6.3.2. Results of the Hubelj - Mrzlek- Podroteja Area

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6.3.2.1. First Tracing Experiment in October 1993

Uranine injected in the ice cave Belo Brezno was detected in the springs Hubelj, Lijak and Mrzlek after the heavy rain events from October 21 till October 25, 1993 (compare Chapter 6.2.1). The uranine breakthrough curves for the three karst springs are given in Fig. 6.6, 6.7 and 6.8. Tab. 6.8 presents an overview of the relevant curve parameters.

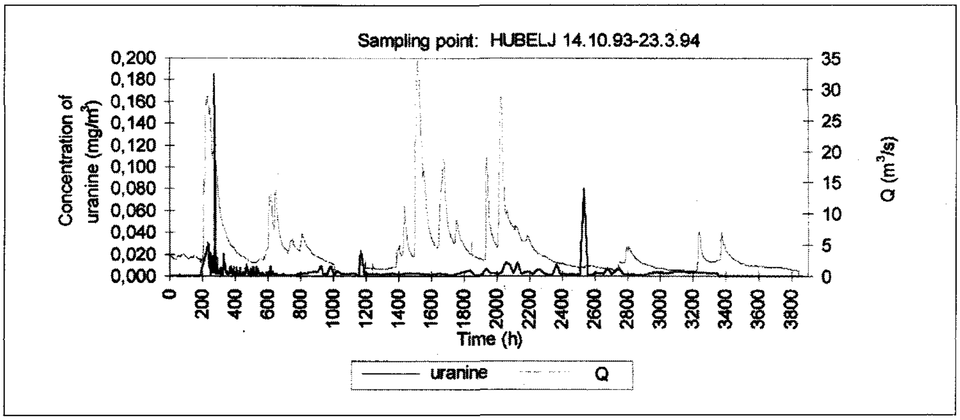

Fig. 6.6: Results of the first tracing experiment, Oct 1993: Breakthrough of uranine in the Hubelj spring and the discharge of the Hubelj during the observation period of 3900 hours.

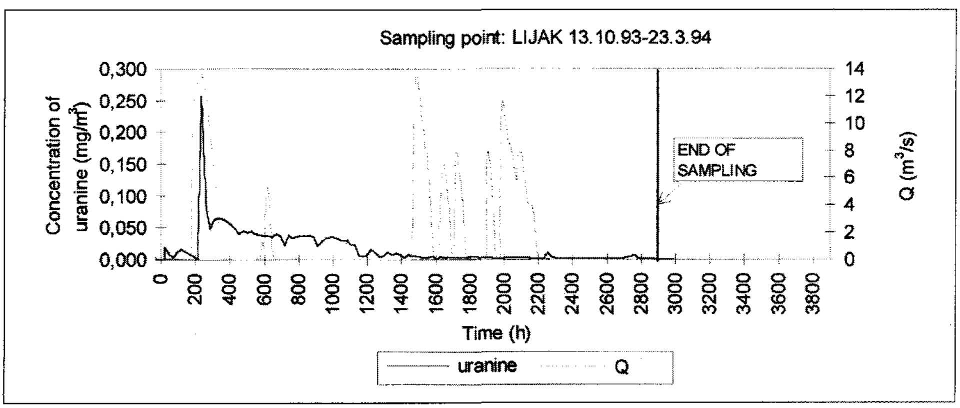

Fig. 6.7: Results of the first tracing experiment, Oct 1993: Breakthrough of uranine in the Lijak spring and the discharge of the Lijak measured at the Lijak -Šmihel gauging station during the observation period of 3900 hours.

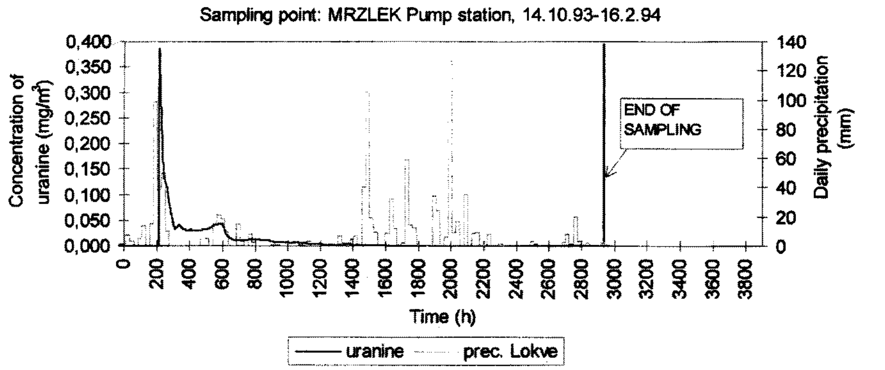

Fig. 6.8: Results of the first tracing experiment, Oct 1993: Breakthrough curve of uranine in the Mrzlek spring (sampling in the pumping station) during the observation period of 3900 hours. Hence the spring is situated in the Soča river no discharge measurements are available. To describe the hydrologic situation the daily precipitation heights of the station Lokve is depicted.

Tab. 6.8: Overview of relevant parameters derived from the uranine breakthrough curves in the springs Hubelj, Mrzlek and Lijak in the first tracer test, Oct 14, 1993: time(t_{max}), concentration (C) and velocity (v_{max}) of the first appearance, time of maximal concentration (t_{max}), maximal concentration (C_{max}) and dominant velocity (v_{dom}) in the springs and the recovery (R).

Spring	C [mg/m³)	t_{max} [h]	v_{max} [m/h]	C_{max} [mg/m³]	t_{dom} [h]	v_{dom} [m/h]	R [kg]	R [%]
Hubelj	0.0300	196	35.1	0.1850	234	29.4	0.107	2.14
Mrzlek pumping station	0.3850	216	92.4	0.3850	216	92.4	2.0 (1.45)*	40 (29)*
Lijak	0.0009	214	63.0	0.2570	238	56.6	0.507	10.10
Hotešk	0.0027	309	67.9	0.0027	309	67.9	*1)	

2.00 = recovery rate for the Mrzlek estimated on the basis of Q_{mean} for 1961 to 1990
(1.45)* = recovery rate for the Mrzlek estimated on the basis of Q_{mean} for 1993 to 1995
*1) = only a singular peak, no recovery estimation

Hence the spring Lijak is only temporarily active (compare Chapter 2.6.2) in the framework of former investigations a borehole was drilled nearby to enable a regular monitoring of the karst groundwater. The regular sampling during the tracing experiment for the sampling point Lijak was not in the spring itself but in this nearby borehole. Only for the long-term investigation direct samples of spring were analysed. The comparison of the results is striking, but so far explainable. The concentrations in the spring samples were definitely higher than in the borehole samples at the approximately the same time (Tab. 6.9).

Tab. 6.9: Comparison of the uranine concentrations in the Lijak spring and Lijak borehole

	Uranine - mg/m^3	
Date / hour	Lijak borehole	Lijak spring
28.10.93 / 11:30	0.065	
28.10.93 / 10:00		0.112
23.12.93 / 10:45	udl	
23.12.93 / 13:00		0.088
19.01.94 / 11:30	udl	
19.01.94/ 13:00		0.054
udl = under detection limit		

Uranine was not detected in the samples taken from the smaller karst springs Skuk and Gorenje in the vicinity of the Hubelj spring. In the spring Hotešk only one singular uranine peak with a very low concentration (0.0027 mg/m^3) was detected in the sample taken on October 27, 1993. This peak should not be overemphasised; it might represent a background value which ranges up to 0.006 mg/m^3 (compare Chapter 6.3.4)

6.3.2.2. The Second Tracing Experiment in April 1994

Uranine

The repeated injection of uranine in the injection point Belo Brezno in spring 1994 resulted in uranine breakthrough in the springs Hubelj and Mrzlek, but astonishingly not in the spring Lijak (Fig. 6.9 and 6.10). Compared to the first tracing experiment a distinct delay of the breakthrough of the maximal uranine concentration occurred (Tab. 6.10). On the other hand uranine appeared earlier for the first time than in the first tracing experiment.

It has to be taken into account that the appearance of uranine in two samples taken on April, 19, 1993, and April, 20, 1993, could possible originate from the first tracing experiment. In comparison with the first tracing experiment the maximal concentrations were much lower in the Hubelj, but higher in the Mrzlek (Tab. 6.10).

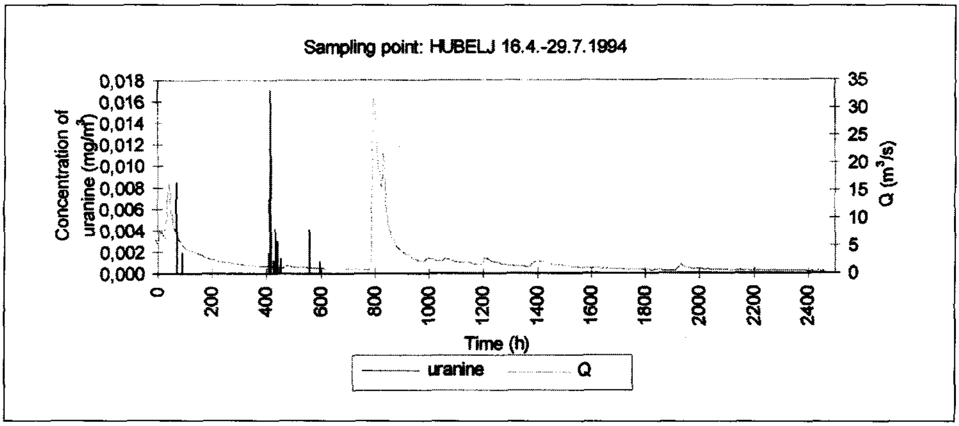

Fig. 6.9: Results of the second tracing experiment, April 1994: Breakthrough of uranine in the Hubelj spring and the discharge of the Hubelj during the observation period of 2500 hours.

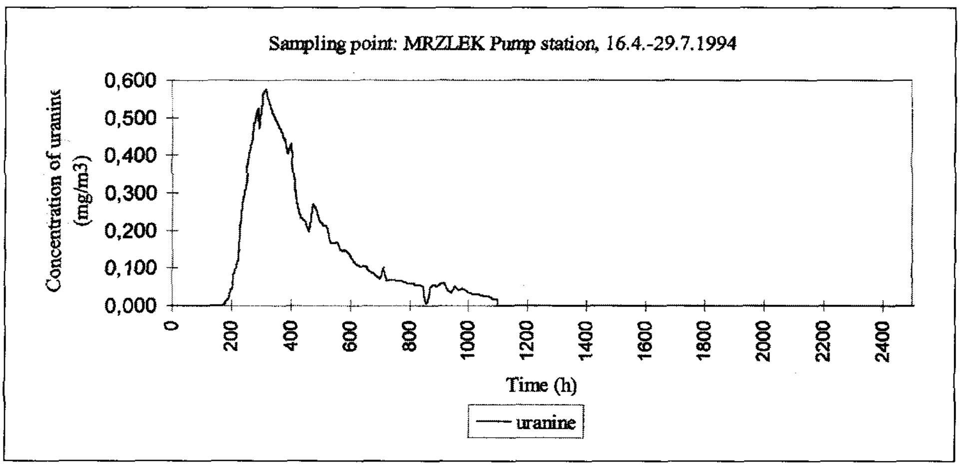

Fig. 6.10: Results of the second tracing experiment, April 1994: Breakthrough curve of uranine in the Mrzlek spring (samples from the pumping station) during the observation period of 2500 hours.

Tab. 6.10: Overview of relevant parameters derived from the uranine breakthrough curves in the springs Hubelj and Mrzlek in the second tracer test, April 16, 1994: time(t_{max}), concentration (C) and velocity (v_{max}) of the first appearance, time of maximal concentration (t_{max}), maximal concentration (C_{max}) and dominant velocity (v_{dom}) in the springs and the recovery (R).

Spring	C [mg/m³)	t_{max} [h]	v_{max} [m/h]	C_{max} [mg/m³]	t_{dom} [h]	v_{dom} [m/h]	R [kg]	R [%]
Hubelj	0.0085	70	98.2	0.017	414	16.6	0.001	0.02
Mrzlek pumping station	0.0009	168	119	0.579	318	62.8	2.98 (2.15)*	59.6 (43)*

2.98 = recovery rate for the Mrzlek estimated on the basis of Q_{mean} for 1961 to 1990
(2.15)* = recovery rate for the Mrzlek estimated on the basis of Q_{mean} for 1993 to 1995

Pyranine

Pyranine, injected in the doline Mrzli Log, was detected in the samples of the karst spring Podroteja and Divje Jezero (Fig. 6.1). While in the spring Podroteja an almost classical pyranine breakthrough curve was observed, only one single pyranine peak occurred, with a much lower concentration in the Divje Jezero (Fig. 6.11). An overview on the determined values gives Tab. 6.11.

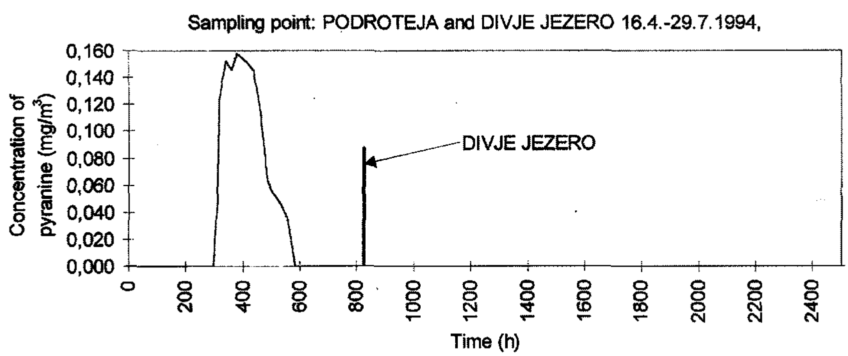

Fig. 6.11: Results of the second tracing experiment, April 1994: Analysed pyranine concentrations in the karst springs Podroteja and Divje Jezero during the observation period of 2500 hours.

Tab. 6.11: Overview of relevant parameters derived from the pyranine breakthrough in the springs Podroteja and Divje Jezero in the second tracer test, April 16, 1994: time(t_{max}), concentration (C) and velocity (v_{max}) of the first appearance, time of maximal concentration (t_{max}), maximal concentration (C_{max}) and dominant velocity (v_{dom}) in the springs and the recovery (R).

Spring	C [mg/m³)	t_{max} [h]	v_{max} [m/h]	C_{max} [mg/m³]	t_{dom} [h]	v_{dom} [m/h]	R [kg]	R [%]
Podroteja	*0.0507*	*309*	*24.7*	*0.1579*	*380*	*20.1*		
Divje jezero	0.0870	822	9.2	0.0870	822	9.2		

6.3.2.3. Third Tracing Experiment in August 1995

Uranine

This tracing experiment was realised at low water conditions (compare Chapter 6.2.3) and the results are quite different from the previous ones. In the Hubelj the first appearance and the maximal concentration of uranine were reached earlier compared to first two tracing experiments. While in the first period of the observation time a continuously breakthrough occurred, later only single samples were uranine positive. At all the uranine concentrations

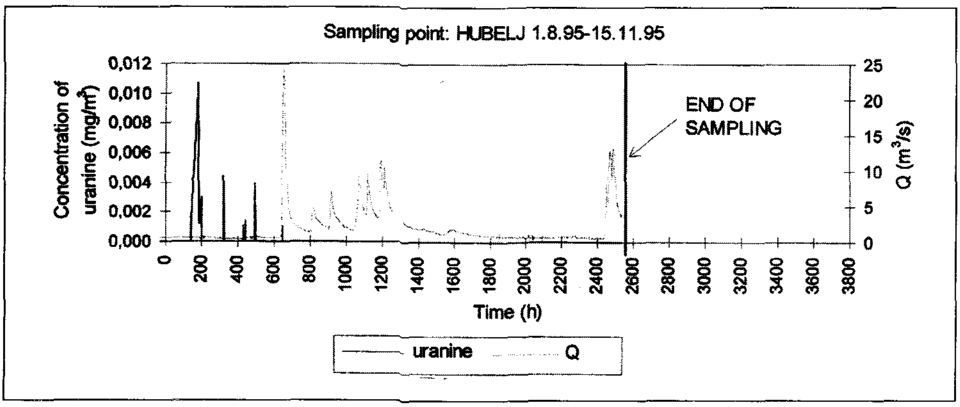

Fig. 6.12: Results of the third tracing experiment, August 1995: Analysed uranine concentrations and the discharge in the karst spring Hubelj during the observation period.

were low (Fig. 6.12). Contrary to the Hubelj the first appearance and the maximal uranine concentration in the Mrzlek pump station was reached much later (Tab. 6.12). While for the first and the second experiment only water samples from the Mrzlek pumping station were available, both, the pumping station and the spring in the Soča river were sampled for the third experiment. The comparison of the result proved the assumption that the karstic flow was practically the same in both sampling points (Fig. 6.13 and 6.14).

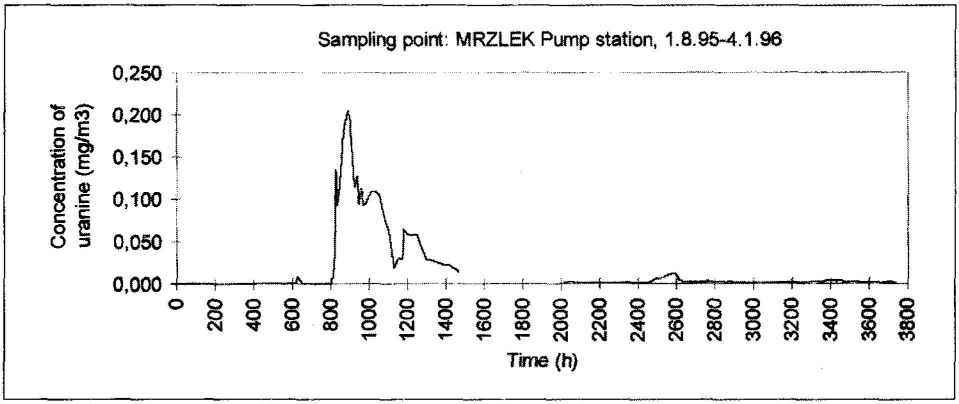

Fig. 6.13: Results of the third tracing experiment, August 1995: Uranine break-through curve in the Mrzlek pumping station.

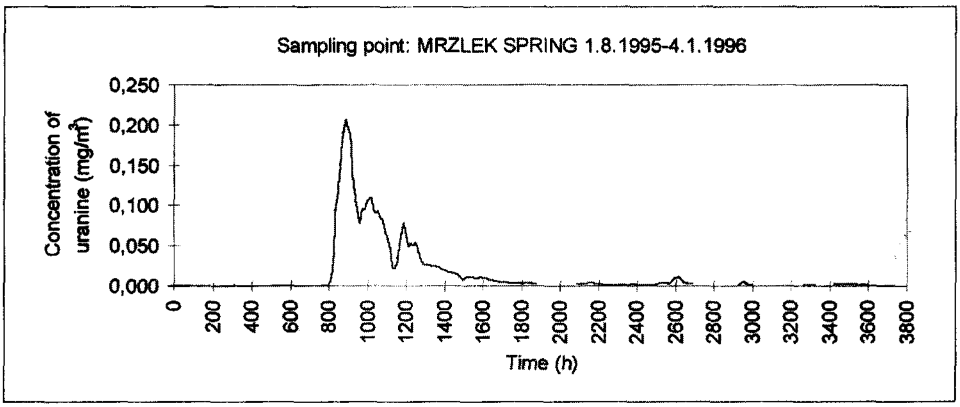

Fig. 6.14: Results of the third tracing experiment, August 1995: Uranine break-through curve in the Mrzlek spring itself in the Soča river.

Tab. 6.12: Overview of relevant parameters derived from the uranine breakthrough in the springs Hubelj and Mrzlek (for both the pumping station and the spring in the Soča river) in the third tracer test, August 1, 1995: time(t_{max}), concentration (C) and velocity (v_{max}) of the first appearance, time of maximal concentration (t_{max}), maximal concentration (C_{max}) and dominant velocity (v_{dom}) in the springs and the recovery (R).

Spring	C [mg/m³]	t_{max} [h]	v_{max} [m/h]	C_{max} [mg/m³]	t_{dom} [h]	v_{dom} [m/h]	R [kg]	R [%]
Hubelj	0.0019	144	47.7	0.0107	180	38.2	0.0008	0.01
Mrzlek pumping station	0.0028	804	24.6	0.2042	888	22.3	4.6 (3.2)*	66 (45.7)*
Mrzlek Spring	0.0010	798	24.8	0.2057	887	22.3	5.05 (3.6)*	72 (51.4)*

4.6 = recovery rate for the Mrzlek estimated on the basis of Q_{mean} for 1961 to 1990
(3.2)* = recovery rate for the Mrzlek estimated on the basis of Q_{mean} for 1993 to 1995

The Lijak spring was only active for a short period of time. Only two water samples taken on August 28, 1995, and September, 19, 1995 were analysed. The latter had an uranine concentration of 0.023 mg/m³. Unfortunately no sampling in the borehole was possible due to technical reasons.

Pyranine

Pyranine injected in the doline Malo Polje was detected in the karst springs Podroteja and Divje Jezero (Fig. 6.1). Unfortunately, the pyranine breakthrough took place just in the time period when samples got lost for those two sampling points. Therefore only 5 samples for a time period of in 9 days are available. Despite the missing samples the concentration curves look like a periodical content of the tracer (Fig. 6.15, Fig. 6.16)

Compared to the second experiment by high water conditions the time of first appearance and of maximal concentration in Podroteja was longer as expected by prevailing low water conditions. A direct comparison to the single peak characterising the pyranine breakthrough in spring 1994 is not possible. (Tab. 6.13)

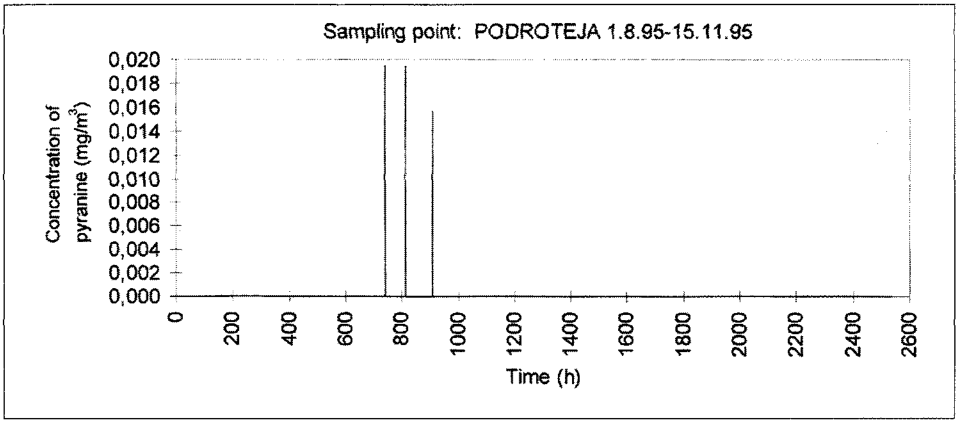

Fig. 6.15: Results of the third tracing experiment, August 1995: pyranine positive water samples in the karst spring Podroteja during the observation period.

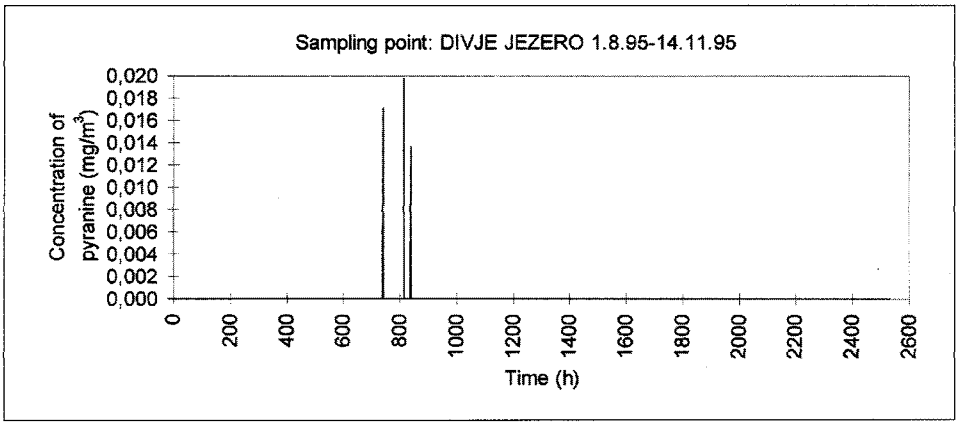

Fig. 6.16: Results of the third tracing experiment, August 1995: pyranine positive water samples in the karst spring Divje Jezero during the observation period.

In the springs Hubelj, Skuk, Gorenje and Vipava 4/7 we analysed neither uranine nor pyranine. In the Vipava spring 4/2 we determined low concentrations (0.001-0.003 mg/m^3) in 5 samples taken from August, 12 till August, 18, 1995. There might be most probably some uranine rest from the previous tracing experiments.

Tab. 6.13: Overview of relevant parameters derived from the pyranine breakthrough in the springs Podroteja and Divje Jezero in the third tracer test, August 1, 1995: time(t_{max}), concentration (C) and velocity (v_{max}) of the first appearance, time of maximal concentration (t_{max}), maximal concentration (C_{max}) and dominant velocity (v_{dom}) in the springs and the recovery (R).

Spring	C [mg/m³)	t_{max} [h]	v_{max} [m/h]	C_{max} [mg/m³]	t_{dom} [h]	v_{dom} [m/h]	R [kg]	R [%]
Podroteja	0.0195	739	14.4	0.0195	739	14.4		
Divje jezero	0.0171	749	14.3	0.0197	829	12.9		

6.3.2.4. Summary

The tracing experiments performed (Tab. 6.1) proved partly the main drainage system given by the structural geological pattern (compare chapter 2.6). The proved flow connections resulting from the combined experiments in the years 1993 to 1995 are depicted in Fig. 6.17.

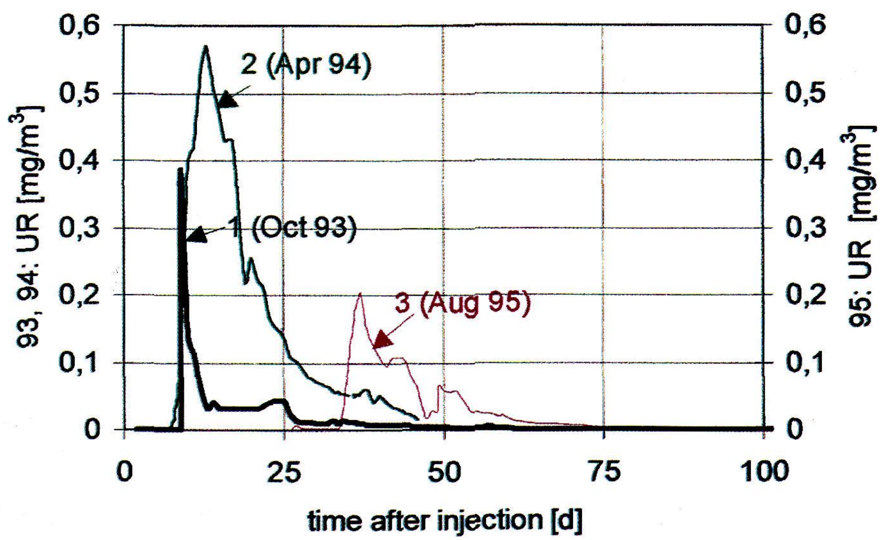

Fig. 6.18: Comparison of the Uranine breakthrough in the Mrzlek spring for the three repeated injections in the ice cave Belo Brezno in autumn 1993, spring 1994 and summer 1995.

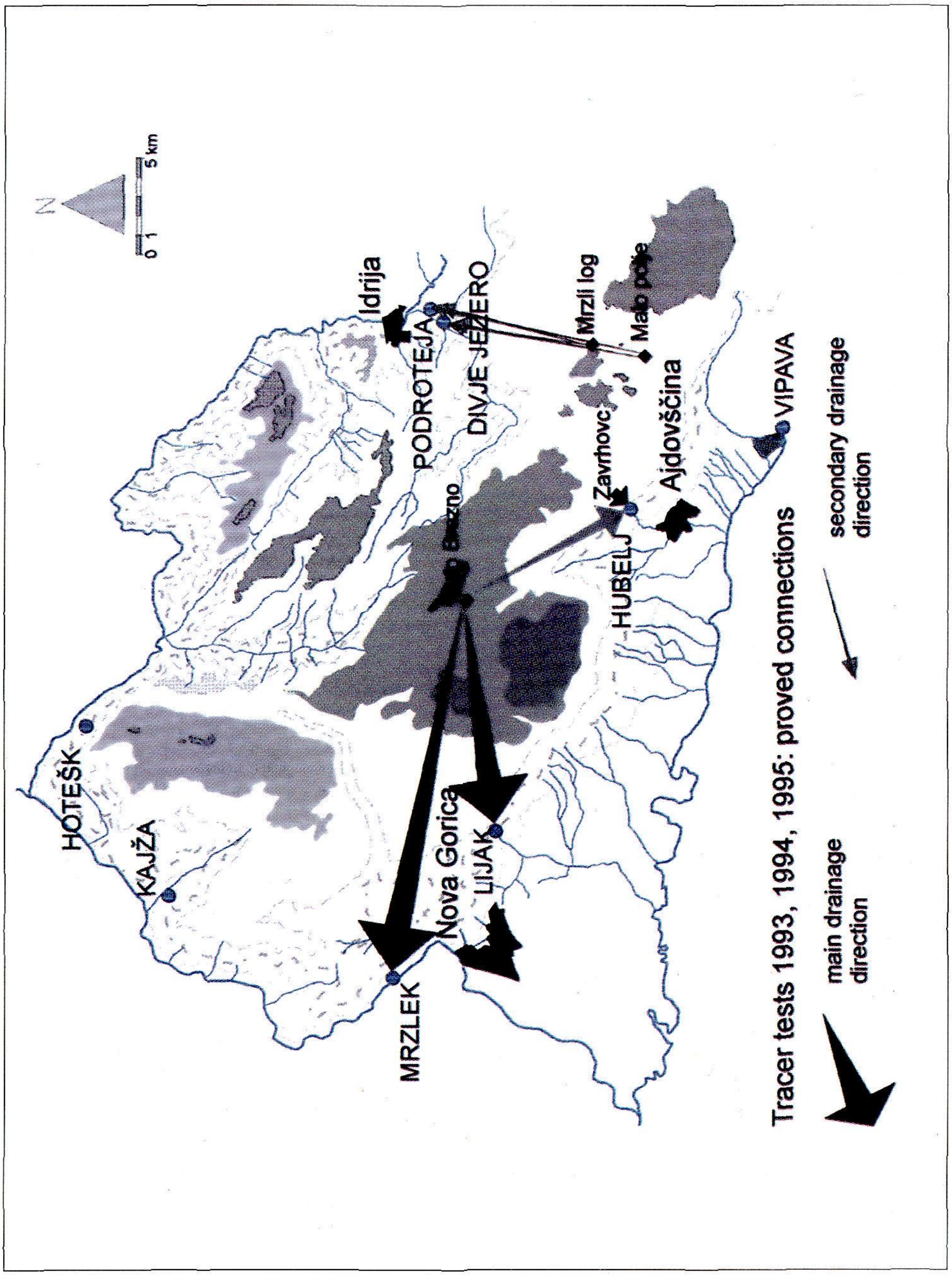

Fig. 6.17: Proved flow connections in the catchment areas of the karst springs Podroteja, Divje Jezero, Hotešk, Kajža, Mrzlek, Lijak and Hubelj resulting from the combined tracing experiments in the years 1993 to 1995.

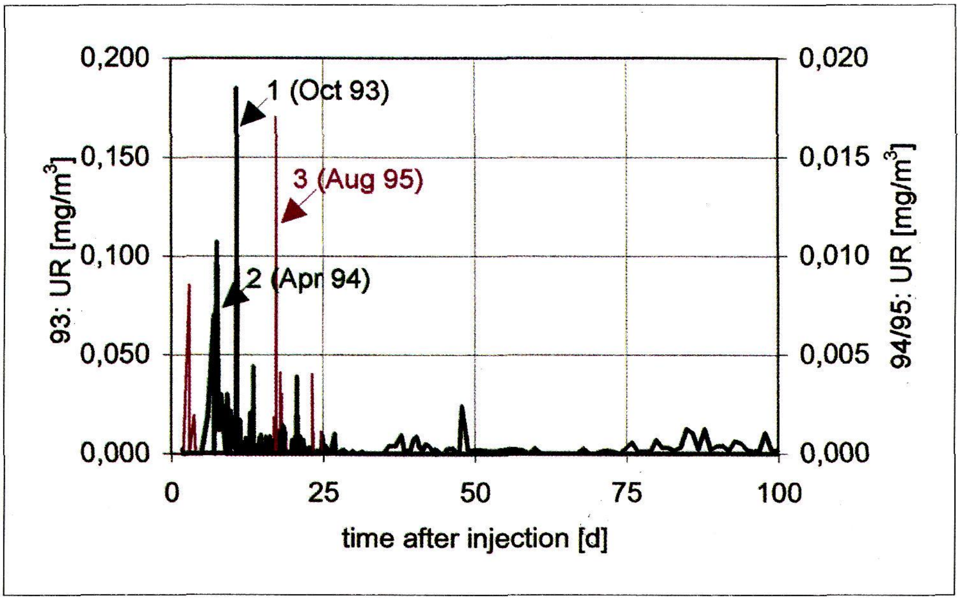

Fig. 6.19: Comparison of the uranine breakthrough in the Hubelj spring for the three repeated injections in the ice cave Belo Brezno in 1993, 1994 and 1995.

The ice cave Belo Brezno, the injection point for repeated uranine tracing under different hydrologic conditions in the central part of the Trnovski Gozd plateau, is developed in the limestones of the Trnovo nappe. Following the general SW dip of the Uppertriassic, Jurassic and Cretaceous carbonate rocks of the Trnovo nappe, directed by the mainly NW-SE striking strike slip faults main reoccurrence of the tracer injected in Belo Brezno is the karst spring Mrzlek at the deepest regional base level of the karst groundwater. During all hydrologic situations tested the Mrzlek spring was the main outlet. A direct comparison of the breakthrough curves resulting from the three uranine injections in experiments is given in Figs. 6.18 and 6.19.

Caused by the flooding of the spring outlet by the Soča river due to the construction of the Solkan hydropower plant, no current discharge measurements are available. Based on a mean discharge calculated from existing long-term observations from 1960 to 1990 the recovery was roughly estimated.