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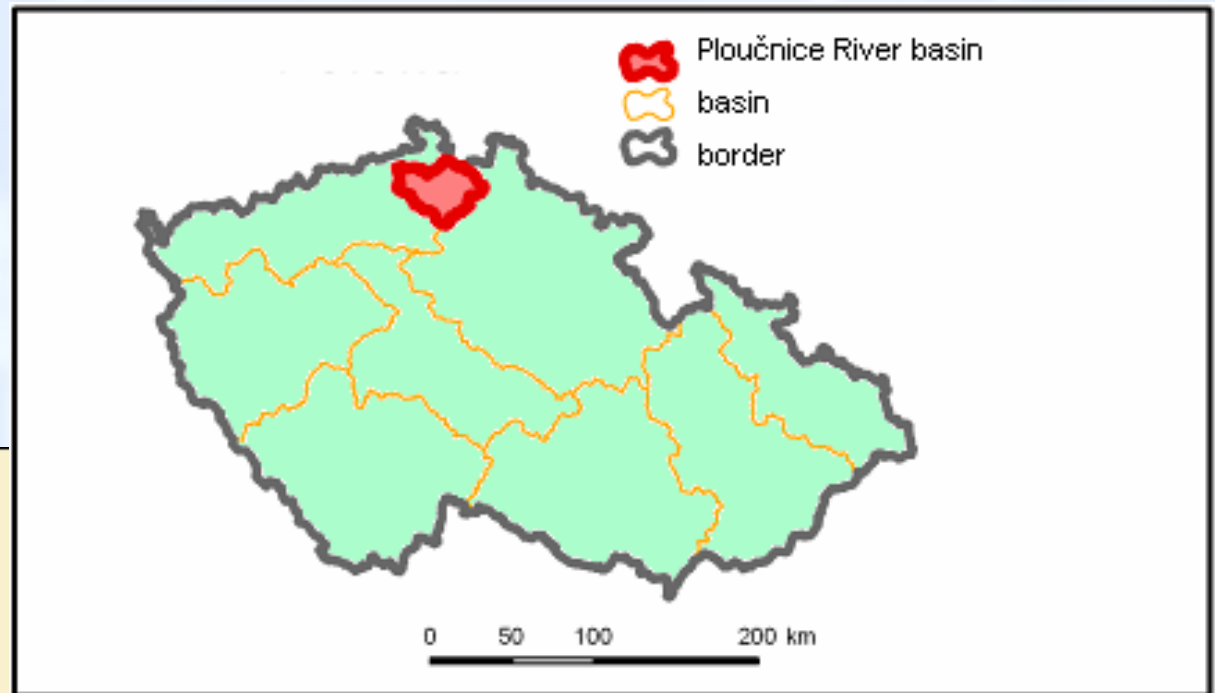
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**EVOLUTION OF RADIOACTIVE CONTAMINATION IN THE  
PLOUČNICE RIVER BASIN (BOHEMIA) DUE TO URANIUM  
MINING IN THE PERIOD 1992-2009**

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**Czech Republic  
position in Europe**

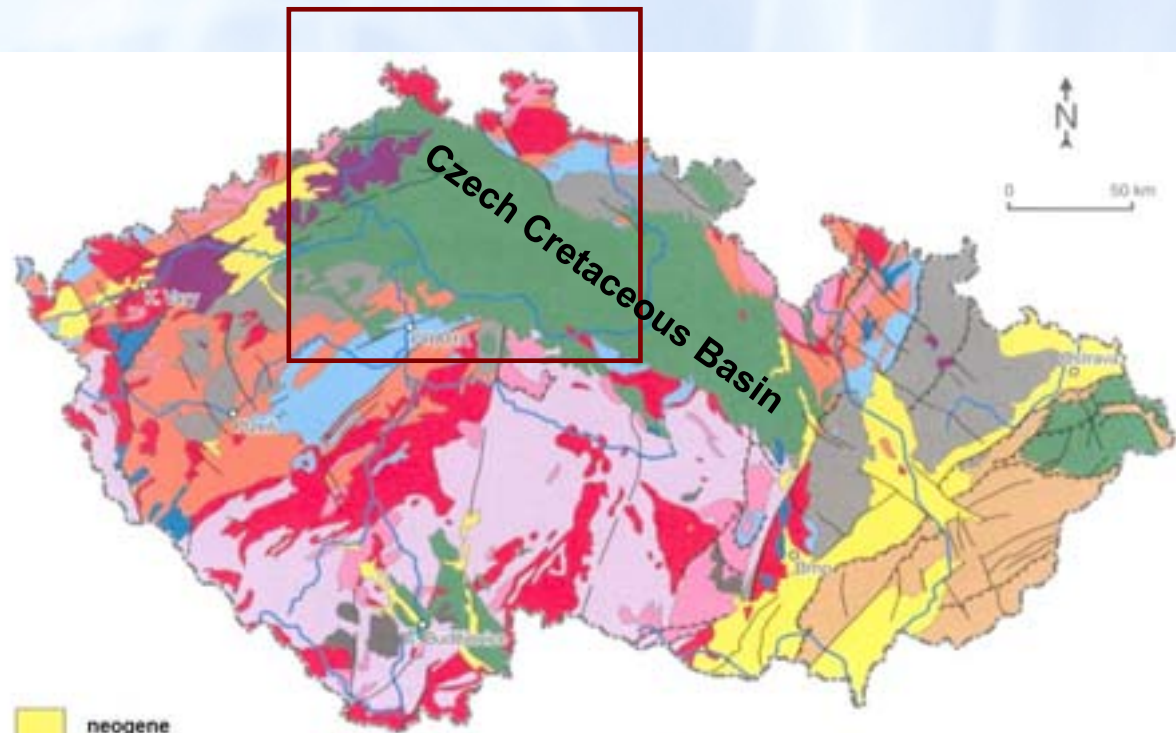
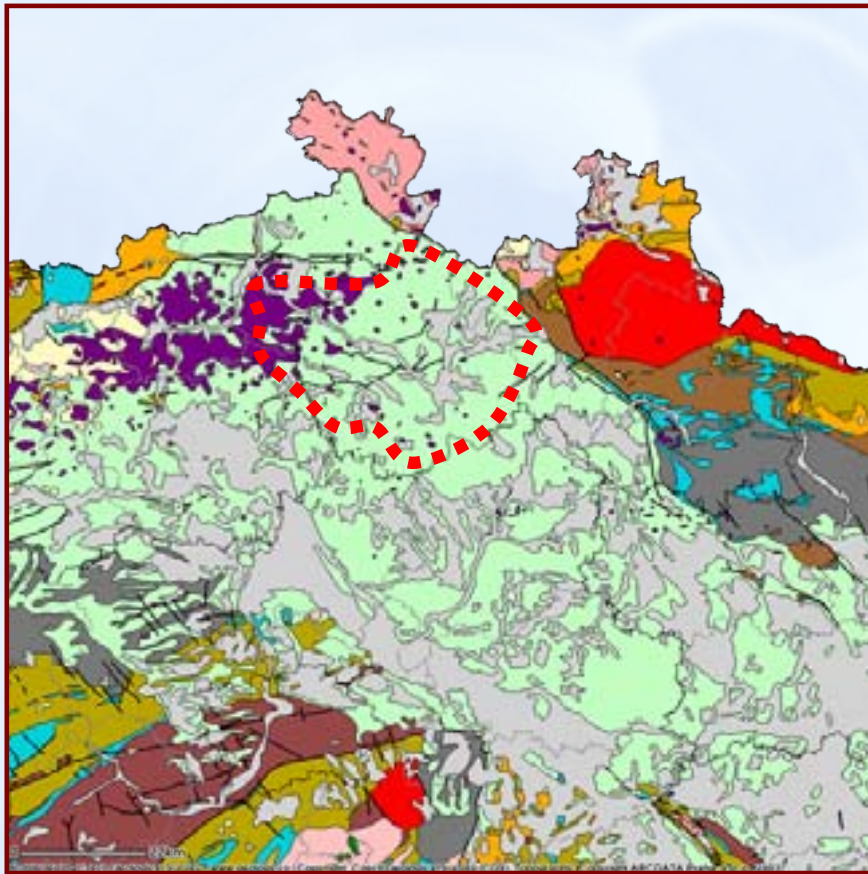


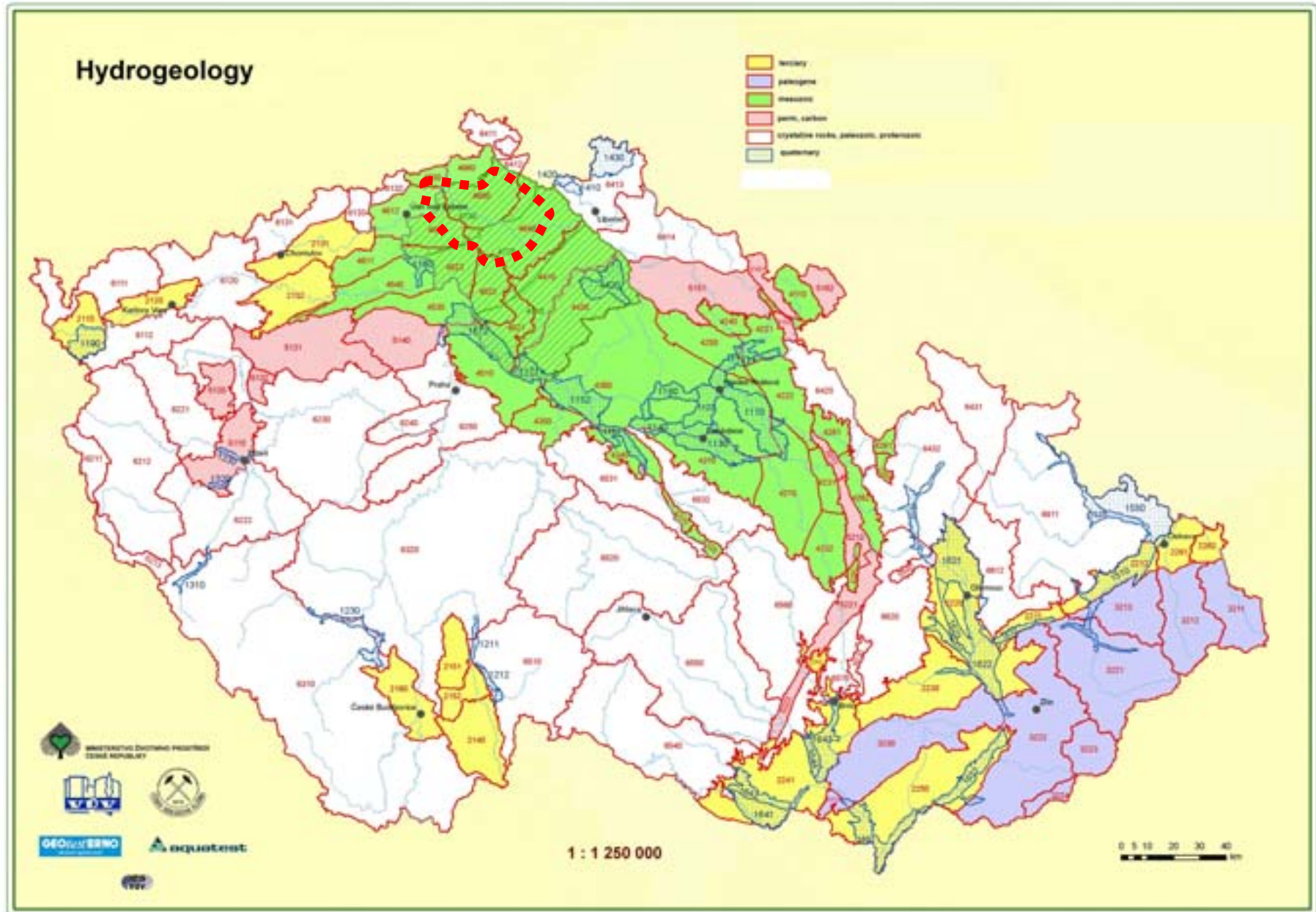
**Ploučnice River basin  
position in Czech Republic**

# INTRODUCTION

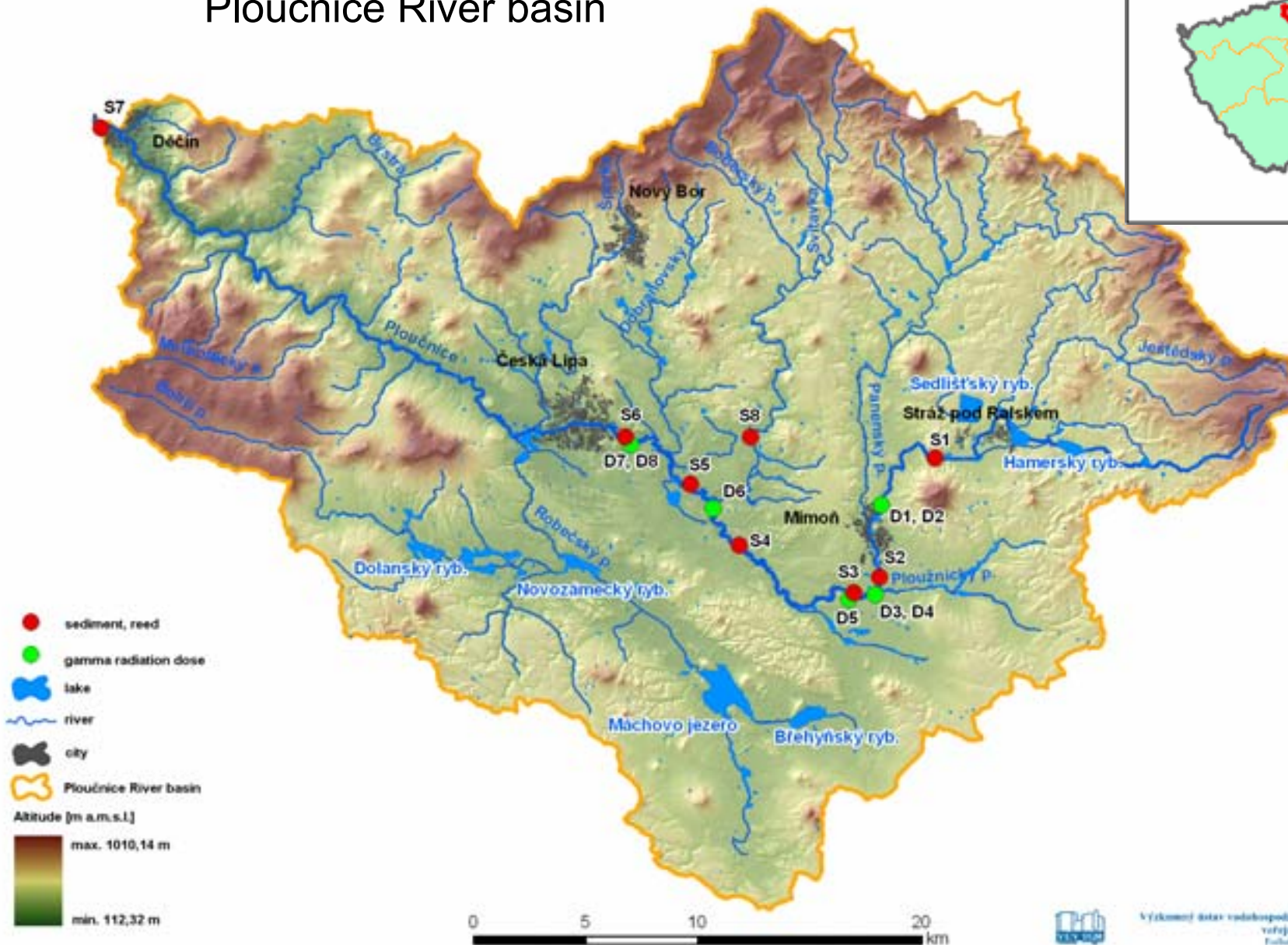
- uranium mining started in the end of the 60's of the last century.
- mining methods - underground mining and acid in-situ leaching
- mine water discharges - about 500 l/s
- 1981- extreme flood on the Ploučnice River
- 1989 - central decontamination station
- 1994 - the uranium mining was terminated
- 1994 - 2009 - monitoring system was consequently established

# Geology





## Ploučnice River basin



# OBJECTIVES

- Gamma radiation in the flooded area
- Contamination of river sediments by radioactive substances
- Contamination of biomas - reed



# METHODS

- in-situ measurements of gamma radiation

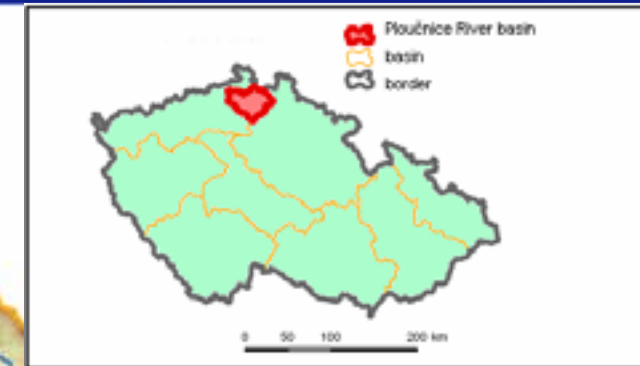
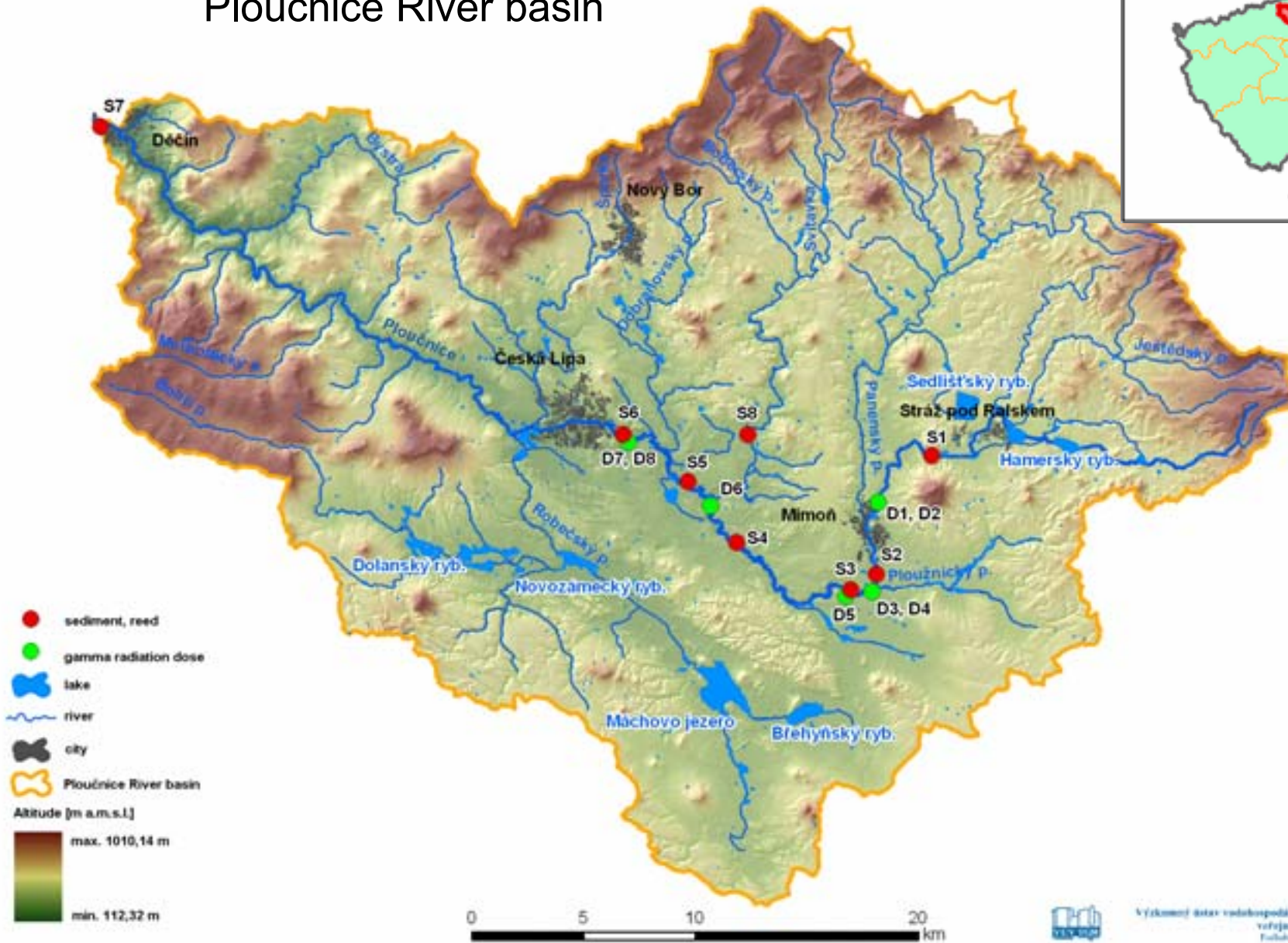


# METHODS

- Sampling and gamma spectrometric analysis of sediments and biomass in laboratory



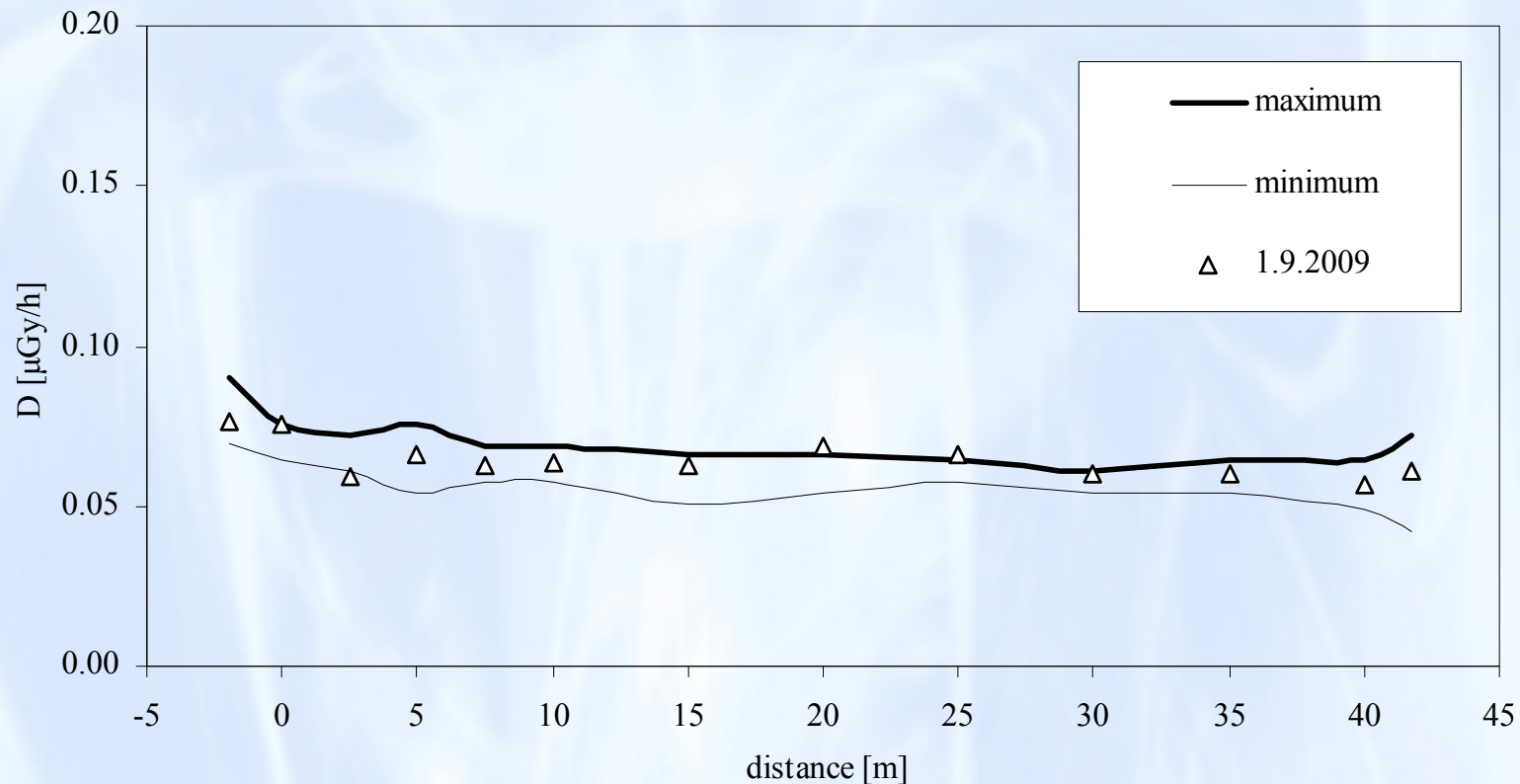
## Ploučnice River basin



*D8 Žízníkov cross section*



# Gamma radiation in the flooded area

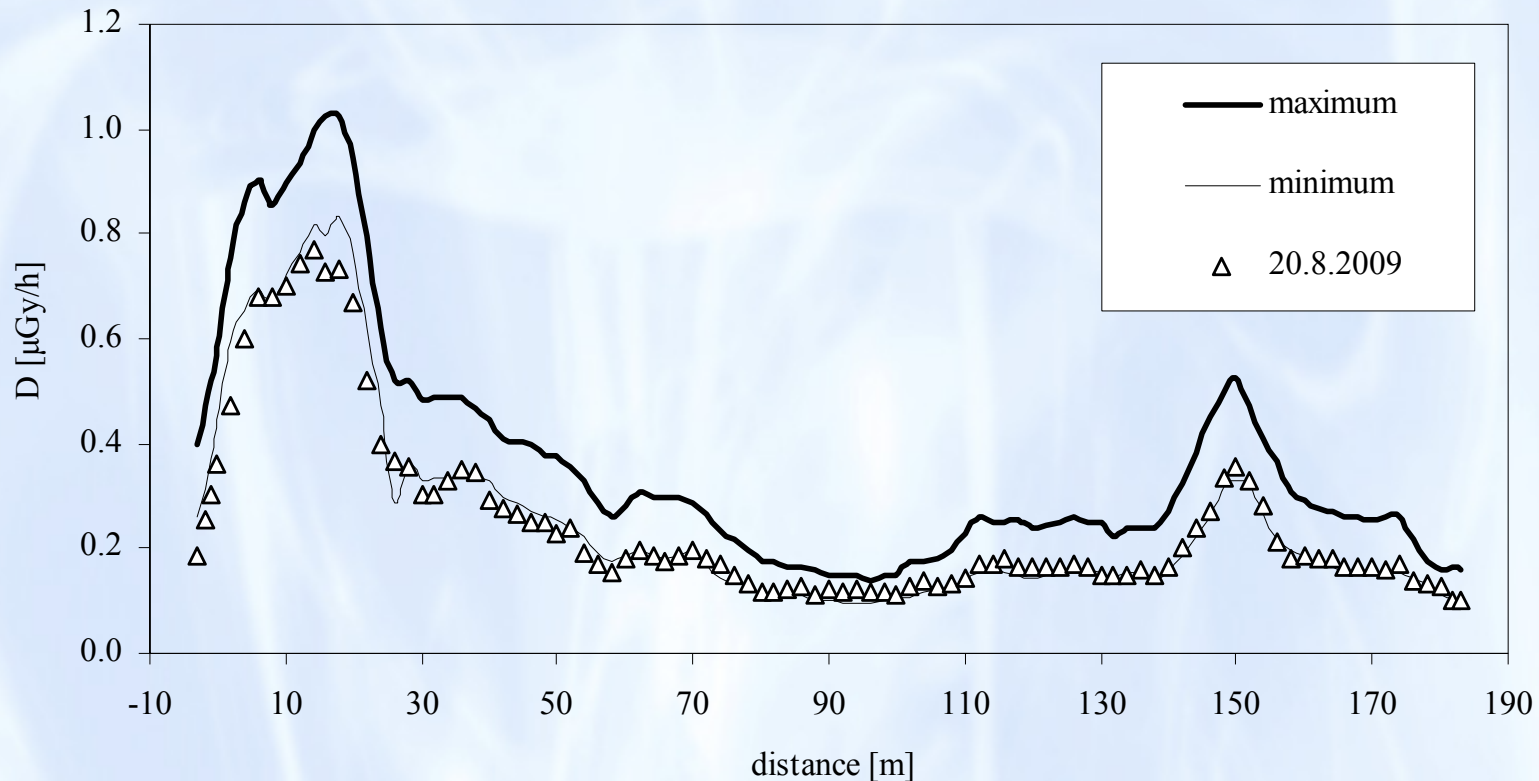


*Gamma radiation in 2009 in an interval of maxima and minima from 1994 – 2004, D8 Žízníkov cross section.*

*D5 Boreček cross section*

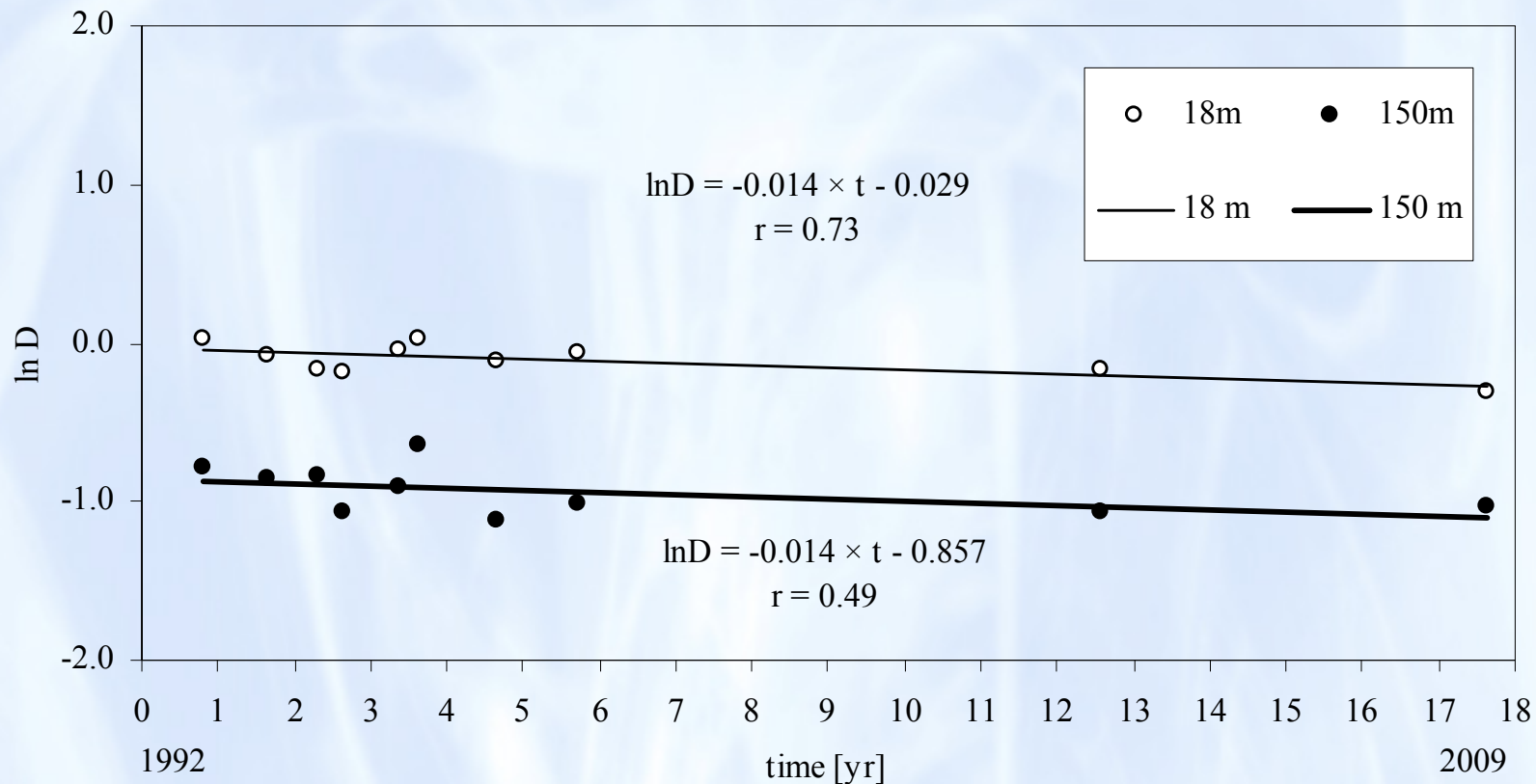


# Gamma radiation in the flooded area



*Gamma radiation in 2009 in an interval of maxima and minima from 1992 – 2004, D5 Boreček cross section.*

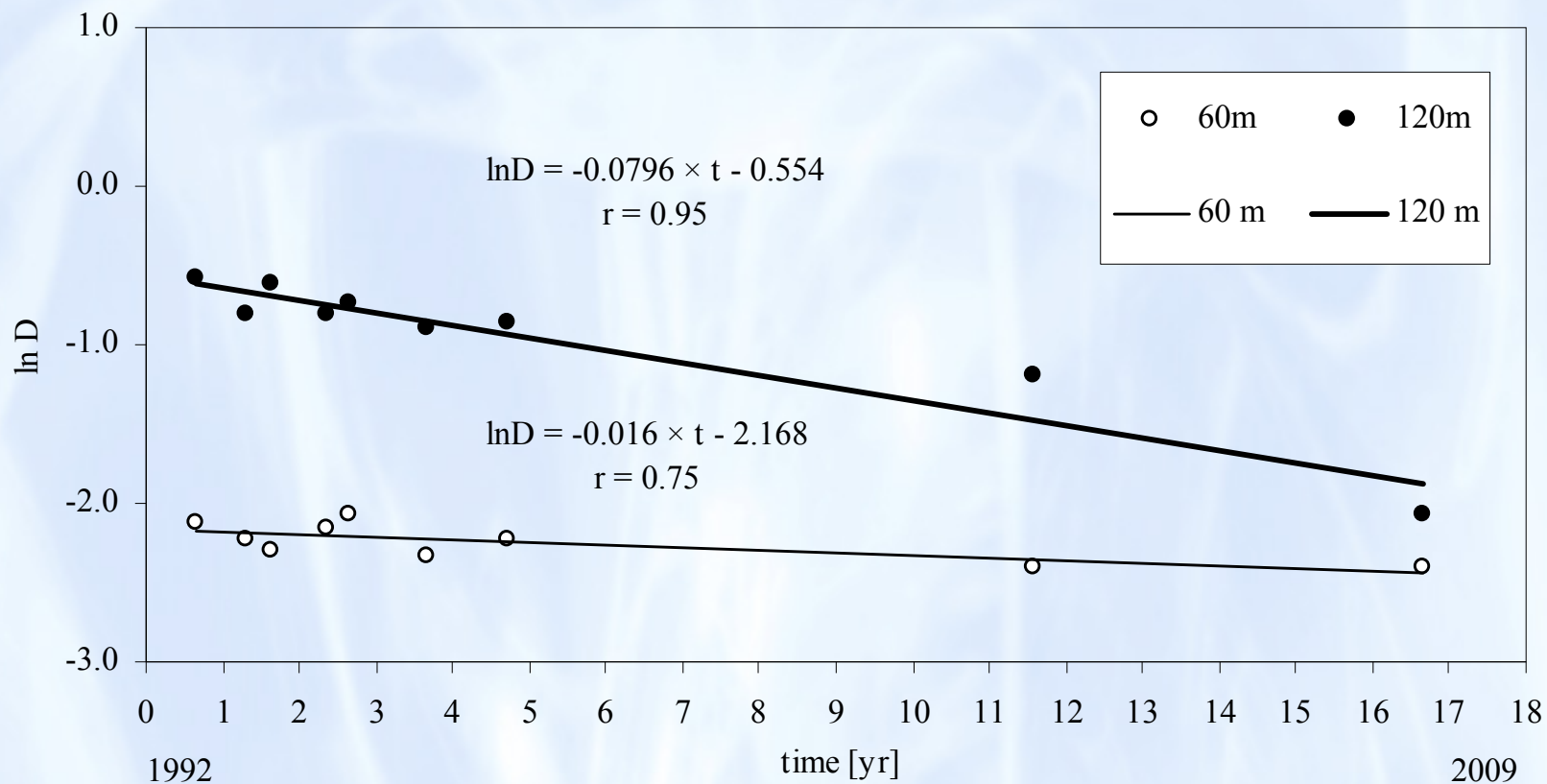
# Gamma radiation in the selected sites of the monitored cross-sections



*Time development of gamma radiation (D) at distances of 18 m and 150 m, D5 Boreček cross section, 1992 – 2009.*



# Gamma radiation in the selected sites of the monitored cross-sections



*Time development of gamma radiation (D) at distances of 60 m and 120 m, D6 Brenná cross section, 1993 – 2009.*

# Gamma radiation in the selected sites of the monitored cross-sections

$$\ln D_{i,j} = -\lambda_{ef,i,j} \times t + q_{i,j}$$

$$T_{ef,i,j} = \frac{\ln 2}{\lambda_{ef,i,j}}$$

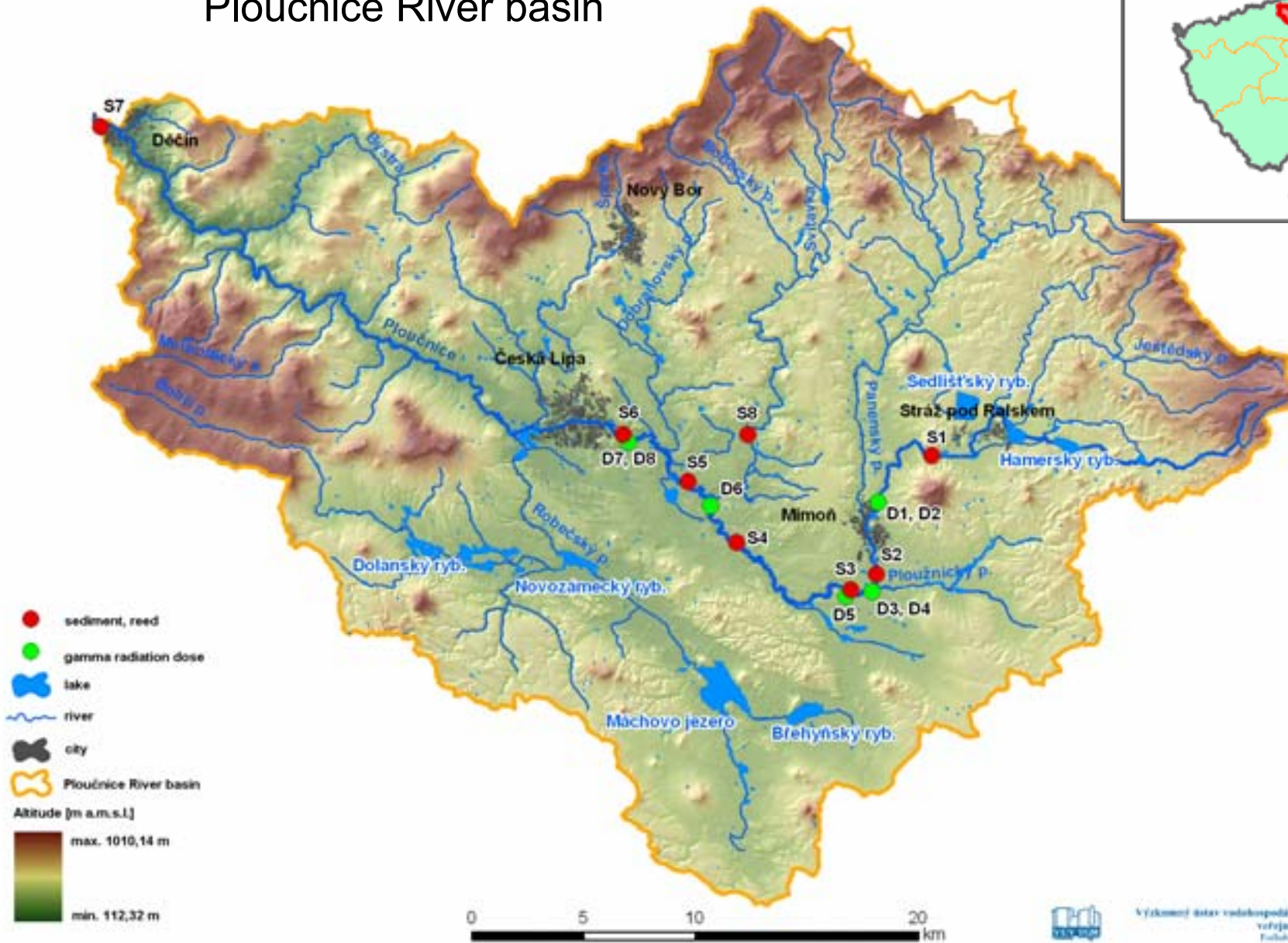
$$D_{i,j}' = D_{i,j} - D_b$$

# Gamma radiation in the selected sites of the monitored cross-sections

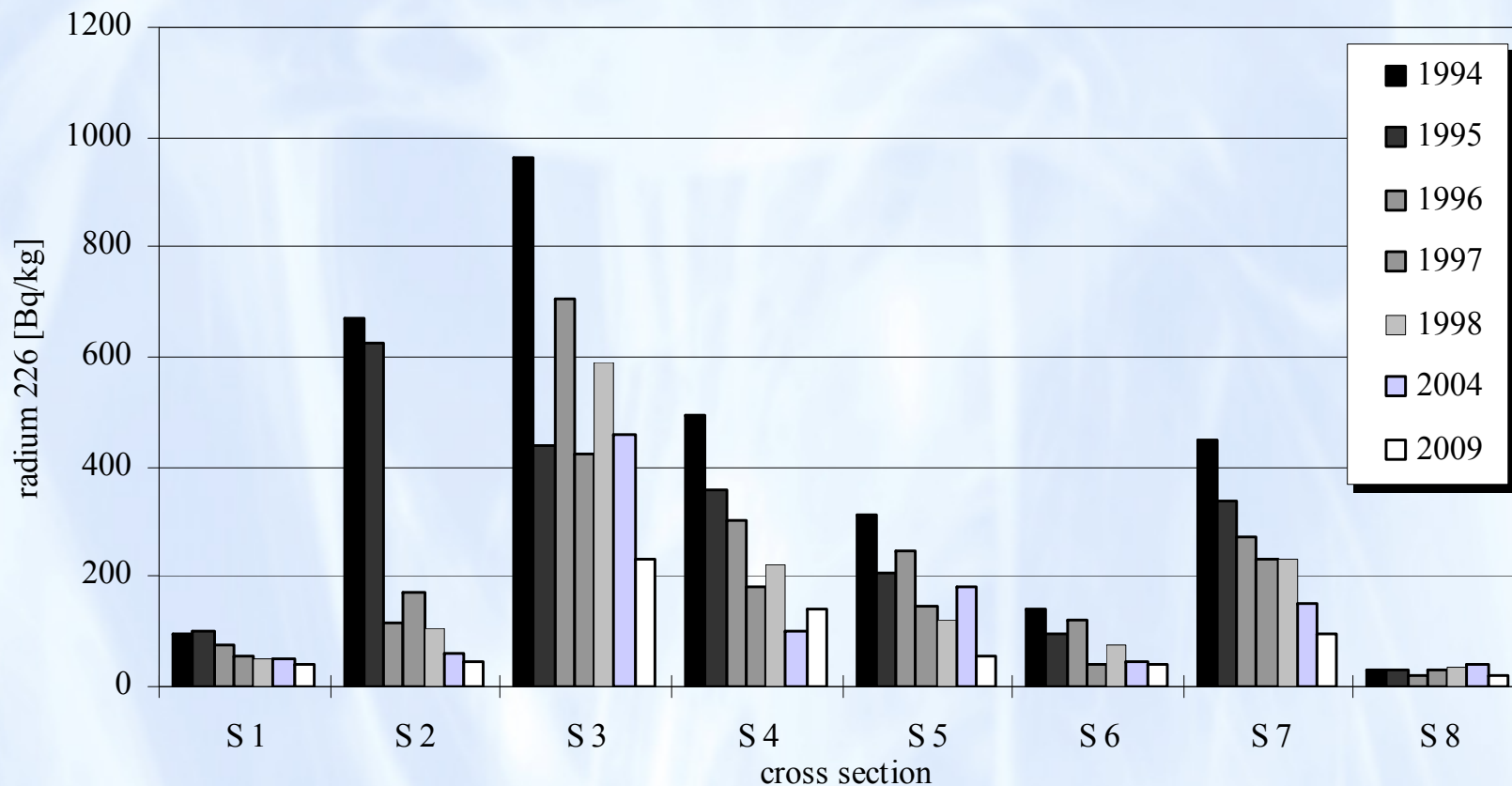
Profil na Ploučnici		l	$\lambda_{ef}$	$T_{ef}$	$\lambda_{ef}'$	$T_{ef}'$
		(m)	(1/r)	(r)	(1/r)	(r)
Mimoň	D1	12	0,019	<b>37,3</b>	0,029	<b>23,6</b>
		22	0,046	<b>15,2</b>	0,057	<b>12,1</b>
Hradčany - vtok	D3	18	0,084	<b>8,2</b>	0,110	<b>6,3</b>
		44	0,085	<b>8,2</b>	0,100	<b>6,9</b>
Hradčany - výtok	D4	22	0,041	<b>16,9</b>	0,059	<b>11,7</b>
		38	0,045	<b>15,3</b>	0,056	<b>12,3</b>
Boreček	D5	18	0,014	<b>49,2</b>	0,015	<b>45,6</b>
		150	0,014	<b>49,5</b>	0,017	<b>42,0</b>
Brenná	D6	60	0,016	<b>42,3</b>	0,042	<b>16,6</b>
		120	0,080	<b>8,7</b>	0,108	<b>6,4</b>

CONSTANTS OF GAMMA RADIATION DECREASE AND EFFECTIVE ECOLOGICAL HALF-LIVES BEFORE AND AFTER SUBTRACTION OF THE BACKGROUND RADIATION, SELECTED SITES OF THE MONITORING CROSS SECTIONS.

# Ploučnice River basin

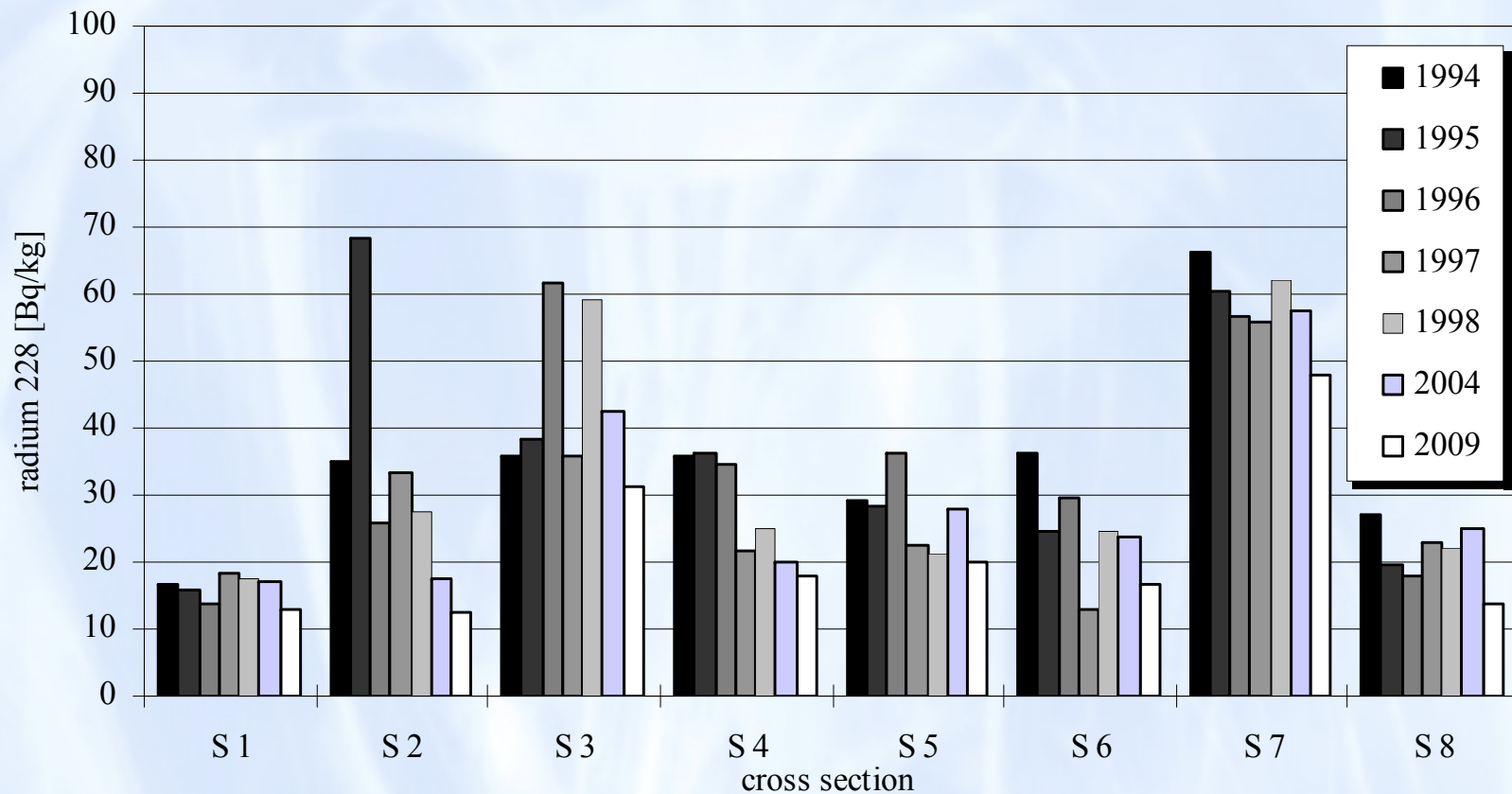


# Contamination of river sediments by radioactive substances



*Radium 226 activities in bottom sediments from the Ploučnice River (S1 to S7 cross sections) and from the uncontaminated cross section of the Svitávka River (S8) in the period 1994 – 2009.*

# Contamination of river sediments by radioactive substances



*Radium 228 activities in bottom sediments from the Ploučnice River (S1 to S7 cross sections) and from the uncontaminated cross section of the Svitávka River (S8) in the period 1994 – 2009.*

# Contamination of river sediments by radioactive substances

$$\ln a_i = -\lambda_{ef,i} \times t + q_i$$

$$T_{ef,i} = \frac{\ln 2}{\lambda_{ef,i}}$$

$$a_i' = a_i - a_b$$

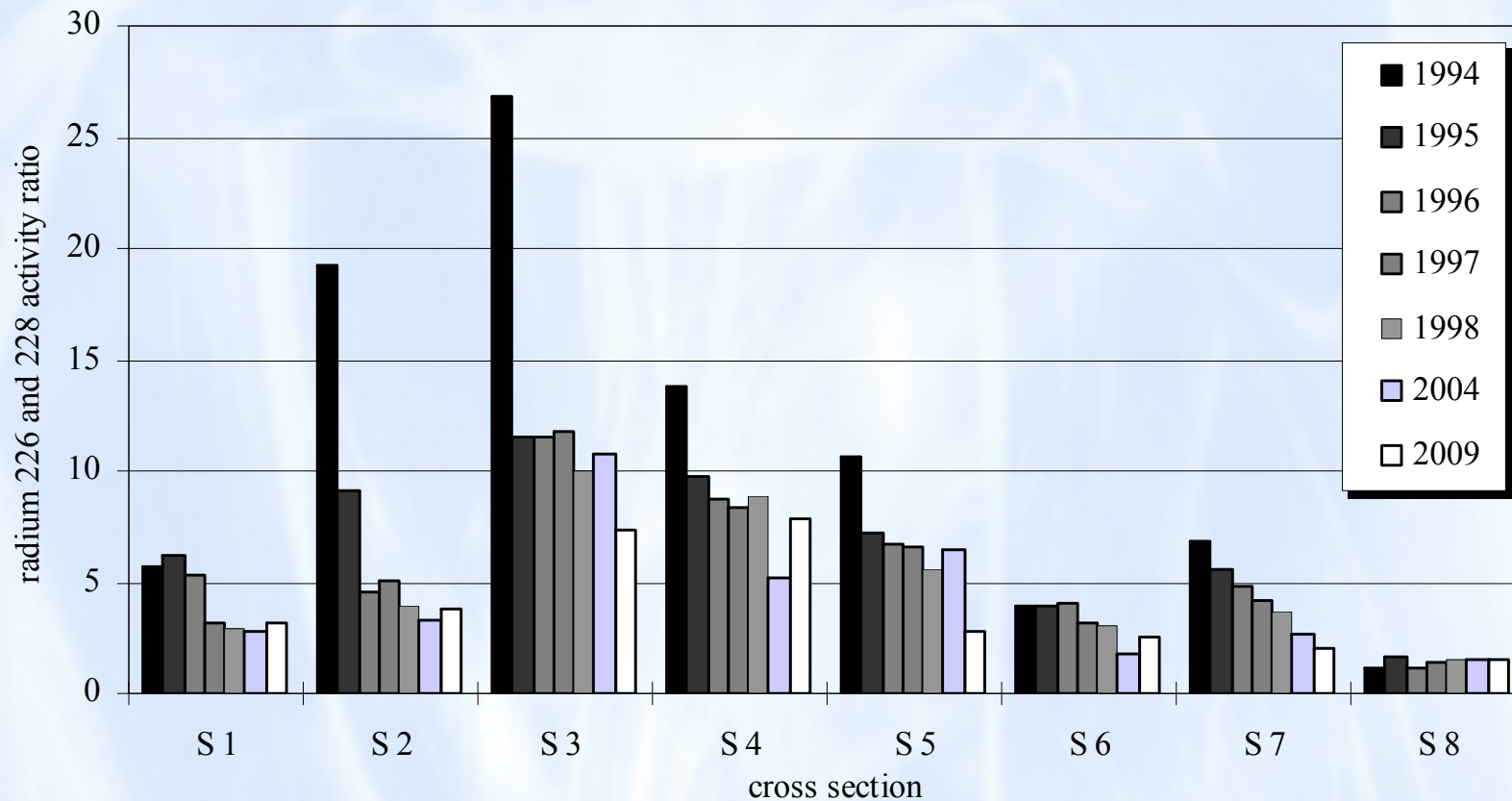
# Contamination of river sediments by radioactive substances

Profil na Ploučnici		radionuklid	$\lambda_{ef}$	$T_{ef}$	$\lambda_{ef}'$	$T_{ef}'$
			(1/r)	(r)	(1/r)	(r)
Noviny	S1	Ra226	0,052	<b>13,3</b>	0,110	<b>6,3</b>
		Ra228	0,012	<b>57,3</b>	- <sup>*</sup> )	- <sup>*</sup> )
Mimoň laguny	S2	Ra226	0,158	<b>4,4</b>	0,222	<b>3,1</b>
		Ra228	0,084	<b>8,3</b>	0,417	<b>1,7</b>
Boreček	S3	Ra226	0,064	<b>10,8</b>	0,070	<b>9,9</b>
		Ra228	0,015	<b>45,0</b>	0,035	<b>20,0</b>
Veselí	S4	Ra226	0,080	<b>8,6</b>	0,095	<b>7,3</b>
		Ra228	0,046	<b>15,0</b>	0,366	<b>1,9</b>
Vlčí Důl	S5	Ra226	0,082	<b>8,4</b>	0,117	<b>5,9</b>
		Ra228	0,019	<b>35,7</b>	0,213	<b>3,3</b>
Žízníkov	S6	Ra226	0,069	<b>10,0</b>	0,133	<b>5,2</b>
		Ra228	0,027	<b>26,0</b>	0,205	<b>3,4</b>
Zámecký rybník	S7	Ra226	0,089	<b>7,8</b>	0,107	<b>6,5</b>
		Ra228	0,015	<b>46,2</b>	0,025	<b>28,3</b>

CONSTANTS OF GAMMA RADIATION DECREASE AND EFFECTIVE ECOLOGICAL HALF-LIVES BEFORE AND AFTER SUBTRACTION OF THE BACKGROUND RADIATION, SELECTED SITES OF THE MONITORING CROSS SECTIONS



# Contamination of river sediments by radioactive substances



*Ratio of the activities of radium 226 and radium 228 in bottom sediments of the Ploučnice River (S1 to S7 cross sections) and in S8 Svitávka Zákupy uncontaminated section, period 1994 – 2009.*

# Reed

## Radium 226 activities (related to dried matter)

- S1 to S6 : 4 to 36 Bq/kg

## Radium 228 activities (related to dried matter)

- mostly below the detection limit
- S2 and S5 : 5 Bq/kg and 7 Bq/kg



# CONCLUSIONS

- The results of the gamma radiation monitoring in the period 1992 – 2009 showed that the contamination by the radioactive substances was decreasing. The effective ecological half-lives were derived in the range from 8.2 to 49,5 years.
- After correcting the results by subtracting the background activities derived from D8 Žízníkov uncontaminated cross section, the effective ecological half-lives were shorter, in the range 6 – 45.6 years.

# CONCLUSIONS

- The results of the monitoring of the bottom sediments substantiated that the activities of both radionuclides were decreasing.
- The calculated values of the effective ecological half-life of radium 226 were in the range of 4.4 – 13.3 yr.
- The decrease in the activities of radium 228 was significantly smaller. Its half-life was in the range of 8.3 – 57.3 yr.
- The values of the corrected effective ecological half-life that were derived from the activities of radium 226 was in the range 3.1 yr to 9.9 yr.
- The values of the corrected effective ecological half-life of radium 228 are associated with higher uncertainty.