vendar se je že v suhem

of the valley of the Kamniška Bistrica were affected by the hydrological drought. In the groundwater hydrology drought is defined as the low water reserves, pertaining to groundwater levels, that are for a long period of time below the low multiannual mean (Hnp) and are affecting extensive areas of aquifers.

Water levels were continuously decreasing from March onwards. In March the drought affected the aquifers of Vrbanski plato and Dravsko polje. The drought on Dravsko polje persisted until the end of the year. In April the drought affected also the Šentjernejsko polje while the levels in other aquifers had for the most part already decreased under the annual mean. In May the hydrological drought spread to Ptujsko polje and to peripheral parts of some other aquifers. In hot June, when the high air temperatures caused great water losses through evaporation, the hydrological drought affected also the major part of aquifers in Prekmurje and Celjska kotlina.

Short cool spells and precipitation in July brought a short-term improvement of hydrological situation in surface watercourses, but did not affect the groundwater regime, except for the narrow riparian areas. In spite of precipitation, the drought was spreading and in the hot dry August it reached its peak, regarding the extent of the affected areas.

In August 2000 all alluvial aquifers were affect-januarju 2000, ki je bil skoraj brez padavin, decembrsko izboljšanje izničilo. Konec januarja so bile v pretežnem delu vodonosnikov gladine že pod letnim povprečjem primerjalnega obdobja. Le na Prekmurskem, Murskem in Apaškem polju so bila zniževanja tako majhna, da so se tam gladine ohranile nad povprečjem. Februarja so bila ponekod manjša prehodna izboljšanja, vendar je vodonosnika Vrbanskega platoja in doline Kamniške Bistrice kljub temu zajela hidrološka suša. Kot sušo v hidrologiji podzemnih voda opredeljujemo stanje vodnih zalog, ko so na sklenjenem območju gladine podzemne vode dalj časa pod nizkim povprečjem (Hnp) dolgoletnega primerjalnega obdobja.

Od marca naprej so se vodne gladine zdržema zniževale. V marcu so bile sušne razmere v vodonosnikih Vrbanskega platoja in Dravskega polja. Suša na Dravskem polju je potem trajala vse do konca leta. V aprilu je suša zajela še Šentjernejsko polje, v ostalih vodonosnikih pa so se gladine pretežno že znižale pod letno povprečje. V maju se je hidrološka suša razširila tudi na Ptujsko polje in na obrobne dele nekaterih drugih vodonosnikov. V vročem juniju, ko so visoke temperature zraka povzročile velike izgube vode z evapotranspiracijo, je hidrološka suša zajela še pretežni del vodonosnikov Prekmurja in Celjske kotline.

Prehodne ohladitve in padavine v juliju so sicer kratkotrajno izboljšale hidrološko stanje površinskih vodotokov, z izjemo ozkih obrežnih pasov pa na režim podzemnih voda niso imele vpliva. V tem mesecu se je suša kljub padavinam še širila in je v vročem suhem avgustu dosegla višek glede na obseg prizadetih območij.

V avgustu 2000 so bile sušne razmere v vseh aluvialnih vodonosnikih, razen Vrbanskega platoja, doline Kamniške Bistrice in Vipavsko-Soške doline. Vendar tudi v teh treh vodonosnikih stanje ni bilo ugodno, saj so bile tudi tam vodne zaloge pod letnim povprečjem primerjalnega obdobja.

V septembru se je hidrološka suša končala v vodonosnikih Celjske kotline, na preostalih sušnih območjih pa so se gladine zniževale še ves mesec in so dosegle najnižjo raven na prehodu v oktober. Ena od posebnosti hidrološke suše leta 2000 je bila, da največji prostorski obseg prizadetih vodonosnikov in izrazitost pojava časovno nista sovpadala.

Od oktobra do konca leta so se zaloge podzemne vode povečevale zaradi obilnih padavin in velikih pretokov rek. Kljub temu je bilo ob koncu

ed by drought, except for the Vrbanski plato, the valley of the Kamniška Bistrica and the valley of the rivers Vipava and Soča. However, the situation in the latter three aquifers was not favourable either, as the water reserves were below the annual average value of the comparative period. In September the hydrological drought ended in the aquifers of the basin Celjska kotlina, while in other dry areas the levels were decreasing through the entire month and reached the lowest level at the turn of the month. One of the special characteristics of the hydrological drought in the year 2000 was that the greatest extent of the affected aquifers and the drought peak did not occur at the same time.

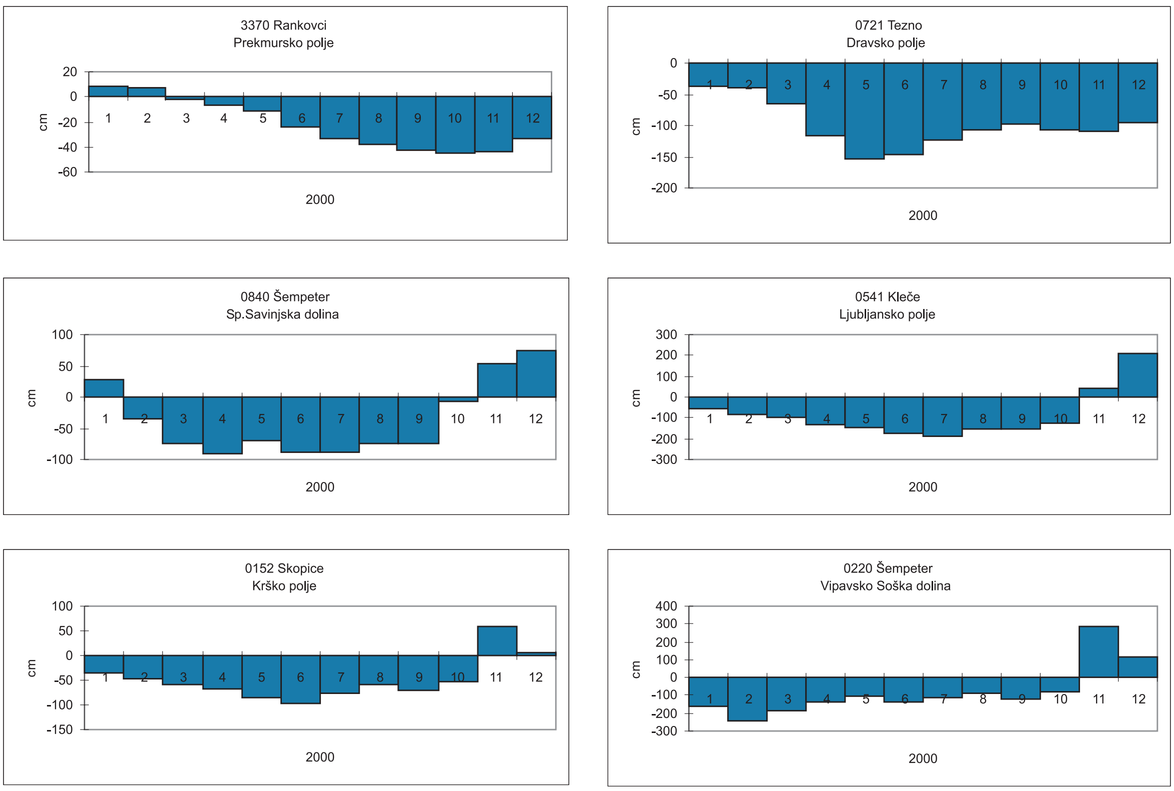
From October until the end of the year the groundwater reserves were increasing due to the abundant precipitation and high river discharges. However, the groundwater reserves at Dravsko and Apaško polje were still low at the end of the year. Hydrological situation from November until the end of the year was unusual. Drought conditions were observed on the two above-mentioned aquifers, while the exceptionally high levels, above the high multiannual means (Hvp), occurred in the aquifers of Kranjsko, Ljubljansko and Mirensko-Vrtojbsko polje. In other aquifers all intermediate water levels were observed. Such a large geographical variability of groundwater reserves is extremely rare event.

With respect to the monthly means in regard to multiannual reference period, monthly water-level deviations in the year 2000 (Graph 13) show some distinctive features of the regime of that year, above all the severe hydrological drought. In spite of the fact that January only got one tenth of the usual precipitation amount, the water levels were at some locations above the monthly average, which resulted from favourable water reserves in December 1999. In the period from February to October 2000, water levels were below the monthly mean values. In most aquifers the negative deviations were the most significant in the summer months. In the alluvial aquifers of northeastern Slovenia these deviations were the greatest in autumn, and as a result of dry conditions they persisted until the end of the year. In other aquifers the level deviations were above average in the last two months of the year due to abundant precipitation and high water quantity in rivers.

Considering annual water-level fluctuations the high peaks of the year were observed mostly between January and March in the aquifers of the

leta na Dravskem in Apaškem polju stanje vodnih zalog še vedno nizko.
Od novembra do konca leta so bile nenavadne hidrološke razmere, saj so bile istočasno sušne razmere na omenjenih dveh vodonosnikih in izjemno visoke gladine, nad visokim povprečjem (Hvp), v vodonosnikih Kranjskega, Ljubljanskega in Mirensko-Vrtojbskega polja. V preostalih vodonosnikih so bila zastopana še vsa vmesna vodna stanja. Tako velike geografsko pogojene razlike v količinah vodnih zalog so izjemno redek pojav.
Mesečna odstopanja gladin v letu 2000 od mesečnih povprečij za primerjalno dolgoletno obdobje (graf 13) odražajo nekatere posebnosti režima tega leta, predvsem pa izrazito hidrološko sušo. Kljub izpadu devetih desetin padavin v januarju, so bile v tem mesecu gladine ponekod nad mesečnim povprečjem, kar je bila posledica ugodnih vodnih zalog iz decembra 1999. Od februarja do oktobra 2000 so bile gladine v vseh mesecih pod mesečnimi povprečji. V večini vodonosnikov so bila največja odstopanja navzdol v poletnih mesecih. Ta odstopanja so bila v aluvialnih vodono-

eastern part of the country, and in the aquifers of central and western Slovenia in November and December. The lowest annual levels were mainly between August and October, the low peaks being recorded most often at the turn of September. An unusual feature, from the hydrological point of view, in the year 2000 was an exceptionally vast range of water levels between the individual parts of the country. In the same year, a multiannual peak minimum was recorded in Prekmurje, as well as multiannual peak maximum at Mirensko-Vrtojbsko polje.
On the whole, the year 2000 was hydrologically dry, with a highly unfavourable regime in the alluvial aquifers of the northeastern Slovenia. In Prekmurje the year began with groundwater reserves above the mean value and ended with reserves below the multiannual mean values. On Dravsko and Ptujsko polje and in some parts of aquifers in Pomurje, the hydrological drought was so severe that even the annual water level mean (Hs) was below the low annual mean (Hnp) of the multiannual comparative period. The climax of hydrological drought at the end of the summer of the year



Graf 13: Odstopanja srednjih mesečnih gladin podzemne vode v letu 2000 glede na srednje mesečne gladine za primerjalno dolgoletno obdobje 1961–1990.
Graph 13: Deviations of mean monthly groundwater levels in the year 2000 with respect to the mean monthly levels in a multiannual comparative period 1961–1990.

snikih severovzhodne Slovenije največja v jesenskih mesecih, kot posledica sušnih razmer, vse do konca leta. V preostalih vodonosnikih so v zadnjih dveh mesecih leta gladine odstopale navzgor, kot posledica obilnih padavin in velike vodnatosti rek. Pri letnem poteku nihanja gladin v vodonosnikih vzhodne polovice države so bile zabeležene visoke konice leta pretežno med januarjem in marcem, v vodonosnikih osrednje in zahodne Slovenije pa v novembru in decembru. Najnižje letne gladine so bile pretežno med avgustom in oktobrom, pri čemer so bile nizke konice največkrat zabeležene na prehodu iz septembra v oktober. Hidrološko je bilo leto nenavadno po izjemno velikem razponu višin vodnih gladin med posameznimi deli države. Tako je bil v istem letu zabeležen obdobni minimum primerjalnega obdobja v Prekmurju in obdobni maksimum na Mirensko-Vrtojbskem polju.

V celoti ocenjujemo leto 2000 kot hidrološko sušno, z izrazito neugodnim režimom v aluvialnih vodonosnikih severovzhodne Slovenije. V Prekmurju se je leto začelo z nadpovprečnimi vodnimi zalogami, končalo pa z zalogami pod dolgoletnim povprečjem. Na Dravskem in Ptujskem polju ter v nekaterih delih vodonosnikov v Pomurju je bila hidrološka suša tako izrazita, da je bilo celó letno povprečje gladin (Hs) pod nizkim letnim povprečjem (Hnp) dolgoletnega primerjalnega obdobja. Višek hidrološke suše, kot je bil v letu 2000 na koncu poletja, je bil normalen pojav za naše klimatske razmere. Nenavadno pa je bilo večmesečno nepretrgano zniževanje gladin od konca zime do jeseni. V spomladanskem času so praviloma zaloge podzemnih voda v aluvialnih vodonosnikih ugodne. Nizke spomladanske zaloge in visoke temperature zraka od pozne pomladi naprej sta bila poglavitna vzroka izrazite hidrološke suše v poletnih mesecih.

2000 was a normal event for climatic conditions in Slovenia. However, it was unusual that the levels were continuously decreasing for several months, from the end of winter until autumn. The groundwater reserves in the alluvial aquifers are generally favourable in spring. Low groundwater reserves of 2000 in spring and high air temperatures from late spring onwards were the two principal reasons for the severe hydrological drought in the summer months.

C. IZVIRI

MONITORING IZVIROV

Niko Trišić

Izviri so ozko omejena območja naravnega iztoka podzemne vode iz vodonosnika. V Sloveniji so raziskovalci po različnih kriterijih izbora našteli preko 10.000 izvirov. Lokacije iztokov pogojujejo hidrogeološke razmere v njihovi okolici, ostale karakteristike iztoka pa hidrogeološke in meteorološke razmere na širšem območju vodonosnika. Na izviru se tako odražajo značilnosti dogajanja v vodonosniku in v njegovem zaledju. Zaradi tega je lahko količinski monitoring izvirov dober pokazatelj hidroloških razmer v vodonosnikih.

Državni hidrološki monitoring izvirov je razvojno usmerjen v zagotavljanje podatkovne osnove za ocenjevanje vodnih zalog podzemnih voda ter ugotavljanje režima in analiziranje trendov njihovega količinskega stanja. Poleg podatkov moni-

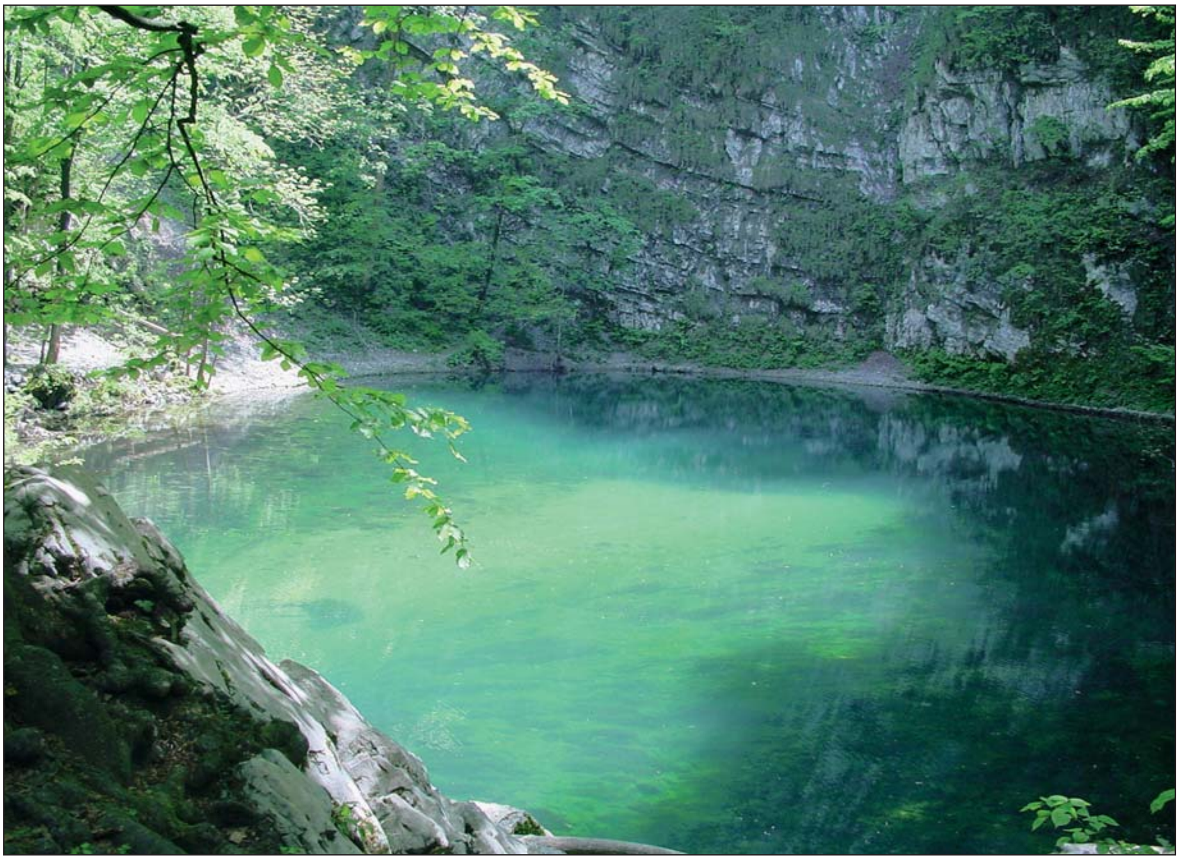
C. SPRINGS

MONITORING OF SPRINGS

Niko Trišić

Springs are very limited areas of natural outflow of groundwater from aquifers. Researchers, using various criteria, found over 10 000 springs in Slovenia. Locations of outflows are conditioned by hydrogeological conditions nearby, while other characteristics of outflows are determined by the hydrogeological and meteorological conditions in the wider area of aquifers. Springs thus reflect the characteristics of events in an aquifer and in its catchment. Therefore, quantitative monitoring of springs can be a good indicator of hydrological situation in aquifers.

The purpose of national hydrological monitoring of springs is to provide data for estimation of groundwater reserves, to determine the regime and to analyse trends of quantity fluctuations. In addition to the spring monitoring data, the data from



Divje jezero pri Podroteji, značilen kraški izvir vokliškega tipa. (foto: Niko Trišić)
Divje jezero (Savage Lake) near Podroteja is a vauclusian karstic spring. (photo: Niko Trišić)

toringa izvirov se pri ocenjevanju količinskega stanja podzemnih voda vključuje tudi podatke merskih profilov iz programa hidrološkega monitoringa površinskih voda. To so vodomerne postaje v bližini izvirov Vipave, Hublja, Ljubljanice, Bistrice v Ilirski Bistrici, Krke, Prečne in tudi Bistrice v Bohinjski Bistrici. Meritve na številnih merskih profilih v bližini izvirov so bile v okviru programa monitoringa površinskih voda v 80-ih in 90-ih letih prejšnjega stoletja prekinjene (Krupa, Težka voda, Veliki Obrh itd.). S tem so na žalost nastale vrzeli v dragocenih podatkovnih nizih za ocenjevanje količinskega stanja, pretočnih režimov in trendov.

Usmerjen program državnega hidrološkega monitoringa izvirov se je pričel v letu 1999 s postavitvijo vodomernih postaj na izvirih Divje jezero in Podroteja pri Idriji. Oba izvira se kljub praktično skupnemu zaledju med seboj hidrološko bistveno razlikujeta. Divje jezero je izvir vokliškega tipa, s prostim iztokom. Struga Jezernice, po kateri se izteka voda izvira Divjega jezera, ob nizkih vodnih stanjih presahne, tok podzemne vode pa se preusmeri proti bližnjim medplastovnim izvirom Podroteje, ki so zajeti za potrebe regionalne preskrbe z vodo.

Zvezno beleženje vodostaja omogoča posredno preko izdelanih pretočnih krivulj tudi beleženje časovne razporeditve izdatnosti izvira. Na podlagi daljših opazovanih nizov se določajo značilnosti pretočnega režima: statistične vrednosti, mesečne razporeditve, trendi pretokov itd. Z natančnim beleženjem vodostajev in primerjavo s padavinami, lahko analiziramo odzivnost izvira na posamezne padavinske dogodke v zaledju.

Temperatura vode daje posredno informacijo o povezavi vodnega toka s površjem oz. atmosfero. Povprečne letne temperature močnih izvirov na območju Visokega dinarskega krasa se gibljejo med 7 °C in 9 °C, nekoliko toplejši je izvir Mrzleka. Temperature izvirov na območju Alp in Kamniških planin so nižje. Temperatura izvira Kamniške Bistrice npr. niha med 5,3 °C in 5,8 °C.

Elektroprevodnost, kot dopolnilni indikator hidrološkega monitoringa izvirov, posreduje okvirno informacijo o mineralizaciji vode ter posredno informacijo o trajanju zadrževanja vode v zaledju oziroma vodonosniku. Elektroprevodnost vode je višja ob nizkih vodnih stanjih, ko je vsebnost ionov v vodi višja, ob visokih vodnih stanjih pa je zaradi razredčenosti s »svežo« padavinsko vodo nižja. Poleg tega je elektroprevodnost lahko tudi indikator onesnaženja.

the gauging stations of surface waters of hydrological monitoring network are included when estimating the groundwater quantity. These are the water gauge stations close to the springs of the Vipava, Hubelj, Ljubljanica, Bistrica in Ilirska Bistrica, Krka, Prečna and Bistrica in Bohinjska Bistrica. Measurements on many gauging cross-sections close to the springs were interrupted within the programme of surface-water monitoring in the 80's and 90's of the previous century (Krupa, Težka voda, Veliki Obrh, etc.). Unfortunately, this caused gaps in valuable series of data for estimation of quantity, discharge regimes and trends.

Programme of national hydrological spring monitoring began in 1999 when the gauging stations on the springs Divje jezero and the Podroteja at Idrija were set up. In spite of their common catchment both springs are hydrologically substantially different. Divje jezero is a vauclusian spring with free outflow. The channel of the Jezernica, through which the water of the spring Divje jezero flows out, runs dry at the low-water conditions. The groundwater flow is directed towards the nearby interlayer springs of the Podroteja, which are tapped for the regional water supply.

Continuous recording of water levels indirectly enables the recording of temporal distribution of spring capacity as well, via the rating curve. On the basis of longer observed series the characteristics of a discharge regime are determined: statistical values, monthly distribution, discharge trends, etc. By accurate registering of water levels and by making a comparison with precipitation, the response of a spring to the individual precipitation events in the catchment area can be analysed.

Water temperature indirectly informs of the connection of spring to the surface or atmosphere. Average annual temperatures of high yield springs in the area of High Dinaric karst range between 7 °C and 9 °C, the Mrzlek spring being somewhat warmer. Spring temperatures in the area of the Alps and Kamniške planine are lower. The temperature of the Kamniška Bistrica spring, for example, fluctuates between 5.3 °C and 5.8 °C.

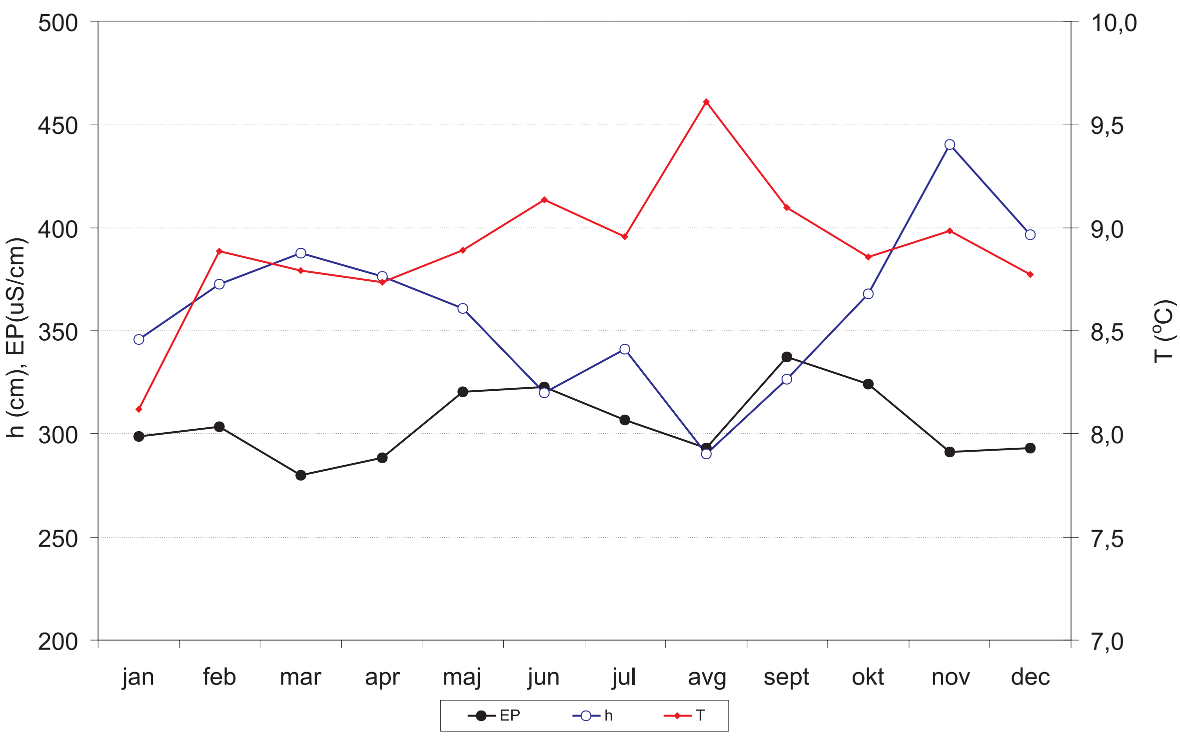
Conductivity as an additional indicator of hydrological spring monitoring gives indicative information on mineralisation of water and indirect information on time of water retention in the catchment area or in an aquifer. Conductivity of water is higher when the water level is low, due to higher ion contents, and lower when the water level is high, due to the dilution with »fresh« precipitation water. Conductivity can indicate pollution as well.

Preglednica 4: Primerjava značilnih (nk, vk) in srednjih (s) letnih vodostajev (H) , temperatur (T) in specifične električne prevodnosti (EP) na hidrološki postaji Divje jezero
Table 4: Comparison of characteristic (nk, vk) and mean (s) annual water levels (H), temperatures (T) and specific conductivity (EP) on the water gauge station Divje jezero.

	vodostaj (cm) water level (cm)			temperatura (ºC) temperature (ºC)			spec. el. prevodnost (uS/cm) spec. conductivity (uS/cm)		
	Hnk	Hs	Hvk	Tnk	Ts	Tvk	EPnk	EPs	EPvk
1999	273	360	519	6,7	8,6	10,3	236	316	375
2000	273	360	562	6,9	8,9	13,9	222	305	363

Nihanja vrednosti posameznih merjenih parametrov so si med obema izviroma sicer podobna, niso pa povsem skladna. Ker se meritve opravljajo šele od leta 1999, ni mogoča podrobnejša analiza trenda, ali primerjava leta 2000 z obdobnimi vrednostmi, temveč le s predhodnim letom.
Primerjava razporeditve vodostajev izvira Divje jezero kaže na podobno razporeditev po posameznih mesecih, za slabega pol metra pa je višji letni maksimum marca leta 2000. Sicer se najnižji vodostaji pojavljajo poleti, avgusta in septembra, najvišji vodostaji pa so novembra in decembra. Drugi, nekoliko nižji maksimum, nastopa v spomladanskih mesecih.
Temperature vode Divjega jezera so bile leta 2000 višje kot leta 1999. Skrajne izmerjene vrednosti

Fluctuations of values of the individual measured parameters are otherwise similar, but do not mutually completely correspond. The measurements began as late as in 1999, therefore it is impossible to make a detailed trend analysis or to compare the year 2000 with multiannual mean values, but only with the previous year.
A comparison of water-level distribution at the spring Divje jezero shows a similar distribution in each individual month, but the annual maximum in March 2000 was higher for almost half a metre. The lowest water levels otherwise occur in the summer, in August and September, and the highest in November and December. The second, somewhat lower maximum, occurs in the spring.
Water temperatures in Divje jezero in the year 2000 were higher than in 1999. The extreme measured



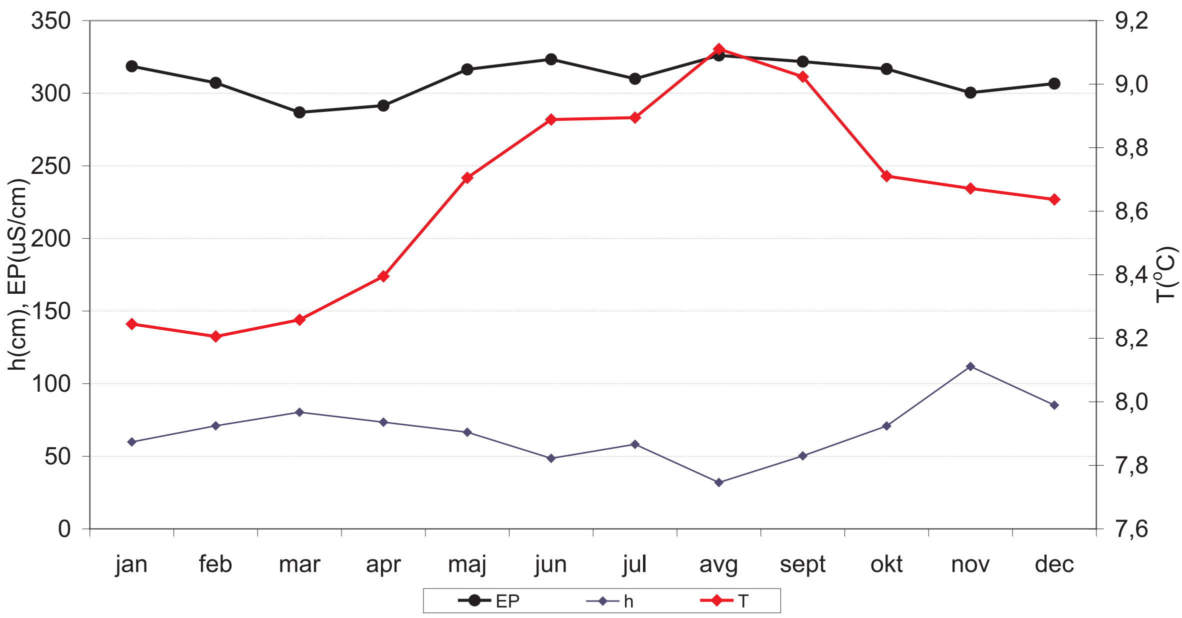
Graf 14: Srednja mesečna temperatura vode (T), vodostaj (h) in specifična električna prevodnost (EP) na hidrološki postaji Divje jezero v letu 2000.
Graph 14: Mean monthly water temperature (T), water level (h) and specific conductivity (EP) at the water gauge station Divje jezero in the year 2000.

Preglednica 5: Primerjava značilnih (nk, vk) in srednjih (s) letnih vodostajev (H), temperatur (T) in specifične električne prevodnosti (EP) na izviru Podroteja.
Table 5: Comparison of characteristic (nk, vk) and mean (s) annual water levels (H), temperatures (T) and specific conductivity (EP) on the Podroteja spring.

	vodostaj (cm) water level (cm)			temperatura (ºC) temperature (ºC)			spec. el. prevodnost (US/cm) spec. conductivity (uS/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

so domnevno posledica lege merilnih sond, ki se ob nižji gladini vode v izviru znajdejo v površinski plasti. Vrednosti specifične električne prevodnosti vode Divjega jezera so bile le nekoliko nižje kot v letu 1999, njihova razporeditev pa je podobna.
Tako kot na izviru Divje jezero, je bila tudi na izviru Podroteja amplituda vodostajev v letu 2000 večja kot leto poprej. Vse tri merjene veličine so se preko leta spreminjale podobno kot na izviru Divje jezero. Opazno je bilo le, da temperatura izvira ni nihala v taki meri, oz. sonde niso bile izpostavljene tako izrazitemu atmosferskemu vplivu.

values were supposedly a consequence of the position of sensors, namely when the water level in the spring is low, they are in the surface layer of water. The values of specific conductivity of water in Divje jezero were only slightly lower than in 1999 and their distribution was similar.
As it was the case on the spring Divje jezero, the amplitude of water levels in the year 2000 was higher than in the previous year on the Podroteja spring as well. Changes of all three measured quantities were similar to those on Divje jezero. The difference was that the temperature of the spring did not fluctuate to that extent, i.e. the sensors were less exposed to the atmospheric influence.



Graf 15: Srednja mesečna temperatura vode (T), vodostaj (h) in specifična električna prevodnost (EP) na izviru Podroteja v letu 2000.
Graph 15: Mean monthly water temperature (T), water level (h) and specific conductivity (EP) on the Podroteja spring in the year 2000.

D. MORJE

PLIMOVANJE MORJA

Mojca Robič

Med najizrazitejšimi naravnimi pojavi na morju je plimovanje. Sestavljajo ga astronomsko plimovanje, ki ga spreminja lastno nihanje morja ter meteorološki in nekateri drugi dejavniki.

Astronomska plima je spreminjanje gladine morja pod vplivom gravitacijske privlačnosti med Zemljo, Luno in Soncem. Najmočnejše je v času mlaja in ščipa, ko sta Sonce in Luna v konjunkciji oz. opoziciji (Sonce, Luna in Zemlja so v isti črti) in se plimotvorne sile seštevajo. Ob prvem in zadnjem krajcu, to je v obdobju kvadrature (položaj, ko Sonce, Luna in Zemlja tvorijo pravokotni trikotnik), se vplivi odštevajo in ima plimovanje manjše amplitude. Spremembe višine morja, ki so posledica astronomskih dejavnikov, je zaradi znanih gibanj nebesnih teles, ki se ciklično ponavljajo vsakih 19,5 let, možno napovedati vnaprej. Plimovanje v Jadranskem morju, kjer se v enem dnevu navadno izmenjata dve plimi in dve oseki, je posledica plimovanja v Egejskem morju.

Na višino plimovanja vplivajo tudi **meteorološki dejavniki**. Najpomembnejša sta zračni pritisk in veter. Padec zračnega pritiska za 1 (en) milibar (mb) povzroči zvišanje vodne gladine za 1 do 1,5 cm, pri čemer vpliv vetra ni izključen. Najpogosteje veter z juga, jugovzhoda ali jugozahoda nariva vodne mase proti slovenski obali in s tem zvišuje gladino. Obratno burja znižuje gladino morja, saj piha s kopnega in odriva vodo proti odprtemu morju. Na zvišanje morske gladine lahko vplivajo tudi močnejši južni vetrovi v južnem Jadranu.

Na višino gladine lahko vpliva tudi **lastno nihanje** Jadranskega morja. Lastno nihanje se pojavi v zaprtih ali delno zaprtih bazenih in traja še po prenehanju delovanja sil, ki ga povzročijo. V primeru juga znaša perioda tega nihanja približno 21 ur, v primeru jugozahodnika pa le nekaj ur. V Slovenskem morju obstaja poleg lastnega nihanja Jadranskega morja tudi lastno nihanje Tržaškega, Koprskega in Piranskega zaliva. Zaradi razčlenjene obale in neenakomerne globine je računanje in ocenjevanje lastnega nihanja oteženo.

Vsi ti vplivi se med seboj prepletajo, součinkujejo ter posledično zvišujejo ali znižujejo gladino morske vode.

D. SEA

SEA LEVELS

Mojca Robič

One of the most distinctive natural phenomena at sea is tide. It consists of astronomic tide, accompanied with the fluctuation of the sea itself and also with meteorological and some other factors.

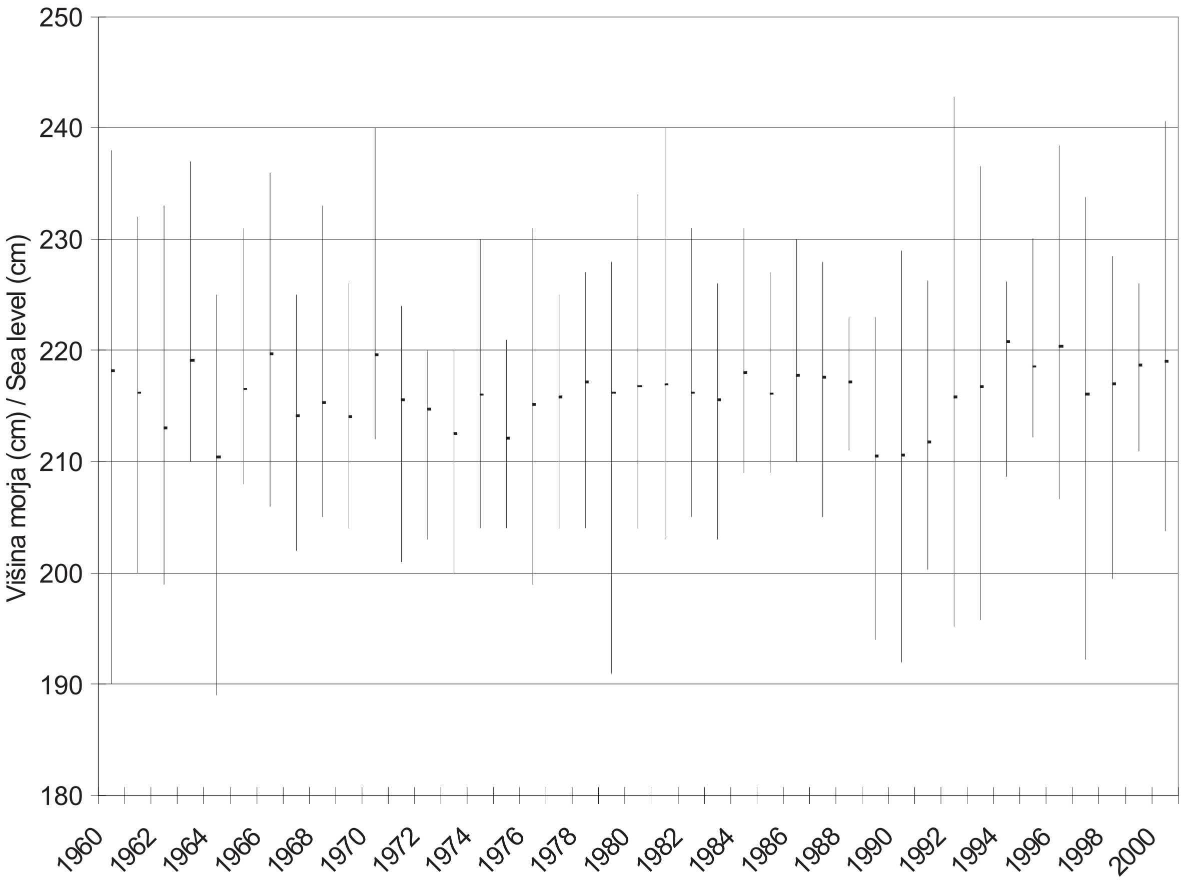
Astronomic tide is a phenomenon where the sea level changes due to the force of gravity between the Earth, the Moon and the Sun. It is the strongest at the time of the new and full moon, when the Sun and the Moon are in conjunction or opposition (the Sun, the Moon and the Earth are in the same line) and the forces causing the tide add up. At the time of the first and last quarter of the moon, i.e. at the time of quadrature (the Sun, the Moon and the Earth form a right-angled triangle), the forces subtract and the amplitudes of tide are smaller. Changes of the sea level, which are caused by the astronomic factors, can be predicted in advance, due to the known motions of celestial bodies, which are repeated in cycles every 19.5 years. Dal dynamics in the Adriatic Sea, where 2 high tides and 2 low tides usually occur in one day, a consequence of the tide in the Aegean sea.

Meteorological factors influence the height of tide as well. The two most important factors are the barometric pressure and wind. If barometric pressure drops by 1 millibar (mb), the water level rises by 1 to 1.5 cm, not excluding the influence of the wind. The wind from the south, southeast or southwest most often pushes the water masses towards the Slovenian coast and thus the water level increases. On the other hand, the north wind causes the sea level to decrease, because it blows from the land and pushes the water towards the open sea. The increase of the sea level in northern Adriatic can also be caused by the strong south winds in southern Adriatic.

The level of the sea can also be influenced by the self induced **fluctuation** of the Adriatic. Self induced fluctuation occurs in closed or partly closed seas and continues after the forces that have caused it, stopped. In case of the south wind, the period of such fluctuation is about 21 hours, and in case of the southwest wind only a few hours. In addition to the fluctuation of the Adriatic Sea,

Na Slovenski obali ima Agencija Republike Slovenije za okolje dve obalni mareografski postaji. Ena deluje v Luki Koper od leta 1991, druga pri Luški Kapitaniji v Kopru od leta 1958. Podatki, objavljeni v hidrološkem letopisu, se nanašajo na gladino morja pri Luški Kapitaniji. Višinska razlika med obema postajama je 6 cm.
Srednja letna višina morja v letu 2000 je bila 218,4 cm, kar je 2 cm nad srednjo obdobno vrednostjo. V primerjavi z višinami v obdobju od leta 1961 do 2000 je to nekoliko nadpovprečna vrednost, ne pa ekstremna. Za zadnje desetletje so značilne nekoliko višje srednje gladine morja kot za pretekla desetletja (graf 16).
V januarju 2000 je bilo morje nekoliko nižje (glej SMV v preglednici D.3). Vse značilne mesečne vrednosti so bile podpovprečne v primerjavi z obdobnimi vrednostmi. Tako nizko gladino je pogojevalo skoraj ves mesec trajajoče stabilno anticiklo-

the Slovenian sea has its own fluctuation of the gulfs of Trieste, Koper and Piran. The estimation of fluctuation of the Slovenian sea itself is difficult, due to the nature of coast line and variations in depth of the sea.
All this influences interact, co-effect and consequently increase or decrease the water level of the sea.
Environmental Agency of the Republic of Slovenia (ARSO) has two mareographic stations at the Slovenian coast. One has been operating in Luka Koper (Koper bay) since 1991, and the other at Luška Kapitanija (Harbour Administration) since 1958. The data published in the Hydrological Yearbook refer to the sea level at Luška Kapitanija. The gauge zero points of the two mareographs are not equal, having a 6 cm difference in height.
Mean annual sea level in the year 2000 was 218.4



Graf 16: Letna povprečja srednjih mesečnih višin morja (SLV) ter največja (Max SMV) in najmanjša (Min SMV) srednja mesečna višina morja na mareografski postaji pri Luški Kapitaniji v obdobju od leta 1960 do 2000 (v cm od izbrane mareografske ničle). Podatki za leto 2000 so v preglednici D.3 (SLV = 218,4 cm; Max SMV = 240.1 cm v novembru; Min SMV = 203,9 cm v januarju).
Graph 16: Annual average values of mean monthly sea levels (SLV) and the maximum (Max SMV) and minimum (Min SMV) mean monthly sea levels at the mareographic station at Luška Kapitanija in the period from 1960 to 2000 (in cm, measured from the selected mareographic gauge zero). Data for the year 2000 are given in Table D.3 (SLV = 218.4 cm; Max SMV = 240.1 cm in November; Min SMV = 203.9 cm in January).

nalno vreme brez večjih padcev zračnega pritiska. Tudi v februarju višine morja niso izstopale, le razlika med najvišjo in najnižjo mesečno gladino je bila večja (preglednica D.2). Petega februarja smo zabeležili najnižjo letno gladino morja, 125 cm (preglednica D.4).

Morje v marcu pa je bilo nadpovprečno visoko za ta letni čas, dosežene višine pa niso bile izjemne. Največje povišanje je ob koncu meseca povzročila značilna meteorološka situacija. Največja **residualna višina**, to je razlika med napovedano – astronomsko in izmerjeno višino morja, je bila izmerjena 29. marca dopoldan. Vzrok je bil nekaj dni trajajoče zniževanje zračnega pritiska in okrepljen veter iz južnega kvadranta. Dosežena višina morja ni bila visoka, saj se obdobje ni ujelo z obdobjem največjih astronomskih plim. Najvišja mesečna gladina morja je bila zabeležena 7. marca, izključno zaradi visokega astronomskega plimovanja.

Morje je bilo v aprilu nadpovprečno visoko. 3. aprila je prvič v letu 2000 doseglo pogojno višino

cm, i.e. 2 cm above the multiannual mean value. Compared to the levels in the period 1961–2000, this value is slightly above the average value, but it is not extreme. Somewhat higher mean sea levels have been characteristic for the last decade, with respect to the past decades (Graph 16).

In January of the year 2000 the sea level was somewhat lower (see SMV in Table D.3). In comparison with the periodical values, all characteristic monthly values were below average. Low level was caused by stable weather practically through the entire month, characterized by anticyclone, without any major barometric pressure drops.

In February the sea levels were close to the mean, but the difference between maximum and minimum monthly level was greater than usual (Table D.2). The lowest annual sea level (125 cm) was recorded on the 5th of February (Table D.4).

The sea in March was high, above average for this season, but the reached levels were not exceptional. The greatest increase at the end of the month was caused by a typical meteorolog-

Visoka plima v Kopru 11. julija leta 2000. (foto: Igor Strojan)
Extreme high tide on the 11th of July 2000 in Koper. (photo: Igor Strojan)

300 cm, ko se v hidrološki dežurni službi začne izredno spremljanje gibanja morske gladine. Ob tej višini morje poplavi nižje ležeče dele obale. To se je v aprilu ponovilo še enkrat, dva dni kasneje. Visoke vrednosti so bile posledica vremenskih vplivov. Ves mesec je prevladovalo slabo vreme z nizkim zračnim pritiskom, en sam dan v aprilu je pritisk presegel srednjo obdobno vrednost 1016 mb. Najvišja višina morja v aprilu, 310 cm, je visoka, vendar ne izjemna in ne najvišja v letu. Izjemno visoka pa je bila za pomladni mesec vrednost srednje mesečne višine in povprečnih visokih voda. V pomladnih mesecih povišane gladine morja zaradi vremenskih vplivov in lastnega nihanja niso tako običajne.

Maj je bil povprečen mesec. Značilne vrednosti niso dosti odstopale od povprečja. Tudi meteorološke značilnosti niso izstopale, z izjemo dvodnevne močne ohladitve, ki jo je prinesla hladna fronta 19. in 20. maja. Ob morju je povzročila močno burjo, ki je znižala gladino morja, v notranjosti Slovenije pa je sneg pobelil vrhove.

Ustaljene vremenske razmere so se nadaljevale v juniju. Višine morja so bile povprečne, le najvišja

ical situation. The greatest **residual height**, i.e. the difference between the predicted – astronomical and the measured sea level, was observed on the 29th of March in the morning. The reason for that was a barometric pressure drop, lasting for a few days, and stronger wind from the direction of southern quadrant. The reached sea level was not high, as the period did not coincide with the period of greatest astronomic tides. The highest monthly sea level was recorded on 7th March, the only reason for that being the high astronomic tide.

The height of the sea level in April was above average. On the 3rd of April, the sea reached, for the first time in the year 2000, the flooding threshold height 300 cm and at that point the hydrological service on duty begins with emergency monitoring of the sea level movement. At this level, the sea floods over the low parts of the coast. The next flood was only two days later. High values were caused by weather influences. Bad weather with low barometric pressure prevailed throughout the month. It was only one day in April that the barometric pressure exceeded the mean value of the period, i.e.

Na morju je po prehodu hladne fronte 19. in 20. maja 2000 zapihala močna burja. (foto: Janez Polajnar)
Strong north-east wind connected with a cold front on the 19th and 20th of May 2000. (photo: Janez Polajnar)

mesečna višina je bila podpovprečna. Napovedane višine so le malo odstopale od izmerjenih.
V juliju je presenetila nenavadno visoka gladina morja, ki je 11. julija dosegla 290 cm. Ob taki višini in ob pomoči valov morje že poplavlja nekatere pomole.
Gladina morja je bila visoka zaradi znižanega zračnega pritiska, predvsem v prvi polovici meseca, in močnejšega južnega vetra ob naši obali. Na povišanje gladine je imelo zapoznel vpliv tudi močno valovanje, ki ga je povzročil jugo na odprtem morju srednjega Jadrana.
Poletje je sicer za pojav visoke vode najmanj pogost letni čas, saj je bilo v zadnjih desetih letih le šest odstotkov pojavov visokih plim v poletnem obdobju.
Avgust je bil spet zelo povprečen mesec. Občutno povišanje gladine je bilo le zadnji dan v mesecu.
Močneje povišane gladine morja se najpogosteje pojavljajo v jesenskih mesecih. Takih primerov je bilo v zadnjih desetih letih več kot polovica.
Jesensko obdobje povišanih voda se je v letu 2000 začelo v drugi polovici septembra. Septembra so bila tri krajša obdobja intenzivnega vpliva meteoroloških dejavnikov na morsko gladino. Prvo je bilo v prvih nekaj dneh, vendar ni sovpadalo z visokim astronomskim plimovanjem, zato ni prišlo do ekstremno visokih plim. Drugo je bilo obdobje od 20. do 22. septembra z izrazitim padcem zračnega pritiska in močnim vetrom. Tudi v tem primeru ni prišlo do sovpadanja vremenskih vplivov z visokimi astronomskimi višinami morja, zato kljub velikim residualnim višinam pogojna vrednost ni bila prekoračena. Po ustaljenem vremenu v zadnji tretjini meseca se je v zadnjih dneh zračni pritisk začel zniževati, pihati je začel južni veter. Krepil se je in največjo hitrost dosegel zadnji dan v mesecu. Takrat je bila izmerjena največja residualna višina (65 cm), ki je nastopila ob drugi nizki vodi. Ob plimi je bila residualna višina nižja (okrog 30 cm), a še vedno dovolj visoka, da je dvignila gladino morja na najvišji nivo v mesecu (296 cm).
Podobno vreme se je nadaljevalo tudi v prvi polovici oktobra. Predvsem v času od 10. do 13. oktobra je morje večkrat poplavilo nižje ležeče dele obale. Močan veter in deževje sta še okrepila vtis poplav. Najvišja višina meseca je bila izmerjena ob dopoldanski plimi 13. oktobra. Residualne višine so se gibale od 30 do 60 cm. V drugi polovici meseca je bilo vreme stanovitnejše in višine gladin morja bolj podobne napoveda-

1016 mb. Maximum sea level in April, 310 cm, is high, but it is not exceptional, and not the highest in the year. The values of mean monthly level and of average high water levels were exceptionally high for a spring month. Increased sea levels, due to weather influence and fluctuation of the sea itself, are not very common in the spring months.
May was a rather average month. Characteristic values did not deviate much from the average values. Meteorological features were not exceptional either, except for a strong two-day cooling due to the cold front on the 19th and 20th of May. The cold front caused strong north-east wind, which lowered the sea level, as well as snow at high altitudes in the interior of the country.
Stable weather conditions persisted in June. The sea levels were average, except for the maximum monthly level, which was below average. The predicted levels were only slightly different than the measured ones.
A surprisingly high sea level was observed in July, reaching 290 cm on the 11th of July. At that level, if there are waves, the sea can already flood over some piers.
The sea level was high, especially in the first part of the month, due to the decreased barometric pressure and strong southern wind along the Slovenian coast. Strong waves, caused by the south wind in the open sea of the central Adriatic, also had a delayed influence on the sea level increase.
Summer is the least common season for the occurrence of high waters. In the last ten years, only 6 % of the high high tides occurred in the summer.
The August situation was normal. A considerable sea level rise was observed only on the last day of the month.
Greater rise of the sea levels occurs mostly in autumn. In the last ten years more than a half such cases were observed.
In the autumn of 2000 the period of increased water levels began in the second half of September. There were three shorter periods of intensive influence of meteorological factors on the sea level in September. The first meteorological situation was in the first few days of the month, but it did not coincide with the high astronomic high tide, therefore the high tides were not extremely high. The second was the period from the 20th to 22nd of September with a substantial drop of barometric pressure and a strong wind. Here, as well, the weather conditions did not coincide with the high astronomic sea level, therefore the conditional value was not exceeded in spite of the high residual val-

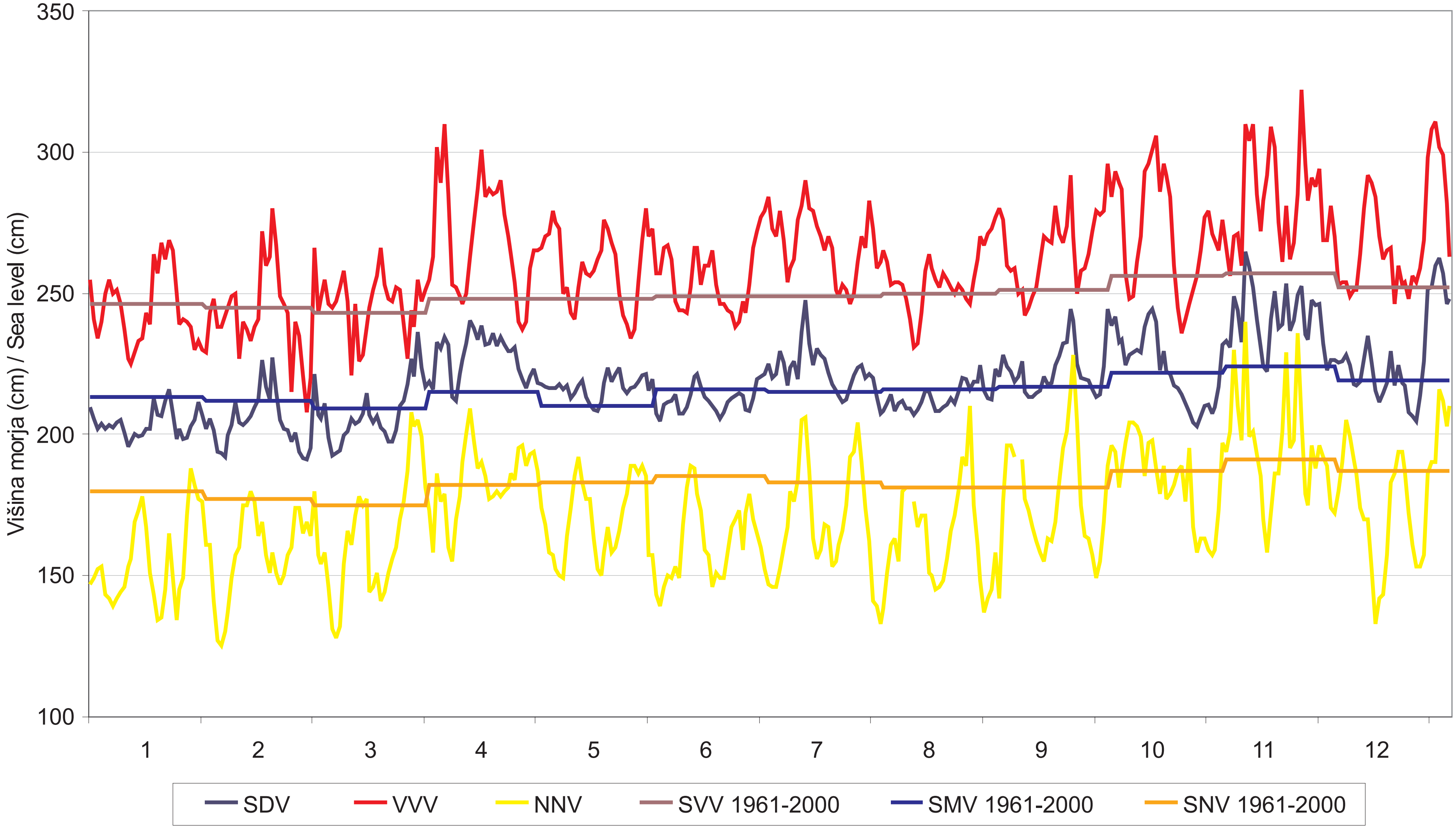
nim vrednostim. Zaradi povišanih gladin v prvi polovici meseca so bile nadpovprečne tudi srednja mesečna višina ter srednja visoka in srednja nizka voda.
Srednja mesečna višina morja v novembru je bila izjemno visoka. Ta višina je za nekaj centimetrov višja od najvišje srednje novembrske gladine morja iz obdobja 1961–2000. Najvišja mesečna in hkrati letna višina morja, 322 cm, je bila izmerjena 21. novembra zjutraj, kar je sicer povprečna najvišja višina v obdobju. Morje je bilo cel mesec višje od pričakovanega. Odstopanja so bila največja med 5. in 10. novembrom. V tem času je bil zračni pritisk izjemno nizek, najnižja vrednost 990 mb, je bila zabeležena 7. novembra zjutraj. Do takrat je prevladoval močan južni veter, v naslednjih dneh pa se je smer spreminjala. Zaradi močnega juga tudi v osrednjem Jadranu je prišlo do pojava lastnega nihanja Jadranskega morja, ki je v naslednjih dneh vplivalo na povišanje morja ob naši obali. V noči s 7. na 8. november so se vsi ti dejavniki sešteli in povišali gladino morja kar za 122 cm (kar je najvišja residualna višina v tem letu), na 310 cm. Čeprav so bile astronomske višine nizke, je morje vseeno preplavilo obalo. Ta je bila poplavljena v naslednjih dneh še nekajkrat. Visoki zračni pritisk je prevladal po burnih vremenskih dogajanjih šele v zadnjih dveh dneh novembra.
Vremenska situacija iz zadnjih dni novembra se je nadaljevala še v prvi polovici decembra. Morje je bilo povprečno visoko. V drugi polovici decembra pa je spet prišlo do hitrega znižanja zračnega pritiska in s tem povišanja gladine morja glede na predvideno. Od 25. do 30. decembra je bilo morje zelo visoko in je kar sedemkrat preseglo pogojno vrednost. Najvišjo gladino v mesecu, 311 cm, je morje doseglo 27. decembra ob 22:10. Srednja mesečna višina morja v decembru je bila zaradi dogajanj v drugi polovici meseca nekoliko nadpovprečna.
Leta 2000 so bile gladine morja nadpovprečno visoke, kar velja tako za srednjo letno kot tudi za srednjo visoko in srednjo nizko vodo. Nekoliko nadpovprečno visoka je bila, glede na obdobje 1961–2000, tudi najnižja voda v letu, najvišja letna pa je bila povprečna.
Med srednjimi mesečnimi vrednostmi sta navzgor izstopali vrednosti v aprilu in predvsem novembru, ki sta bili najvišji v obdobju. Nižje od srednje obdobne vrednosti so bile le srednje mesečne vrednosti

ues. The weather was stable in the last third of the month, but in the last few days the barometric pressure began to drop and the south wind started to blow. It was getting stronger, reaching the maximum velocity on the last day of the month. The greatest residual height was measured then (65 cm), occurring at the second low water level. At the time of the high tide the residual height was lower (about 30 cm), but still high enough to raise the sea level to the maximum level of the month (296 cm).
Similar weather continued in the first half of October. The sea flooded over the low parts of the coast, especially between the 10th and 13th of October. Strong wind and rain intensified the floods. The highest monthly level was recorded at the morning high tide on October 13th. Residual heights ranged between 30 and 60 cm. In the second half of the month the weather was more stable and the sea levels were closer to the predicted values. Due to the increased sea levels in the first half of the month, the mean monthly level, mean high and mean low waters exceeded the average values as well.
Mean monthly sea level in November was extremely high. It was a few centimetres higher than the highest mean November sea level from the period 1961–2000. The highest monthly and also annual sea level, 322 cm, was measured in the morning of the 21st of November. This is also the mean highest sea level of the period. The sea was higher than expected throughout the month. Deviations were the greatest between the 5th and 10th of November. Barometric pressure was extremely low at the time, the lowest value (990 mb) being recorded in the morning of the 7th of November. Until then, a strong south wind prevailed, but it was changing its course in the following days. Due to the strong south wind blowing also in the central Adriatic, the fluctuation of the Adriatic sea itself occurred, which in the following days influenced the rise of the sea level along the Slovenian coast. During the night between the 7th and 8th of November all these factors added up and thus the sea level increased by 122 cm (which is the highest residual level of the year 2000), and reached 310 cm. Despite the fact that the astronomic heights were low, the sea flooded over the coast. The floods repeated a few times in the following days. After the unstable weather the high barometric pressure prevailed only in the last two days of November.
The weather situation from the last days of No-

sečne višine za januar, februar, marec, junij in avgust. Ostali meseci so bili med srednjo in najvišjo obdobno vrednostjo.
Morje je v letu 2000 v 22. primerih poplavilo nižje ležeče obalne predele, trikrat v aprilu, enkrat v septembru in po devetkrat v oktobru in novembru.
Najvišja gladina morja je bila v letu 2000 zabeležena 21. novembra ob 5:26 in sicer 322 cm, najnižja pa 5. februarja ob 15:15, 125 cm. Letna amplituda je torej znašala 197 cm. Razlike med najvišjimi in najnižjimi vrednostmi v mesecu so se gibale od 131 cm v maju do 178 cm v decembru.

Mareografska postaja v Kopru pri Luški Kapitaniji. (foto: Peter Frantar)
Tide gauging in Koper at Harbour Administration. (photo: Peter Frantar)

vember persisted in the first half of December. The sea level was average. In the second half of December the barometric pressure dropped quickly and thus the sea level rose (higher than the predicted level). In the period between the 25^{th} and 30^{th} of December the sea was very high, exceeding the conditional value by seven times. The highest level of the month, 311 cm, was reached on the 27^{th} of December at 22:10. Mean monthly sea level in December was somewhat above average, due to the events in the second part of the month.
The year 2000 was characterized by the above-average sea levels: mean annual as well as mean high and mean low water levels. Somewhat above the average value was also the lowest annual water level, compared to the period 1961–2000, while the highest annual water level was average.
Regarding the mean monthly values, the values of April and November reached the maximum value ever of the period observed. Lower than the mean monthly heights of the period were only the mean monthly levels for January, February, March, June and August. The rest of the months ranged between the mean and the highest values of the period.
In the year 2000 the low coastal parts were 22 times flooded by the sea, three times in April, once in September and nine times in October and in November.
Maximum sea level in the year 2000, 322 cm, was recorded on the 21^{st} of November at 5:26, and the lowest, 125 cm, on the 5^{th} of February at 15:15. Annual amplitude was therefore 197 cm. The range between the highest and lowest monthly levels was between 131 cm in May and 178 cm in December.



Graf 17: Povprečne dnevne višine morja, povprečne dnevne plime in oseke v letu 2000 in pripadajoče povprečne mesečne vrednosti iz obdobja 1961-2000.
Graph 17: Mean, high and low waters in 2000 and mean monthly values from 1961-2000 period.