Practical training course on sustainable sediment management with the Sava River Basin as a showcase

- Serbian part of the Sava river basin -

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Institute Jaroslav Černi, Belgrade

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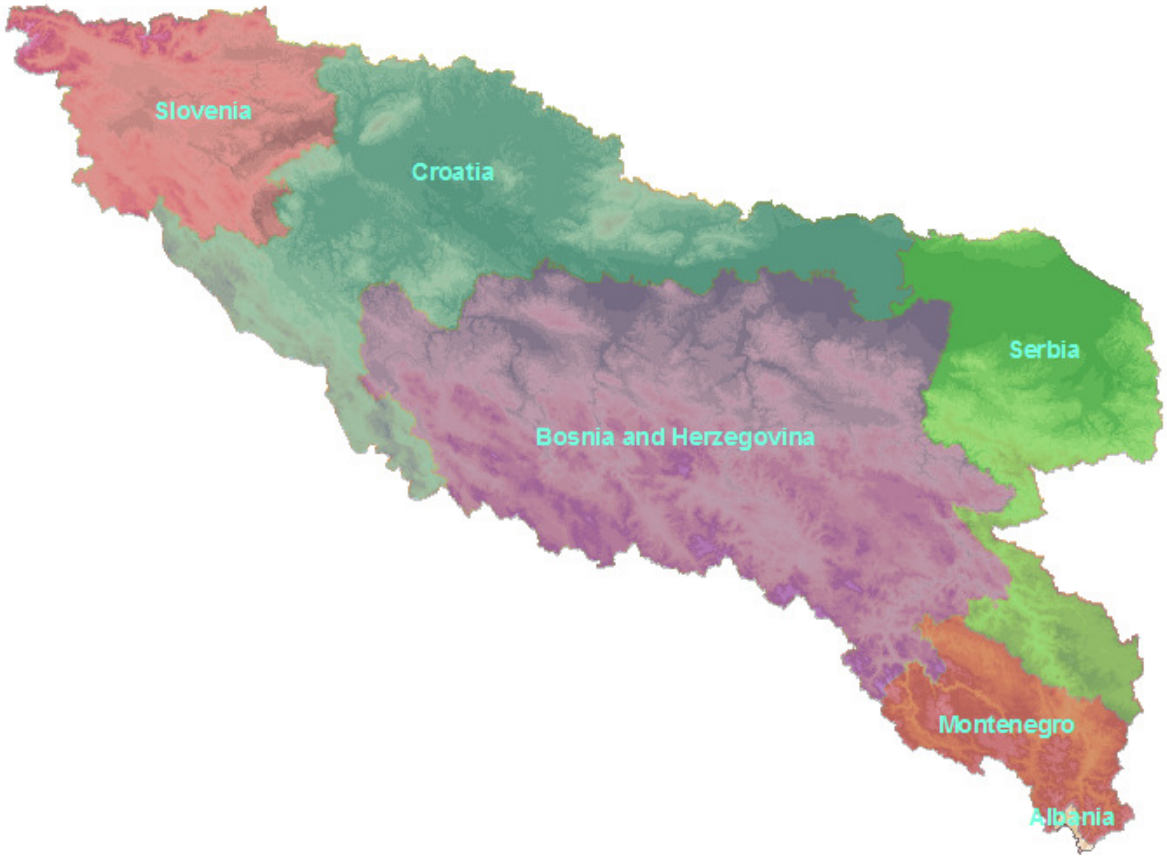
3. Sediment monitoring

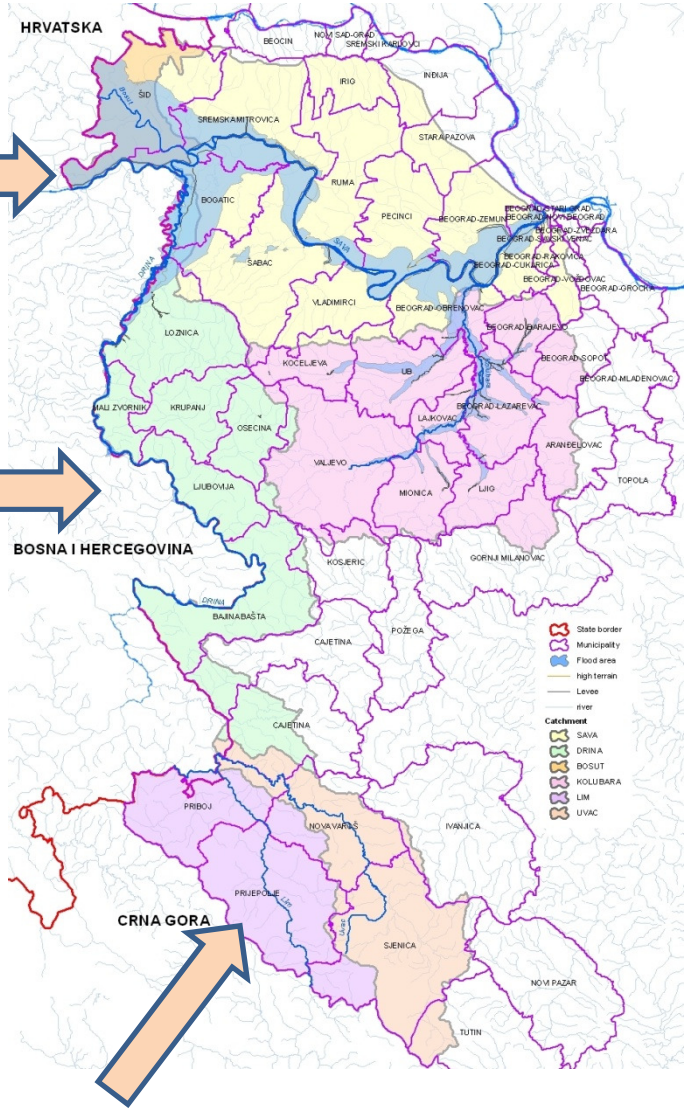
4. Evaluation of sediment quality and quantity



1. OVERVIEW OF THE SERBIAN PART OF THE SAVA RIVER BASIN

River network

- Republic of Serbia (RS) is the most downstream country in the Sava River Basin
- 17% of the Sava river basin
- RS stretch of the **Sava River** is 210 km long
- Main tributaries of the Sava River:
  - **Right:**
    - **Drina River** (A ~ 19,500 km$^{2;}$ 37% B&H 31.5% MNE, 30.5% RS, 1% AL)
    - Several small right tributaries
    - **Kolubara River** (A ~ 3,650 km^2)
  - **Left:**
    - **Bosut River** (A ~ 2,900 km^2; 70.7% CR + 29.3% RS); flow regime completely controlled by sluice and p.s. Bosut located at the mouth
    - Numerous drainage channels – controled inflow (PS)

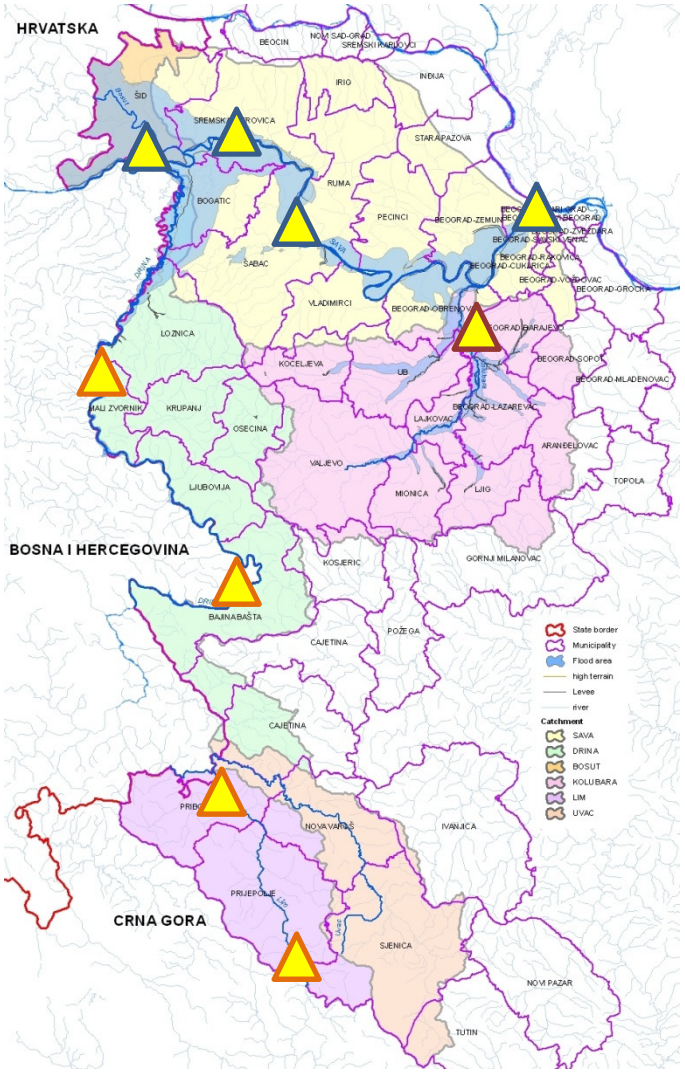


Hydrology

Table 1: Main hydrological characteristics of significant watercourses in the Sava River Basin

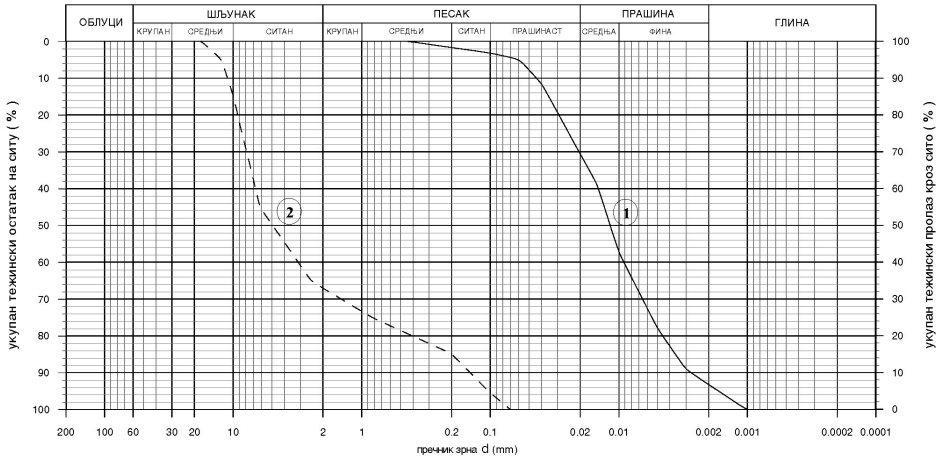
River	Profile	Distance from the mouth	Basin area	Q_{av}	$Q_{1\%}$
		km	km^2	m^3/s	m^3/s
Sava	Jamena	203	64,073	1,180	4,527
Sava	Sr. Mitrovica	139	87,996	1,530	6,750
Sava	Šabac	106	89,490		
Sava	Beograd	2	95,719		
Lim	Brodarevo	98	2,762	72	1,100
Lim	Priboj	45	3,684	96	1,260
Drina	B. Bašta	177	14,797	340	4,990
Drina	Radalj	77	17,490	370	5,830
Kolubara	Draževac	12	3,588	20	640

Republic Hydrometeorological Service of Serbia
(established 1888, WMO member since 1947)

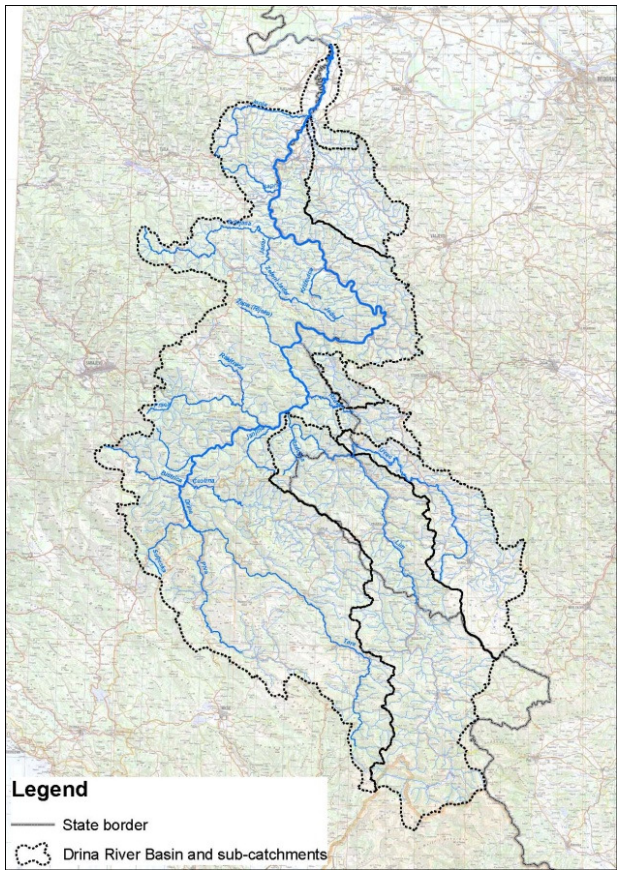


Sava River

- Typical alluvial river flowing through wide lowlands
- Navigable
- Not “heavily engineered” – a few stretches with river structures (mainly revetments and groins)
- Mixture of gravel and sand in the bottom
- Sources of sediment – upstream inflow + tributaries + local bank erosion (not important)
- Sediment regime is altered downstream of Sabac (km 100) – the shallow part of the Iron Gate 1 reservoir



Drina River



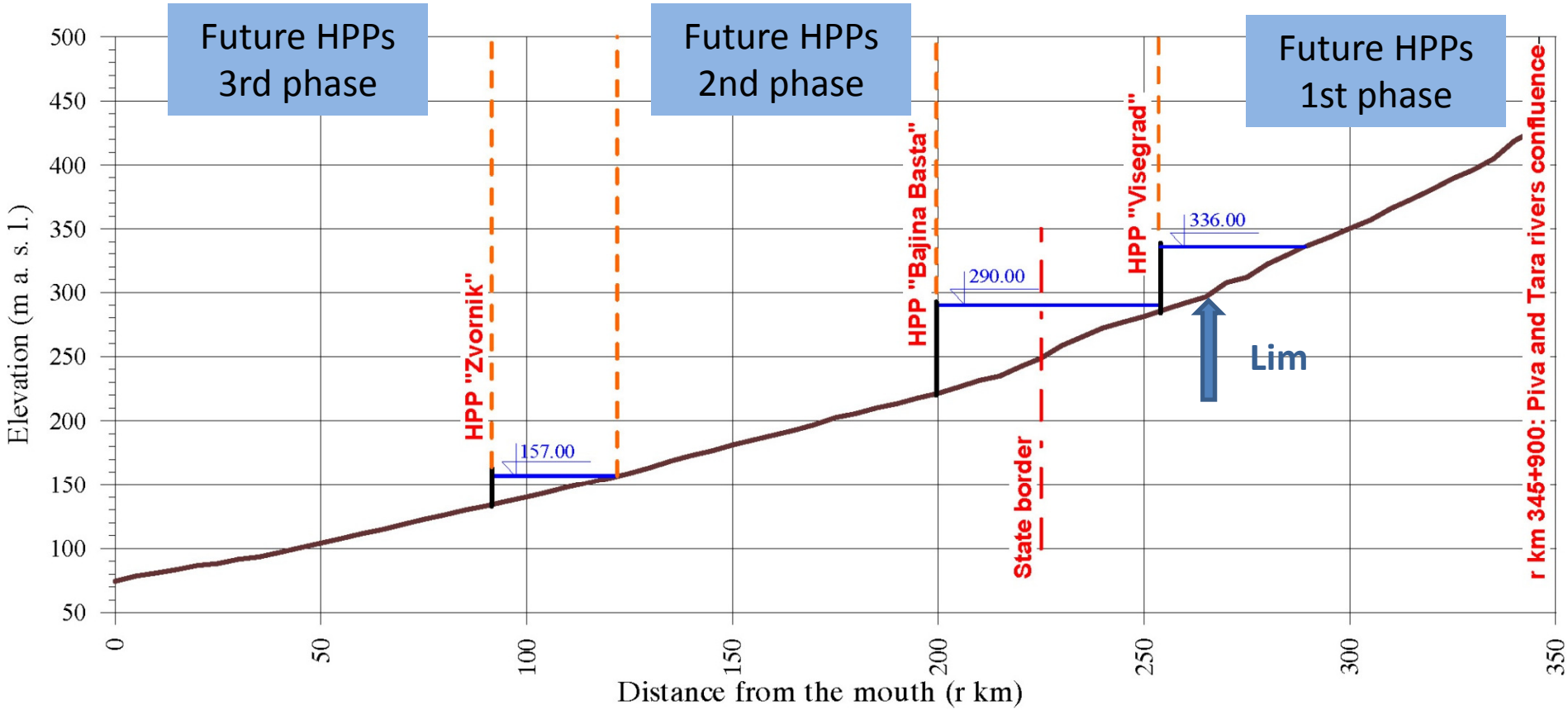
Source: Junction of the Piva and the Tara
Mouth: Sava River

Drina River

The largest water resource and hydropower potential on Balkans

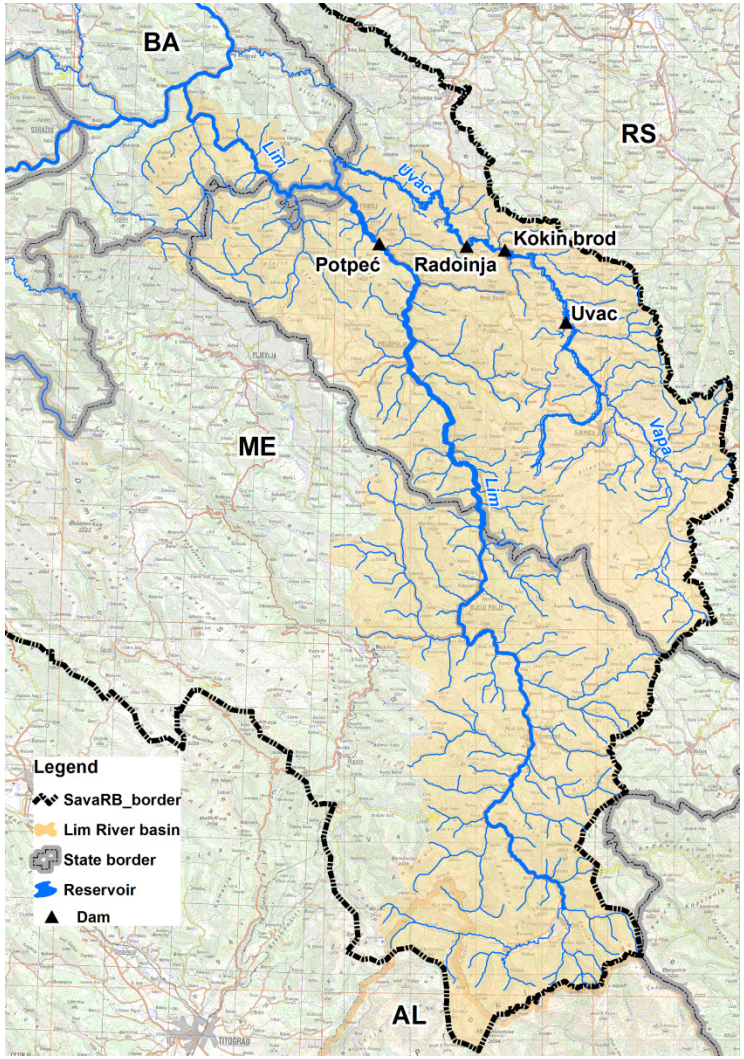
	Reservoir	River	A	Q_{av}	Year	Total volume
			[km^2]	[m^3/s]		[10^6 m^3]
1	**Uvac**	**Uvac**	**920**	**11.5**	**1979**	**200**
2	**Kokin Brod**	**Uvac**	**1170**	**13.9**	**1962**	**250**
3	**Radoinja**	**Uvac**	**3500**	**14.4**	**1959**	**7.6**
4	**Potpeć**	**Lim**	**3605**	**78**	**1967**	**27.5**
5	Otilovići	Ćehotina	352	6.6	1981	20.7
6	Mratinje	Piva	1758	74.4	1973	890
7	Višegrad	Drina	13310	342	1988	161
8	**Bajina Bašta**	**Drina**	**15195**	**349**	**1966**	**340**
9	**Lazići**	**Beli Rzav**	**-**	**-**	**1984**	**170**
10	**Zvornik**	**Drina**	**17423**	**399.4**	**1955**	**95**
11	Sniježnica	Rastošnica	39	-	1985	23.1
Ukupno:						2178.9

Drina River - Existing HPPs



Lim River

Source: Lake Plav (MNE)
Mouth: Drina - Visegrad reservoir (B&H)



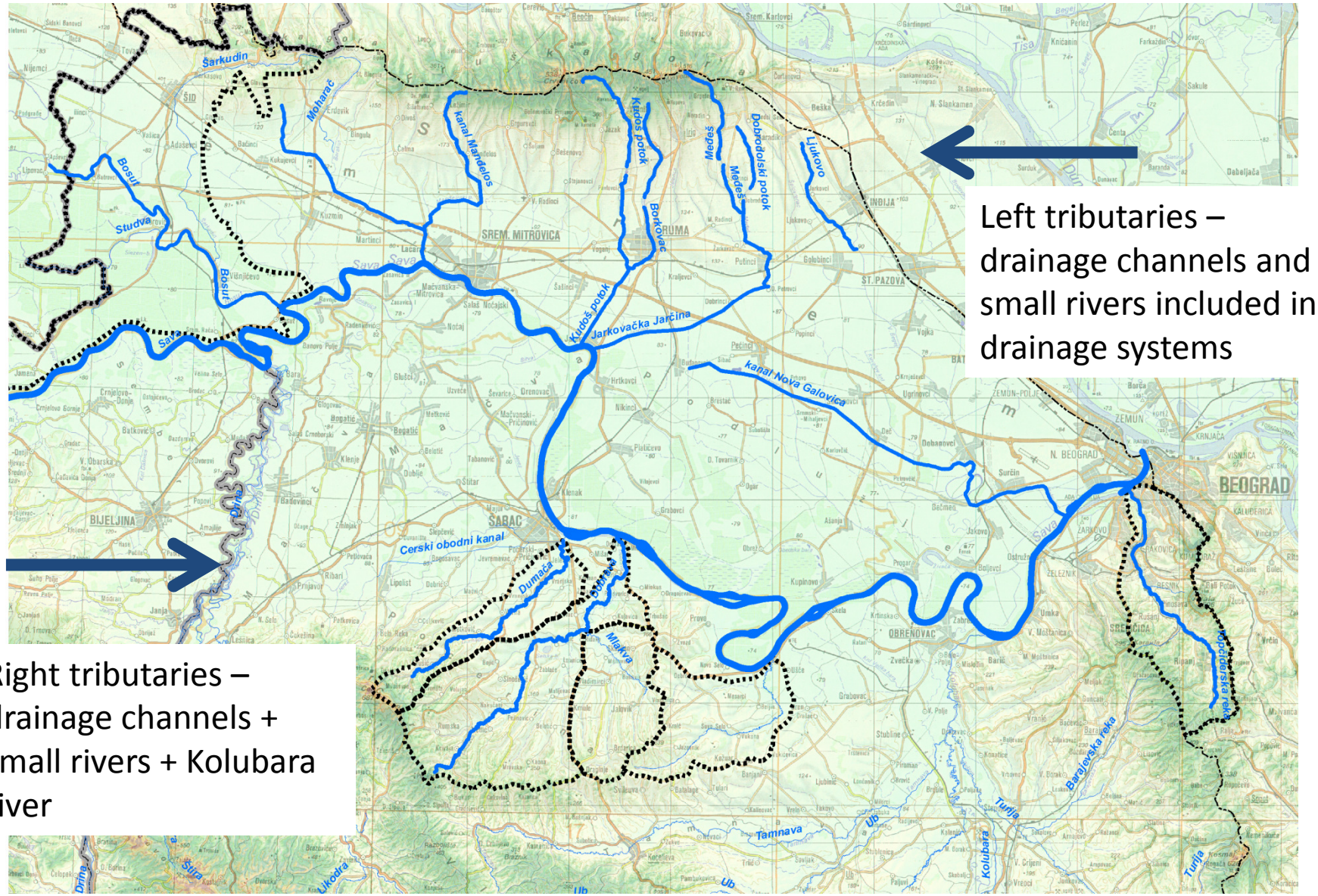
HPP Potpeć

Kokin Brod - Uvac

Bistrica - Uvac

Uvac – Uvac

Small tributaries of the Sava River

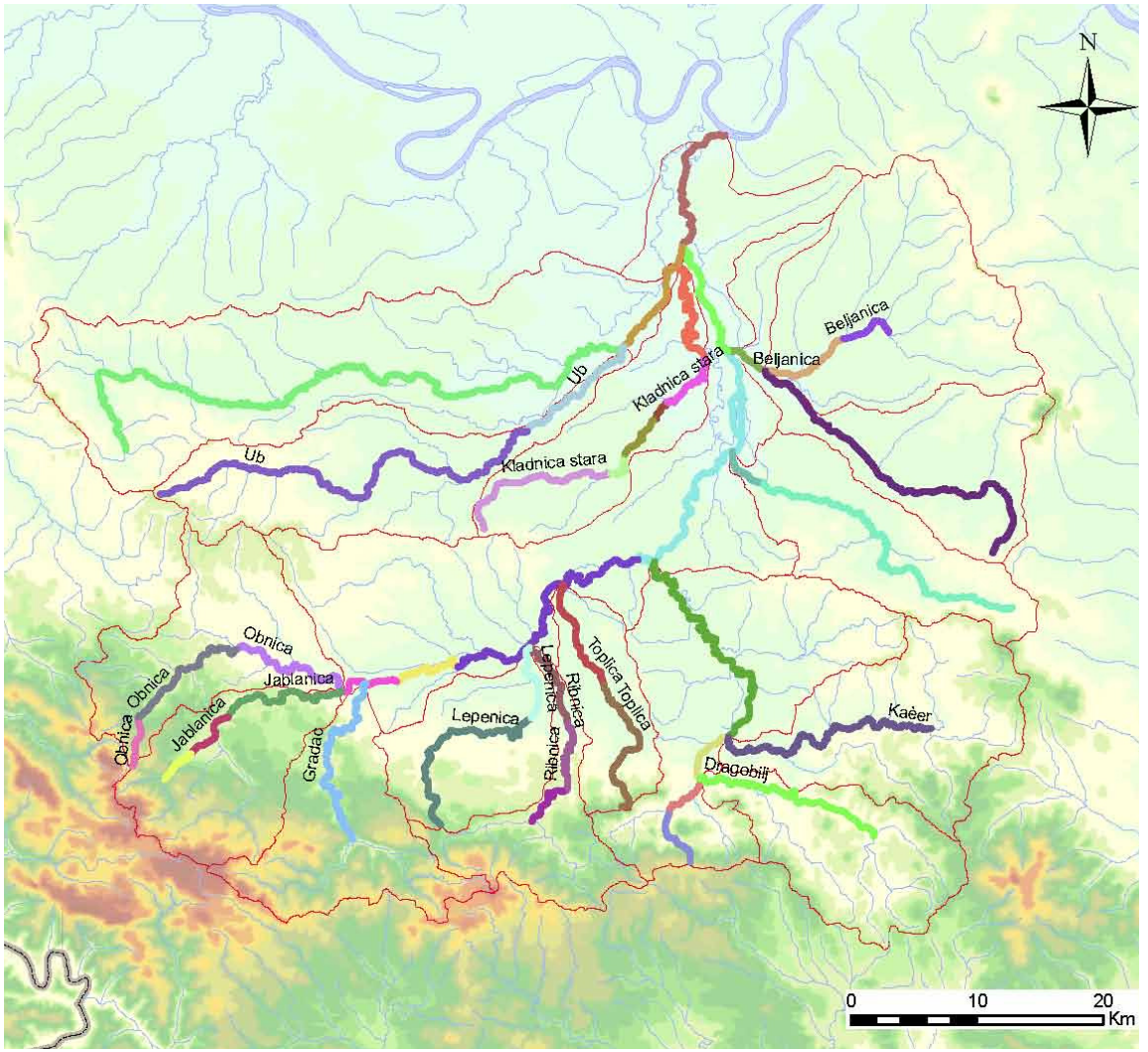


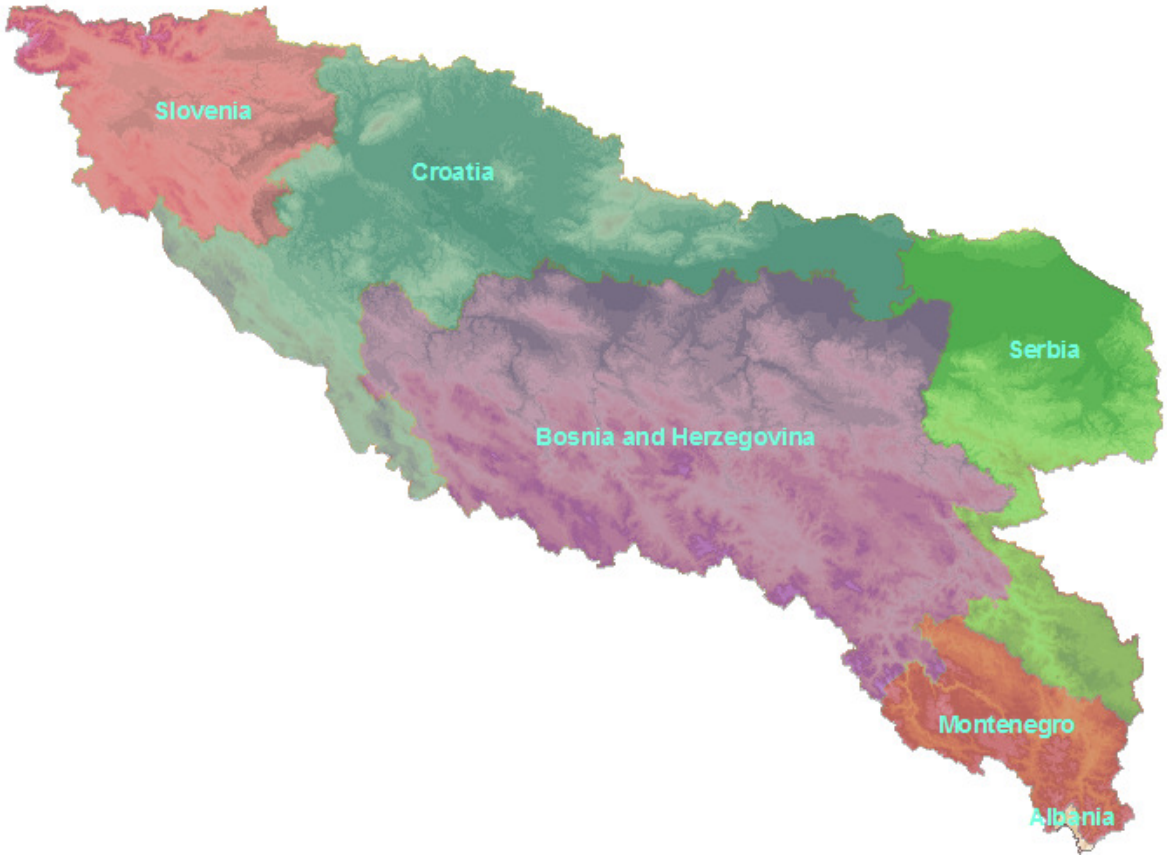
Left tributaries – drainage channels and small rivers included in drainage systems

Right tributaries – drainage channels + small rivers + Kolubara river

Kolubara River

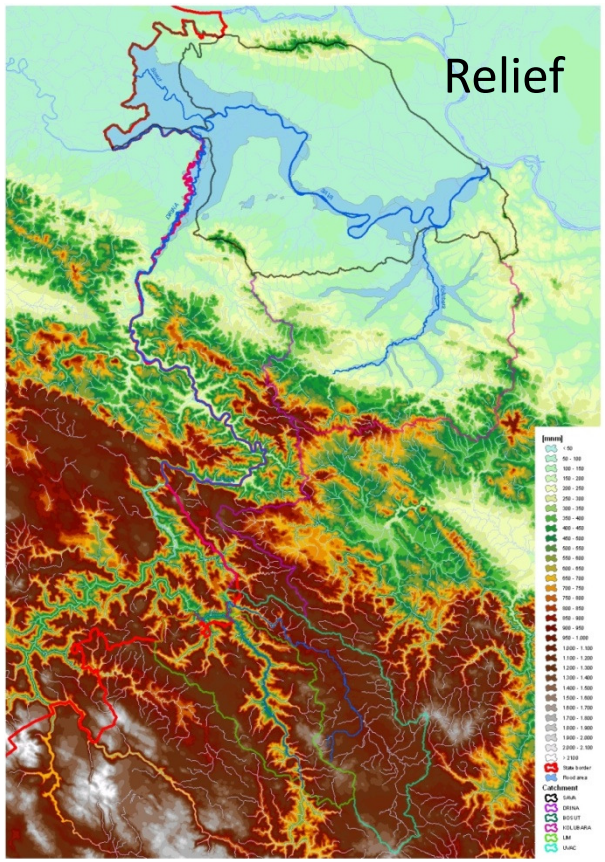
The largest national tributary (A=3.650 km^2, L=86,4 km)
Mouth: Sava River, near Belgrade



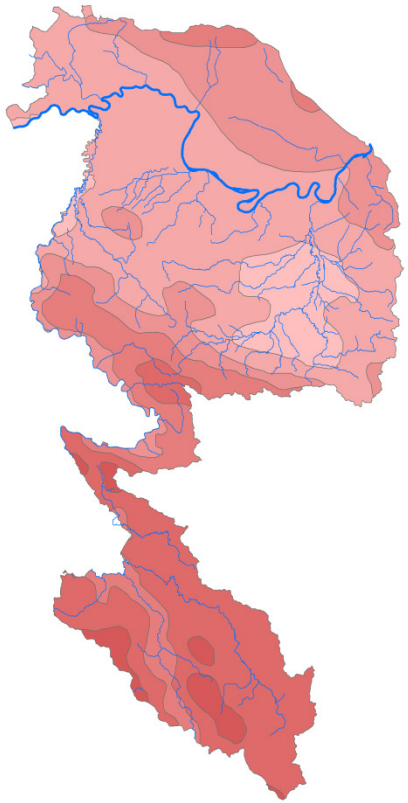


2. SEDIMENT BALANCE

Basic factors of sediment production

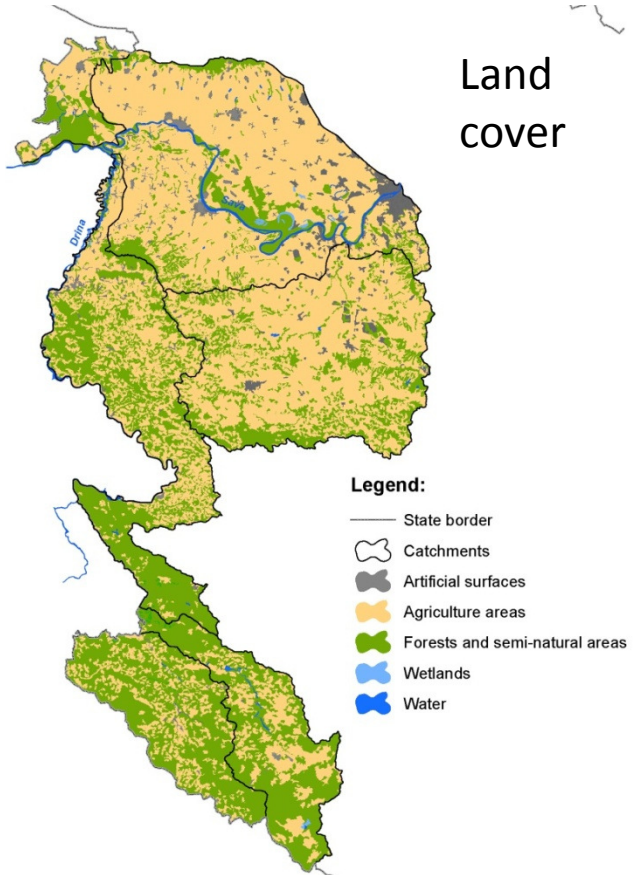


Runoff

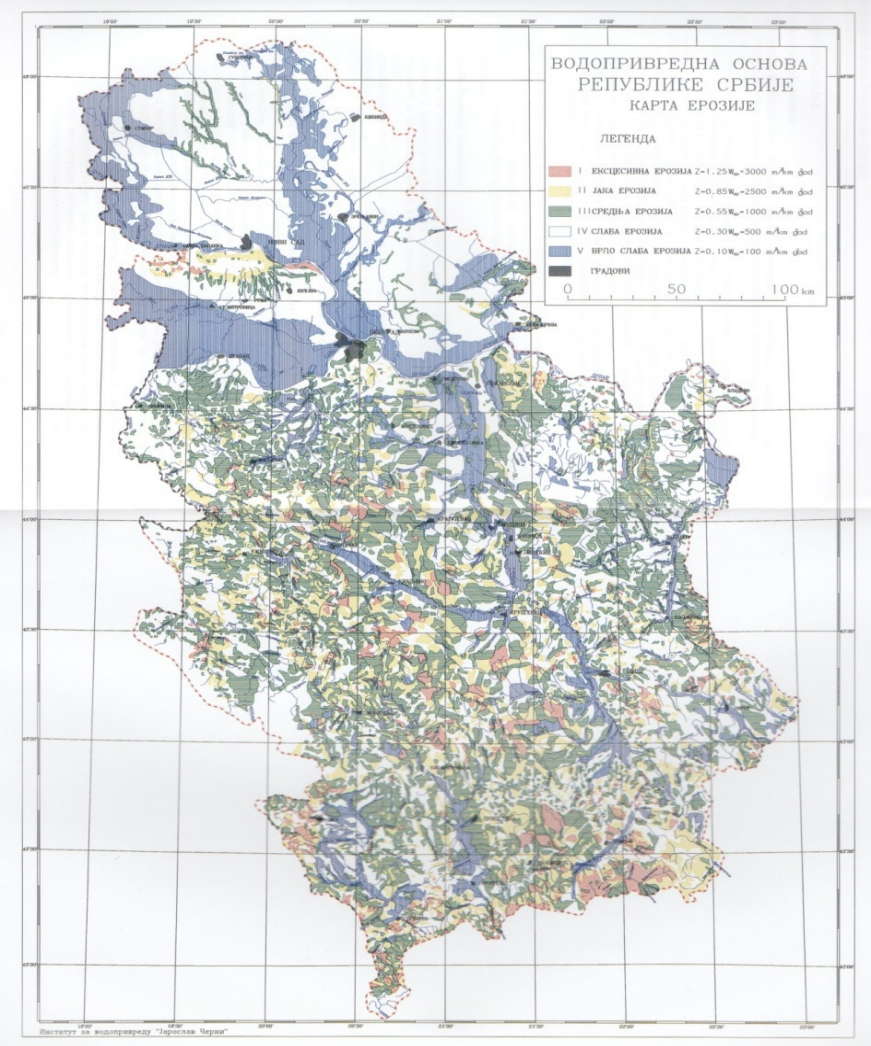


Runoff (mm):
- 150-200
- 200-250
- 250-300
- 300-400
- 400-500
- 500-600
- 600-700
- 700-800
- 800-900
- 900-1000
- 1000-1100
- 1100-1200

Land cover



Sources of sediment



Map of erosion
Water Management Master Plan, 2001
(Erosion potential method)

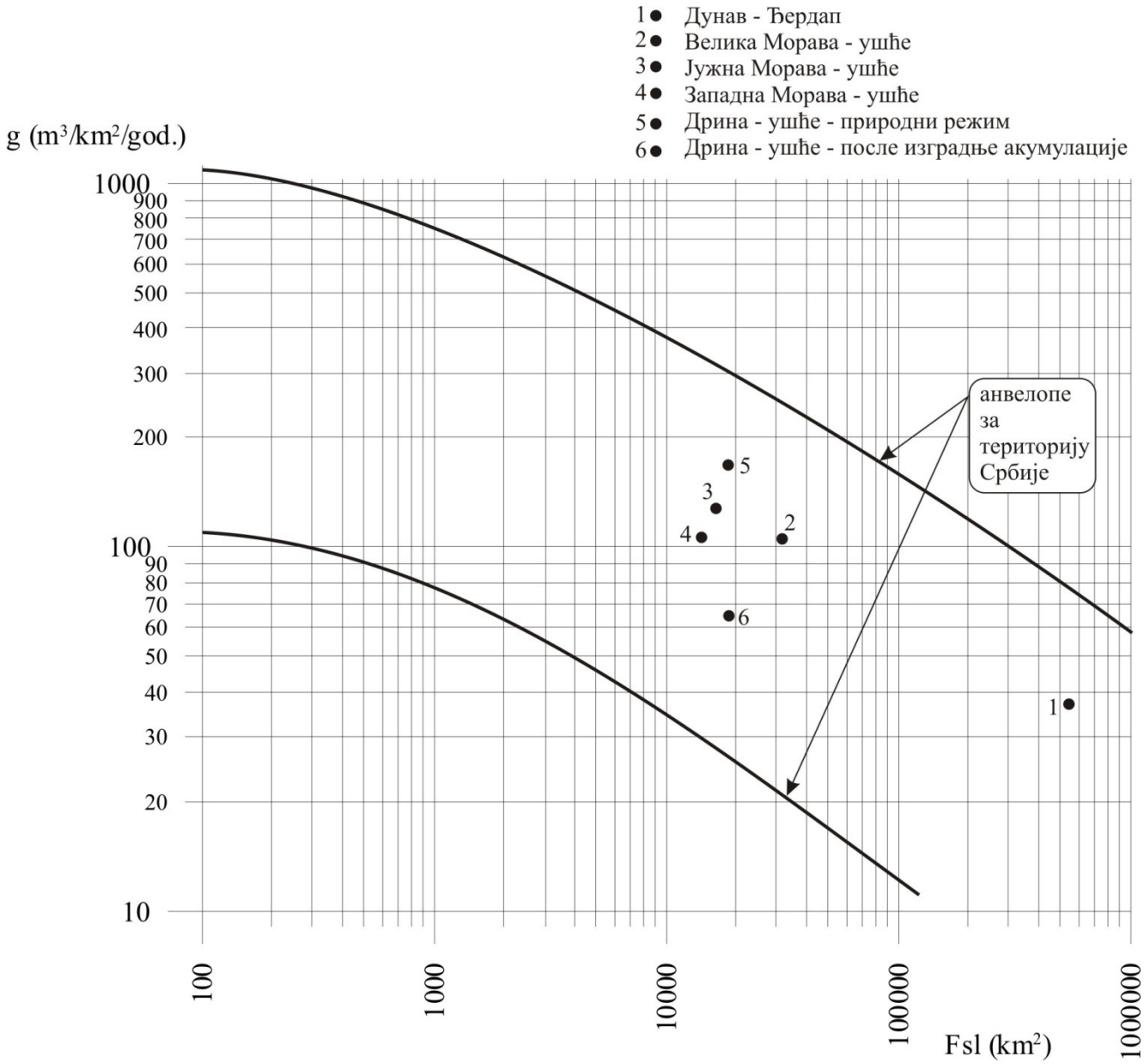
Erosion in the watershed

Classification of erosion

Basin	Cathegory of erosion (% of the area)				
	I	II	III	IV	V
	Excessive	Strong	Average	Weak	Very weak
Lowland parts along the Sava and small tributaries	1%	3%	10%	38%	48%
Drina river basin (Serbian part)	2%	9%	28%	59%	2%
Kolubara river basin	2%	7%	42%	40%	9%

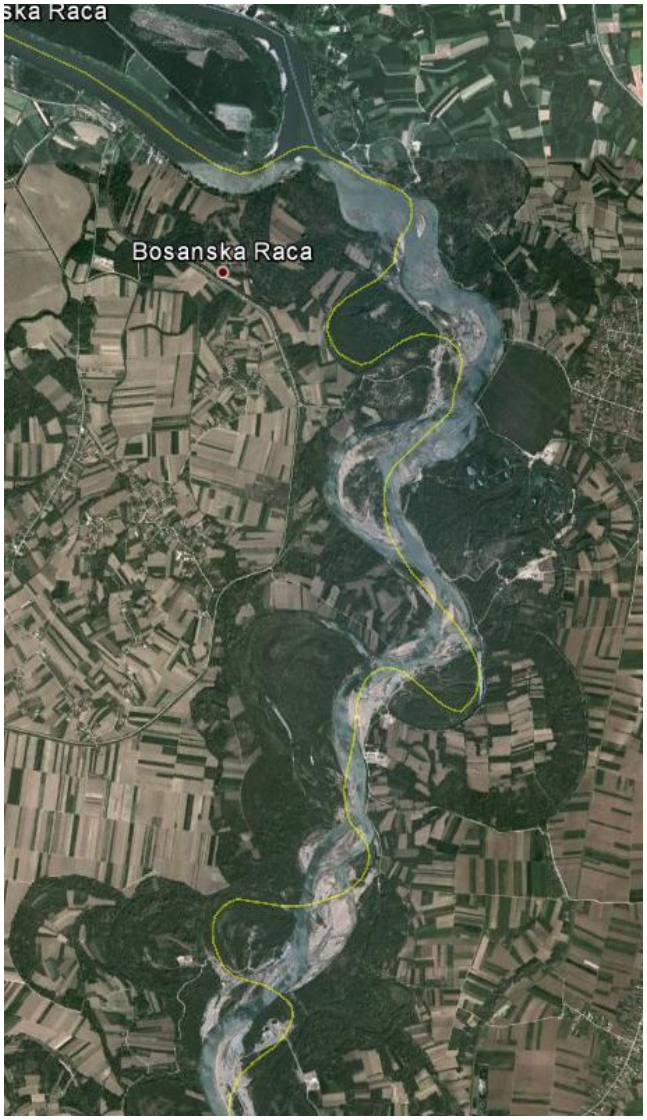
Bank erosion - present on all natural watercourses in the Sava river basin, buth with different intensity – most severe on the Lower Drina (downstream of the Zvornik reservoir)

(Glacial erosion)


1● Дунав - Ђердап
2● Велика Морава - ушће
3● Јужна Морава - ушће
4● Западна Морава - ушће
5● Дрина - ушће - природни режим
6● Дрина - ушће - после изградње акумулације
g (m³/km²/god.)
1000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
анвелопе за територију Србије
1
2
3
4
5
6
100
1000
10000
100000
1000000
Fsl (km²)

Bank erosion

- **Lower Drina (downstream of the Zvornik dam)** - intensive fluvial erosion is accompanied with sediment accumulation and bar formation, and the instability of the river alignment
- Rate of erosion is estimated to 1-0.5 million m^3/year (based on the length of eroded banks)



- **Lower Kolubara**

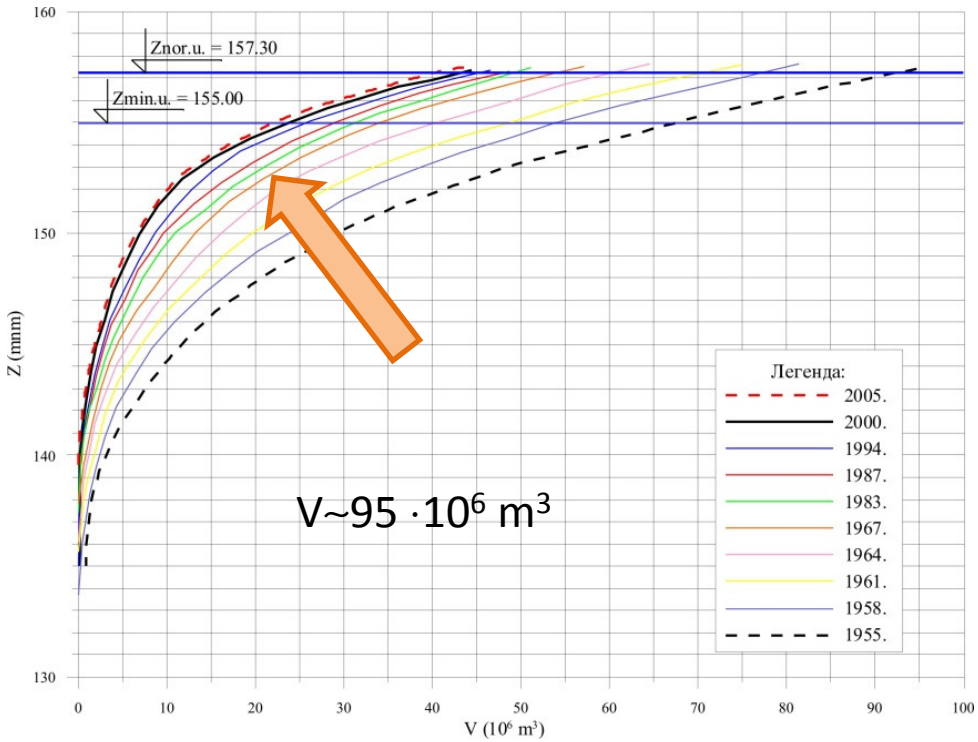
Reservoir sedimentation

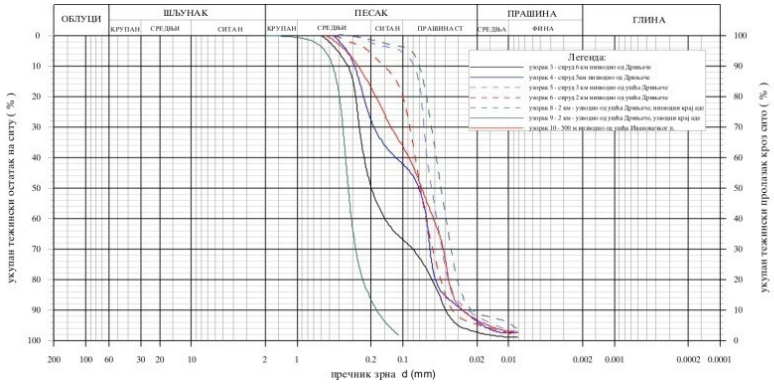
HPP Zvornik reservoir

- The most downstream reservoir in the Drina River basin was built first!
- 1/3 of the initial volume was filled in the 13 first years of operation

  Sedimentation 1955-1967: $\Delta V=38\cdot10^6$ m^3; $2{,}92\cdot10^6$ m^3/year
- After the erection of the upstream Bajina Basta dam, sedimentation exists, but the rate is lower:

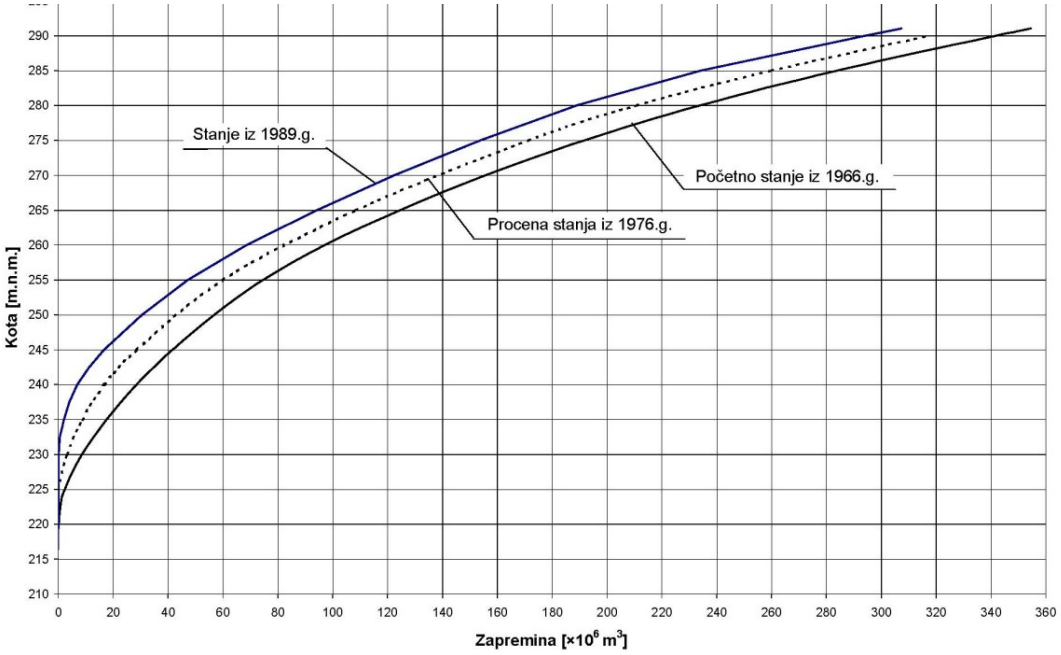
  Sedimentation 1967-2005: $\Delta V=16\cdot10^6$ m^3; $0{,}42\cdot10^6$ m^3/year

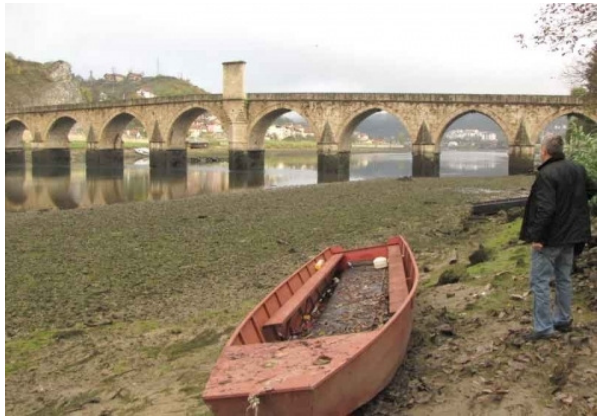




Reservoir sedimentation

HPP Bajina Bašta reservoir

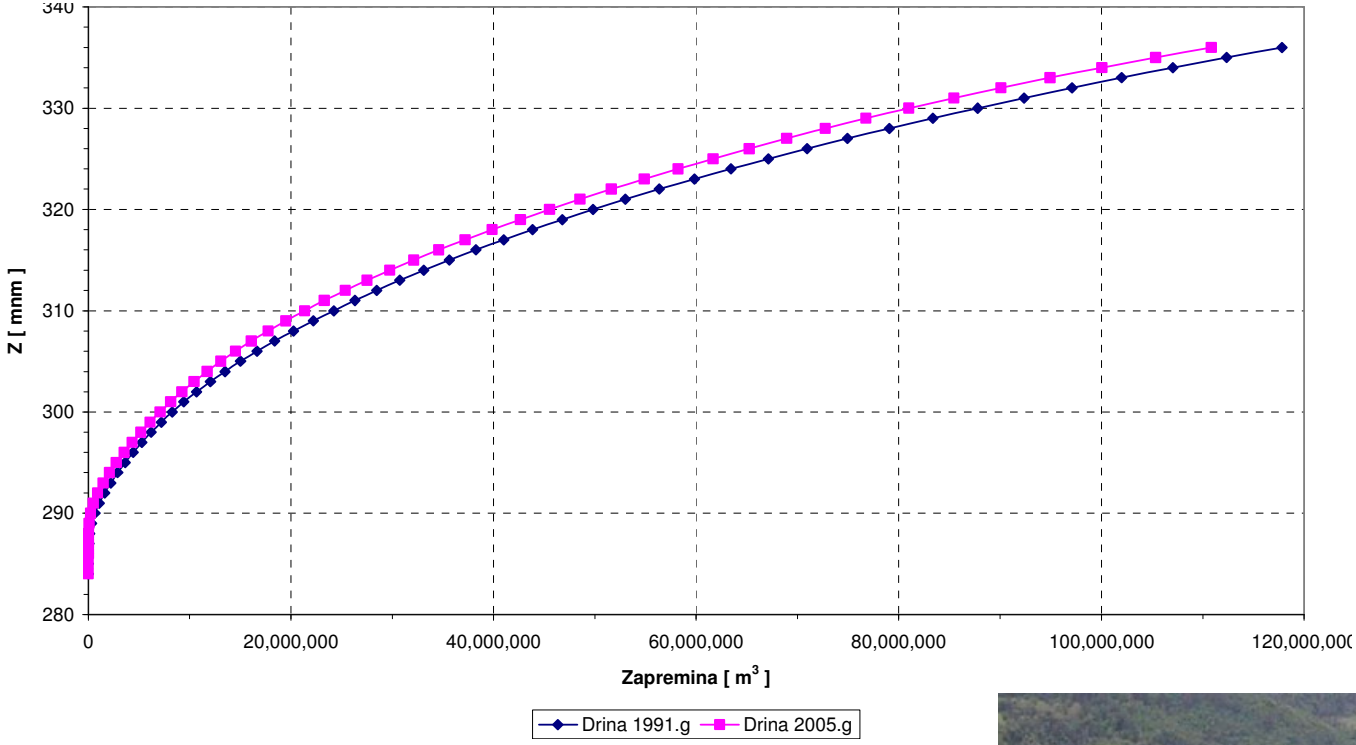




Polluted?

Reservoir sedimentation

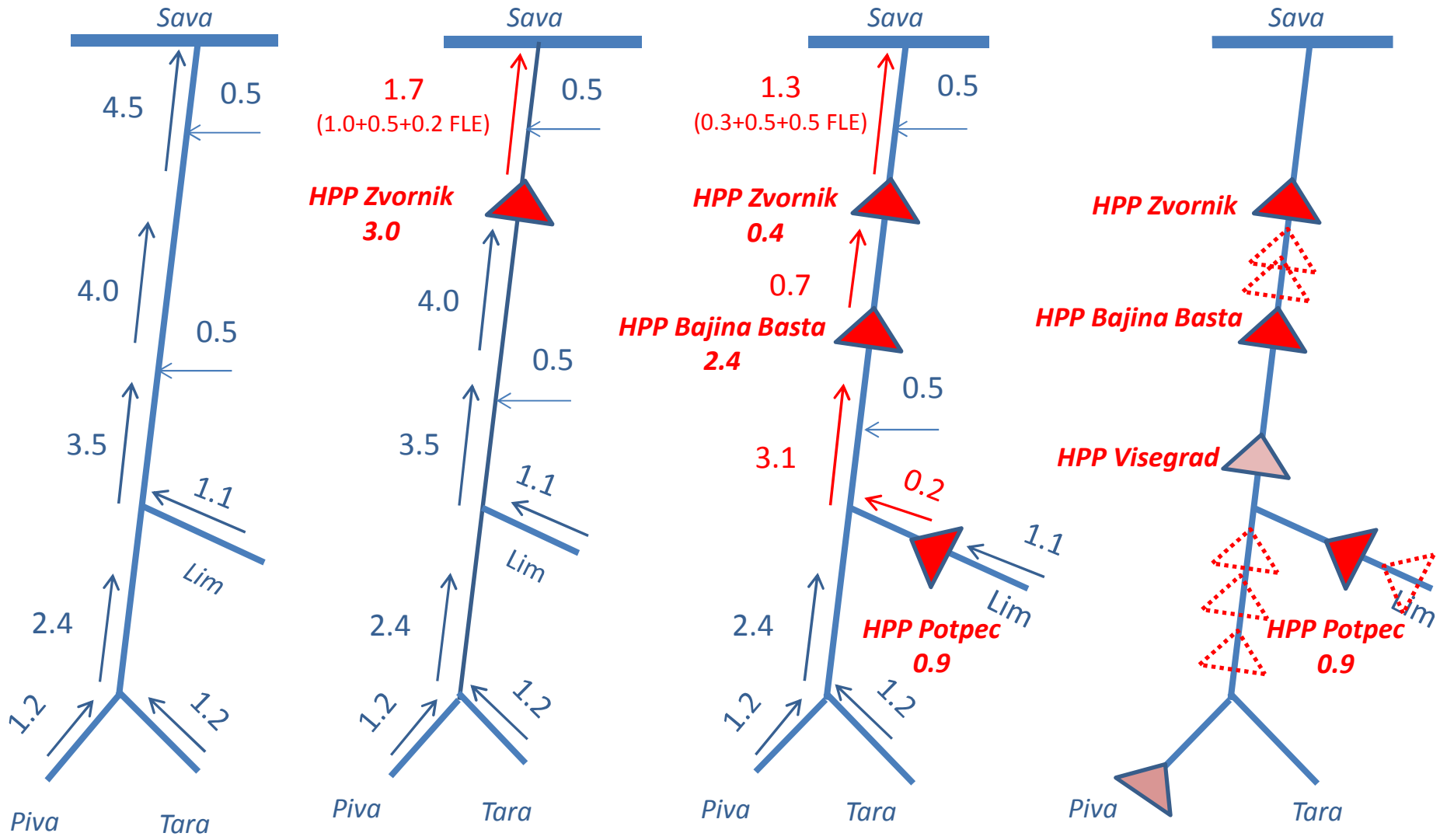
HPP Višegrad reservoir



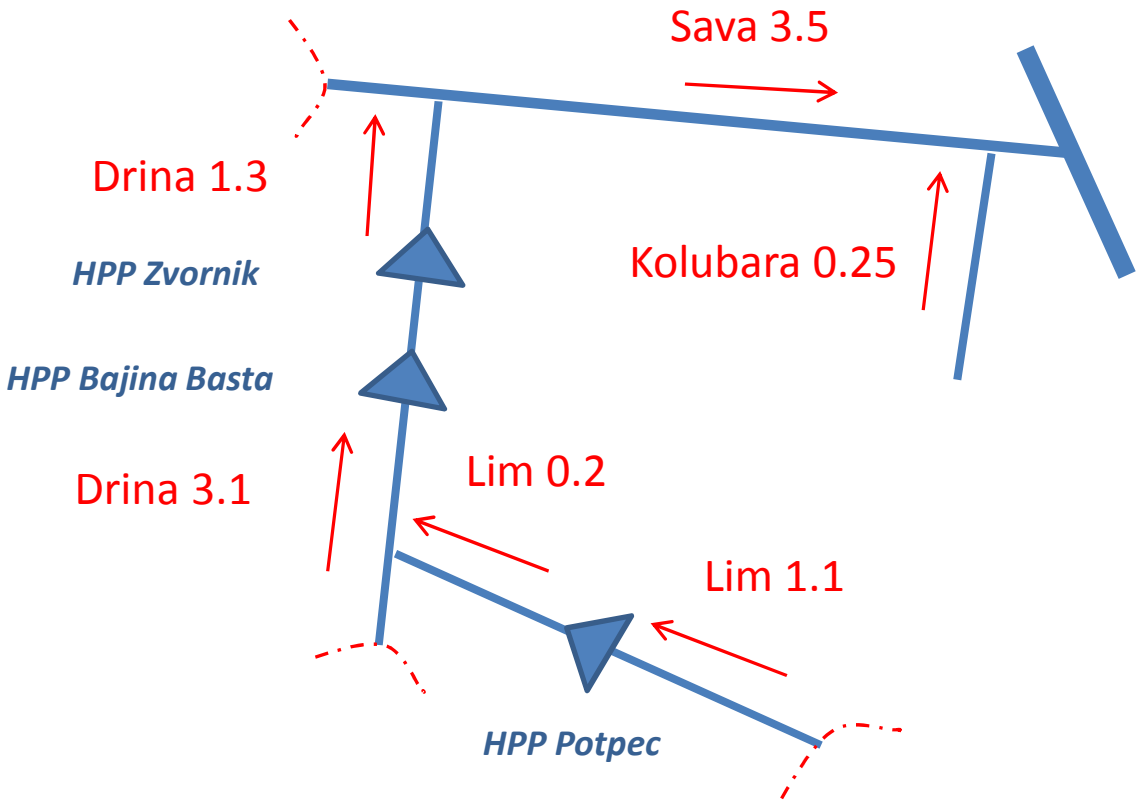
XL bottom outlets = no sedimentation

Sediment balance - Drina river basin

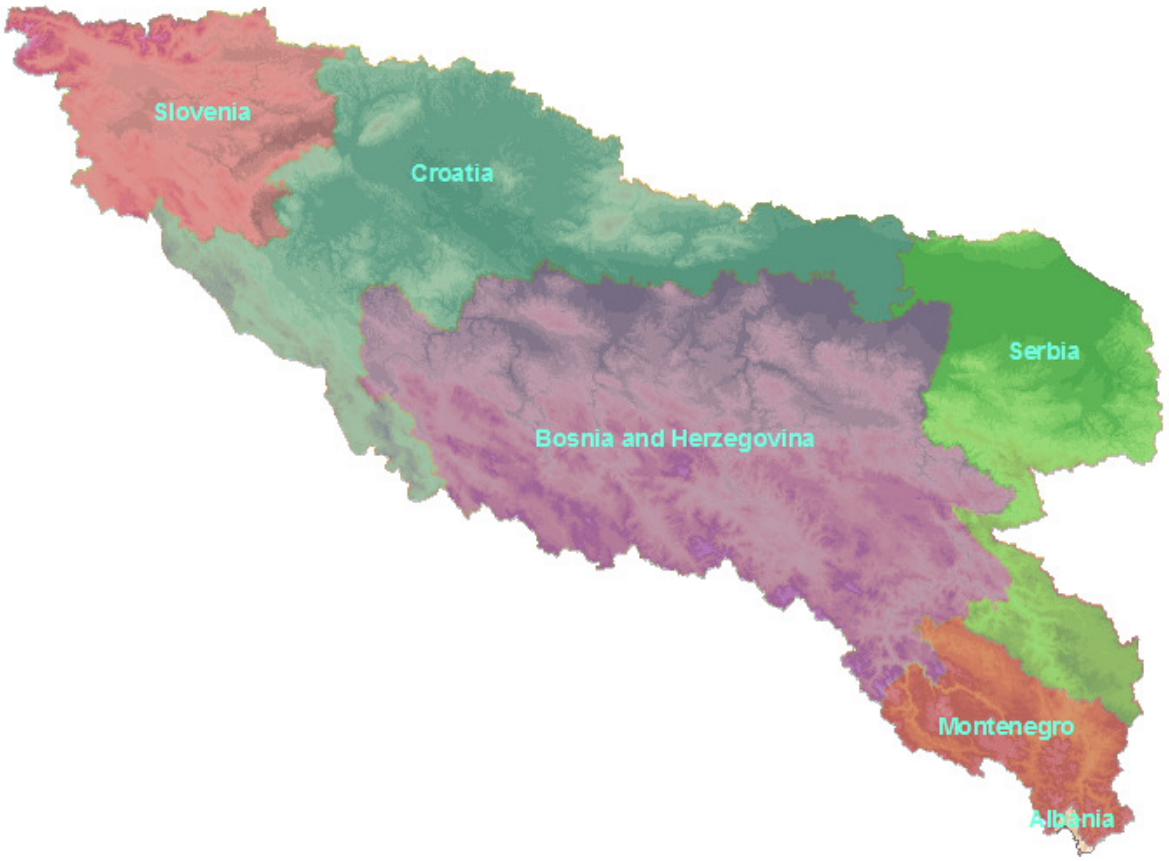
The average yearly sediment transport (million m^3)



SRB - Estimate of present sediment balance



The average yearly sediment transport (million m^3)



3. SEDIMENT MONITORING

No regular measurements of suspended and bed load transport in the river system!!!

Drina River

Very heterogeneous database

1. Measurements of suspended sediment – Republic hydrometeorological service of Serbia, at:
   - Drina: Mihaljevici (1991-2002), Radalj (1984-2002), Badovinci (1990-2001)
   - Lim: Prijepolje (1963-2002)
   - Crni Rzav: Vardiste (1990-1995)
2. Institute Jaroslav Cerni – measurements on Lower Drina (downstream of Zvornik dam), between 1985 and 1987
   - Daily concentrations of suspended sediment
   - Bed load sampling (10 campaigns)
3. Estimates of sediment yield in the Drina river basin, based on erosion maps
4. Bed material sampling along the river and in reservoirs
5. Investigations of the grain size and thickness of alluvial fan on the Lower Drina
6. Surveys and analyses of reservoir sedimentation (EPS)
7. Dredging

Drina River

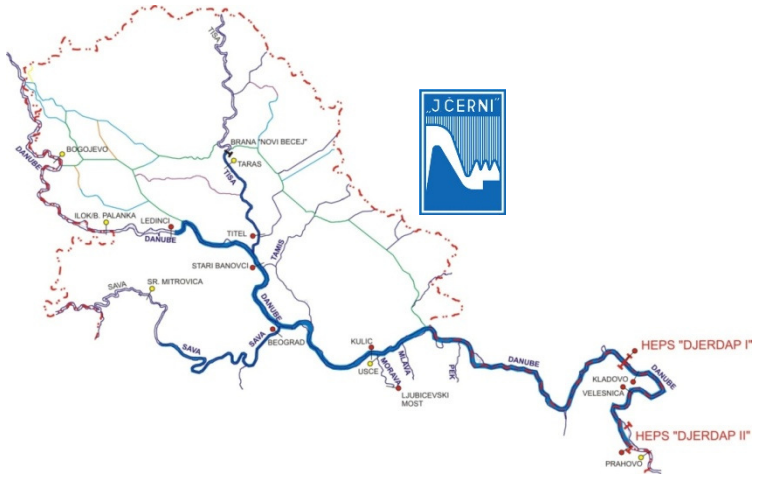
Dredging permits between mouth and km 60, 2005 - 2010:

- 335.925 - 788.507 m^3
- 10 - 31 location (max 175.900 m^3)

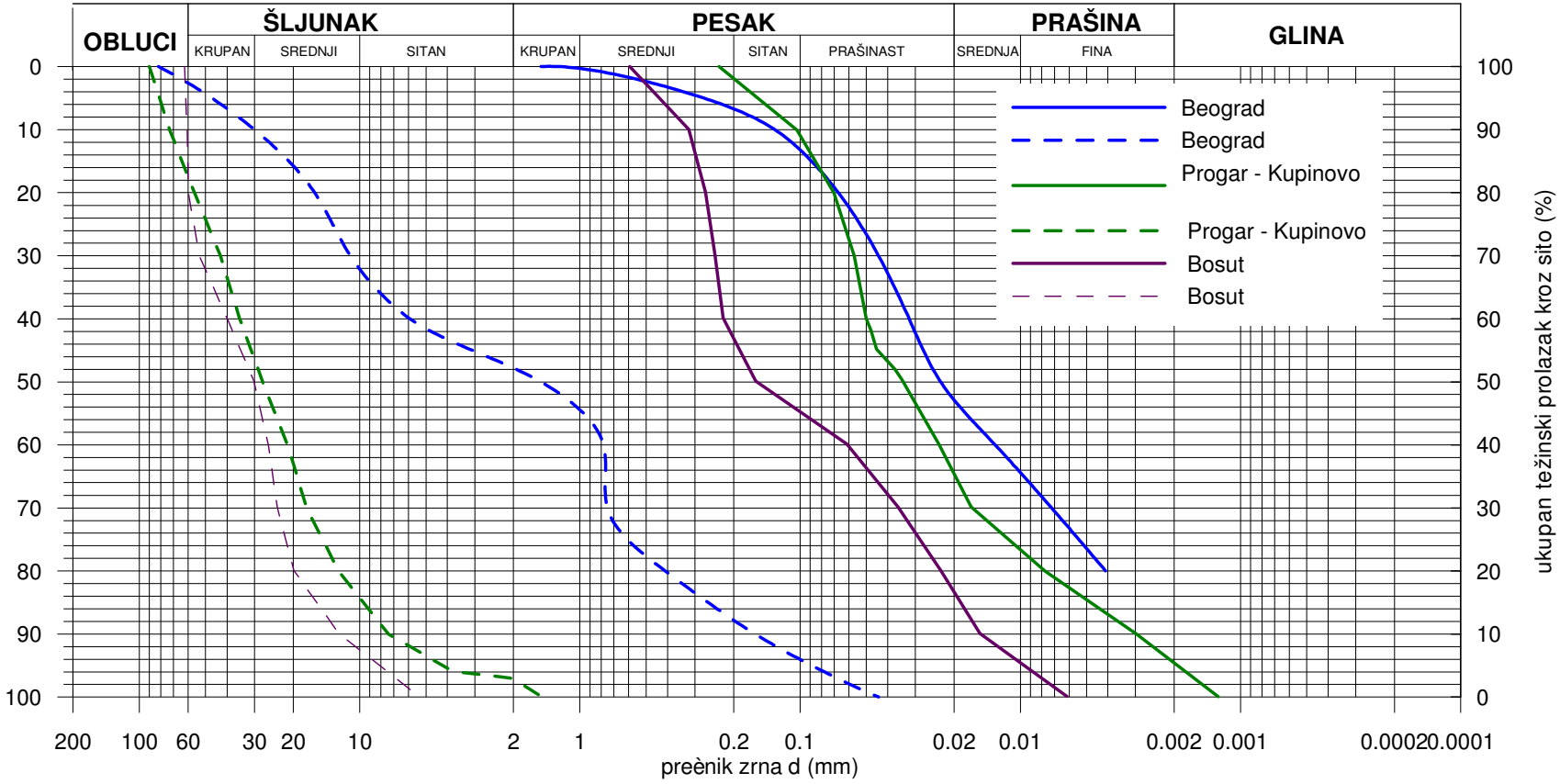
Problem of border between RS and BH

Sava River

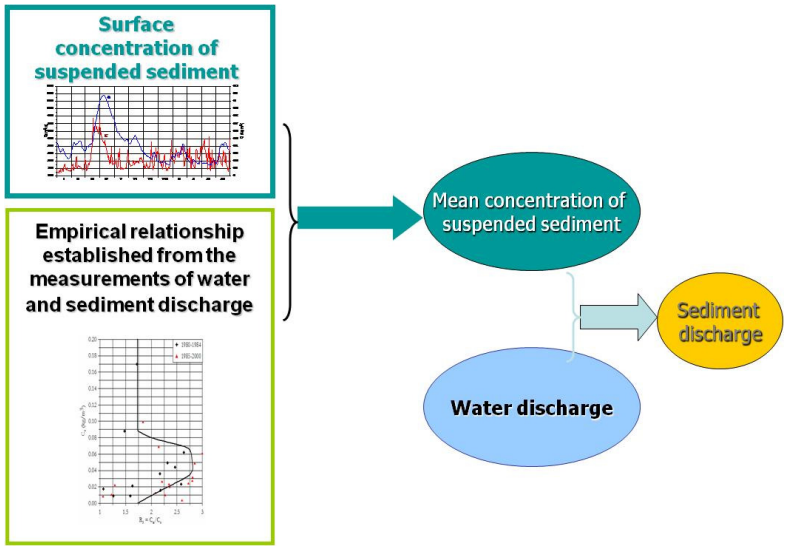
1. Measurements of suspended sediment – Republic hydrometeorological service of Serbia, at:
   - Sremska Mitrovica (1958-1980)
   - Sabac (1958-2002),
   - Beograd (1958-1998)
2. Monitoring of the Iron Gate 1 reservoir sedimentation – Institute Jaroslav Cerni, 1974 – 2012, between the mouth to Danube and Sabac (km 100)
   - Daily concentrations of suspended sediment and suspended sediment transport – Sremska Mitrovica and Beograd
   - Morphological changes in the river bed
3. Various studies, designs etc.
   - Bed material sampling along the river
   - Investigations of the grain size and thickness of alluvial deposits



Sava River


OBLUCI
ŠLJUNAK
KRUPAN
SREDNJI
SITAN
PESAK
KRUPAN
SREDNJI
SITAN
PRAŠINAST
PRAŠINA
SREDNJA
FINA
GLINA
Beograd
Beograd
Progar - Kupinovo
Progar - Kupinovo
Bosut
Bosut
0
10
20
30
40
50
60
70
80
90
100
200
100
60
30
20
10
2
1
0.2
0.1
0.02
0.01
0.002
0.001
0.0002
0.0001
preènik zrna d (mm)
ukupan težinski prolazak kroz sito (%)

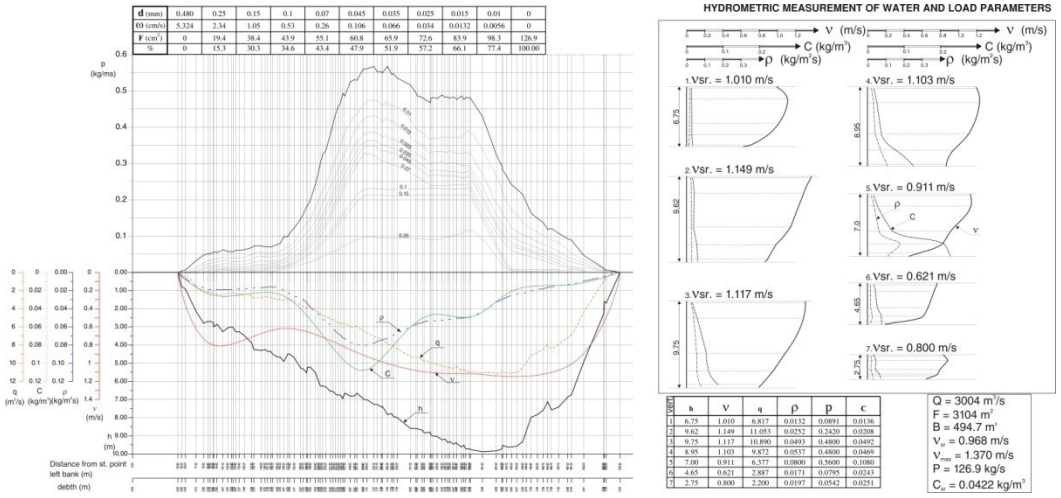
Sava River



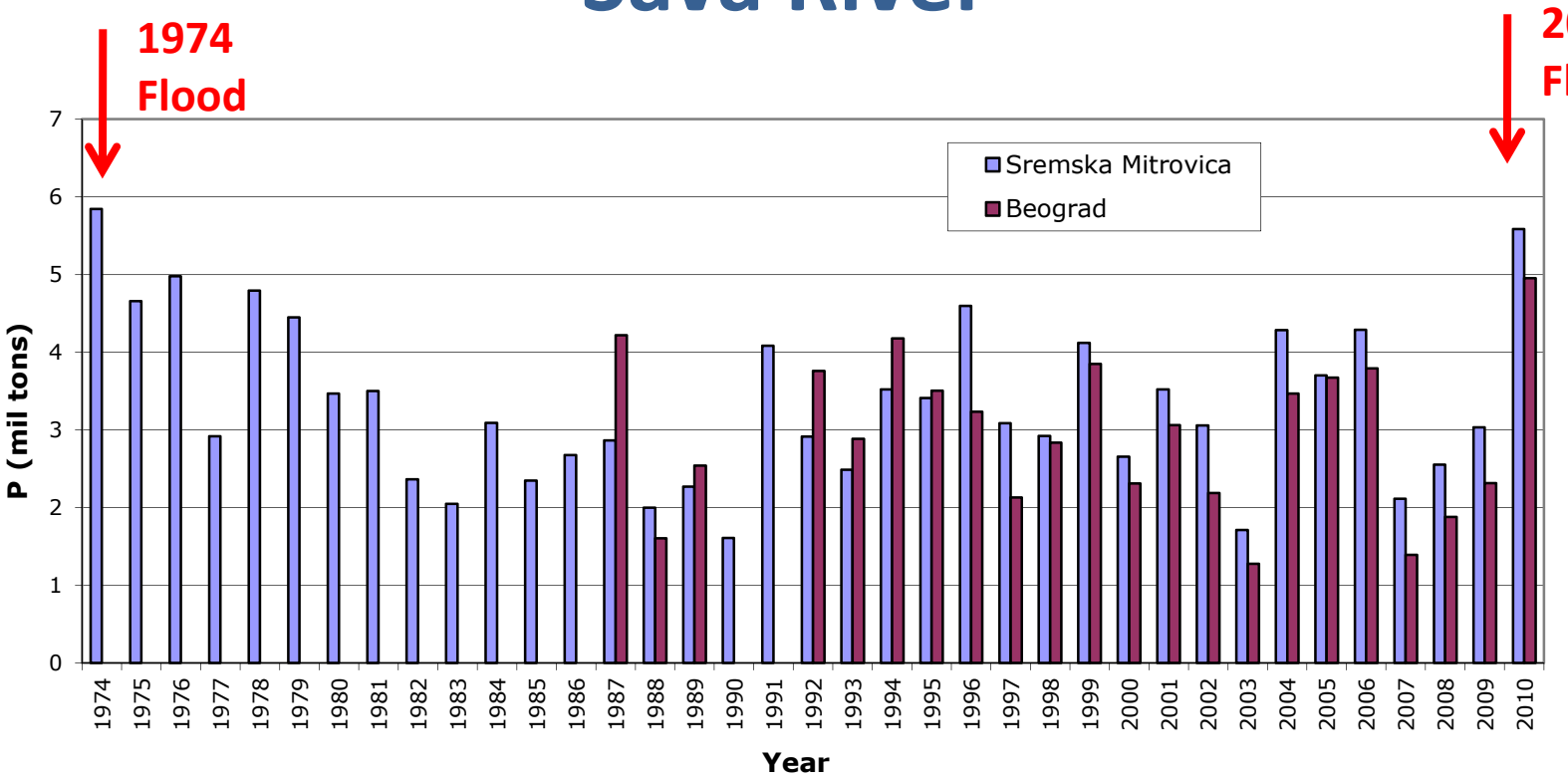
Monitoring of IG 1 reservoir sedimentation

1. Suspended sediment concentration derived from samples (volume 5 l) taken from the fixed point at the water surface
2. Measurements of water and sediment discharge 1-2 times per year: (a) Echo-sounding of river cross-section; (b) Flow velocity measurement; (c) Taking 25 samples of water and suspended sediment (5 points at each of 5 verticals) and (d) Sampling 5 kg of bed material in each vertical.

   Vacuum bathometer (with 40 l bottle) is used for suspended sediment sampling

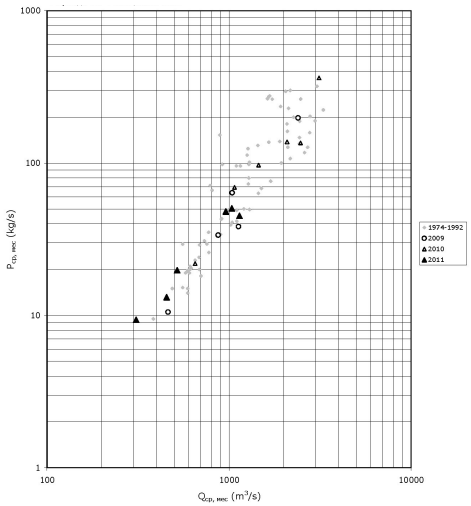


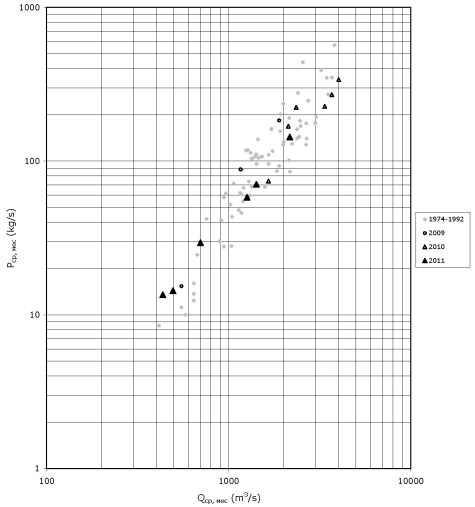
Sava River



April-October

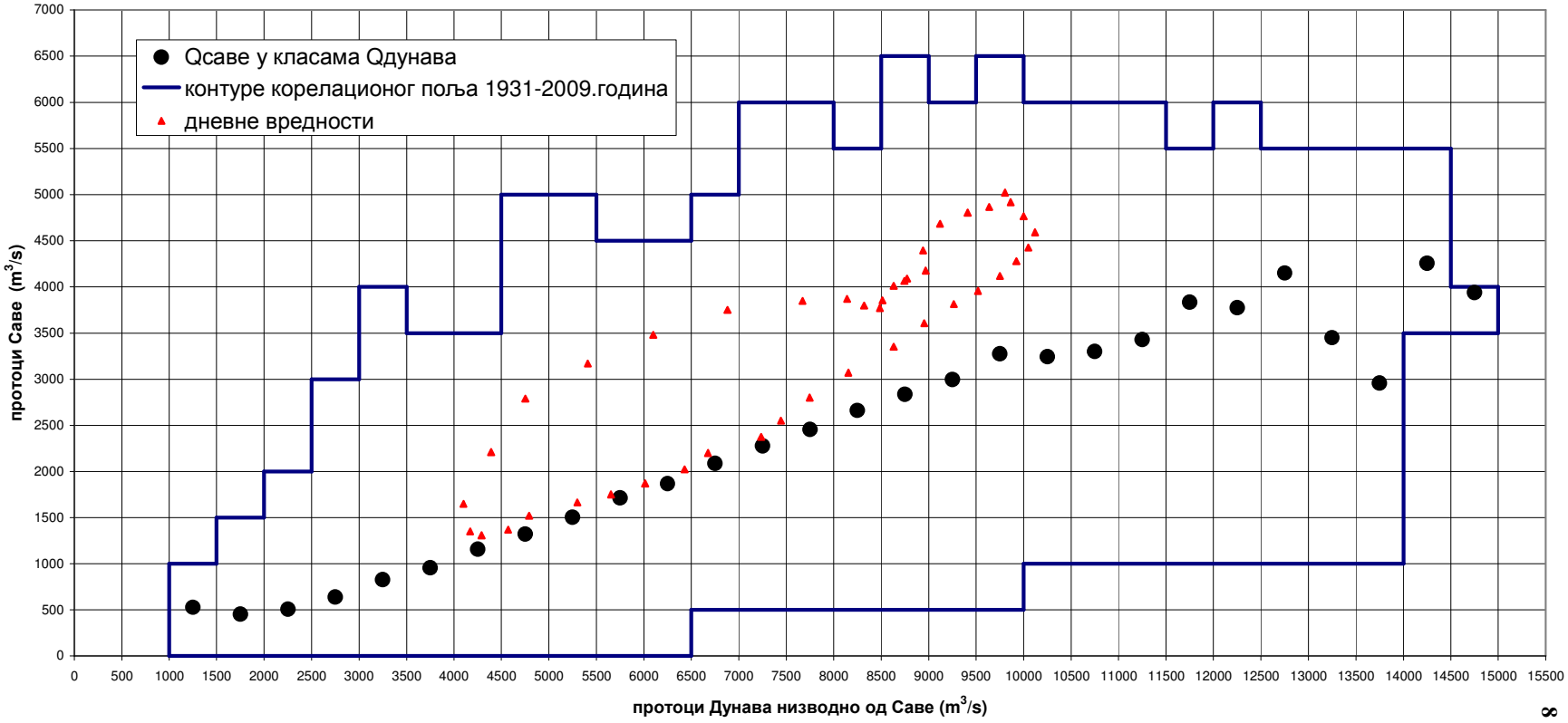
$Q_{av} - P_{s,av}$



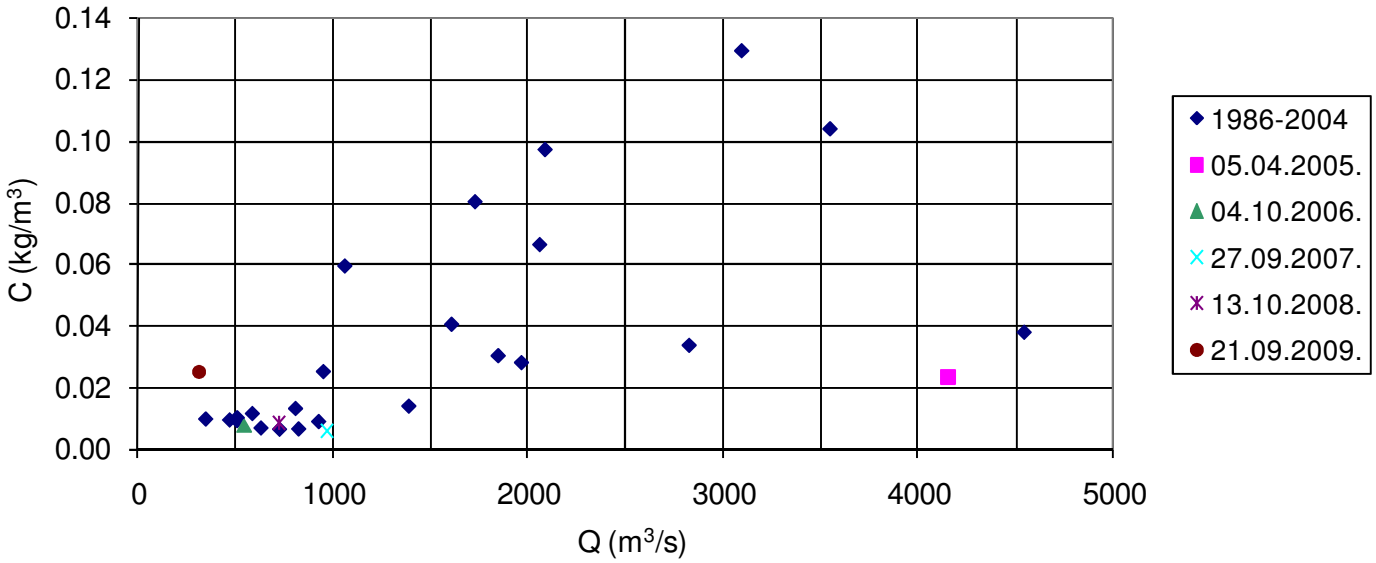


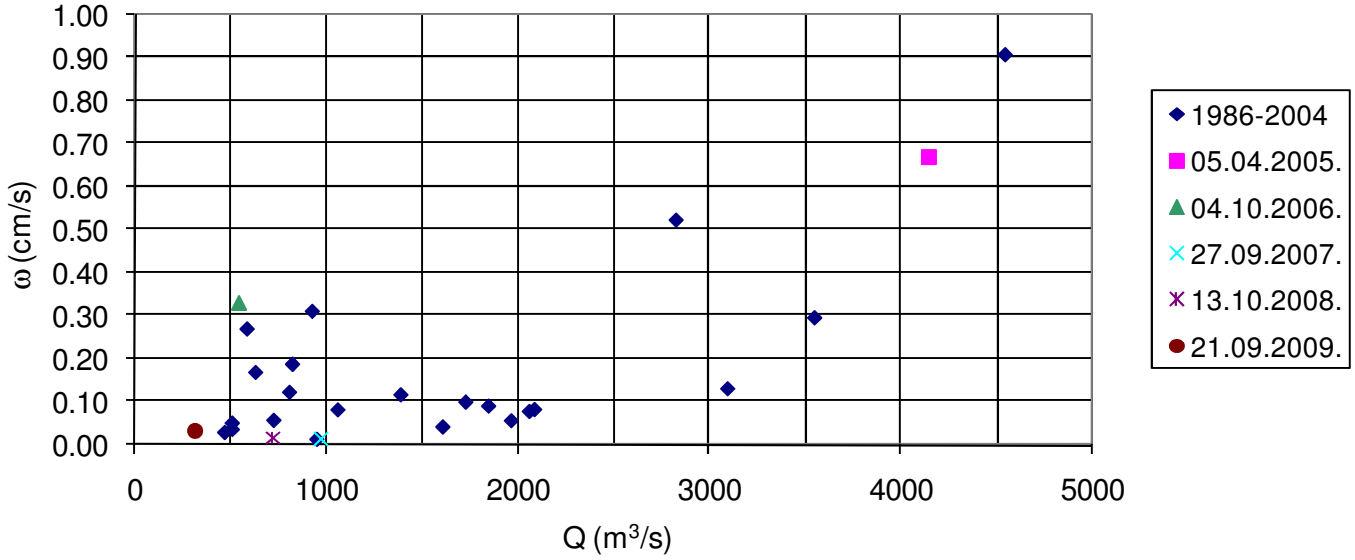
November-March

Sava River


Qcаве у класама Qдунава
контуре корелационог поља 1931-2009.година
дневне вредности
протоци Саве (m3/s)
протоци Дунава низводно од Саве (m3/s)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000
7500
8000
8500
9000
9500
10000
10500
11000
11500
12000
12500
13000
13500
14000
14500
15000
15500

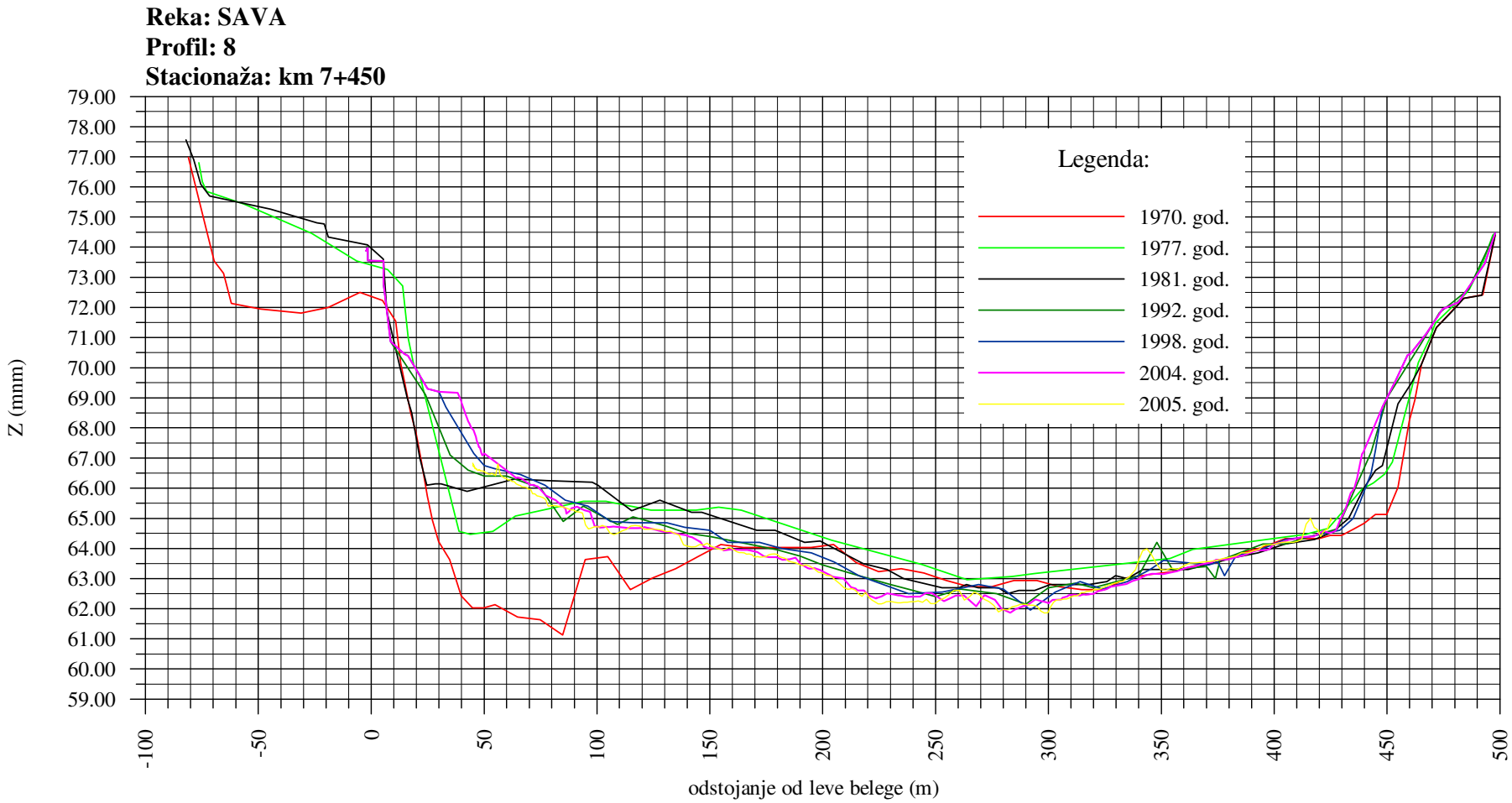
Sava River


0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
C (kg/m3)
0
1000
2000
3000
4000
5000
Q (m3/s)
1986-2004
05.04.2005.
04.10.2006.
27.09.2007.
13.10.2008.
21.09.2009.


1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
ω (cm/s)
0
1000
2000
3000
4000
5000
Q (m3/s)
1986-2004
05.04.2005.
04.10.2006.
27.09.2007.
13.10.2008.
21.09.2009.

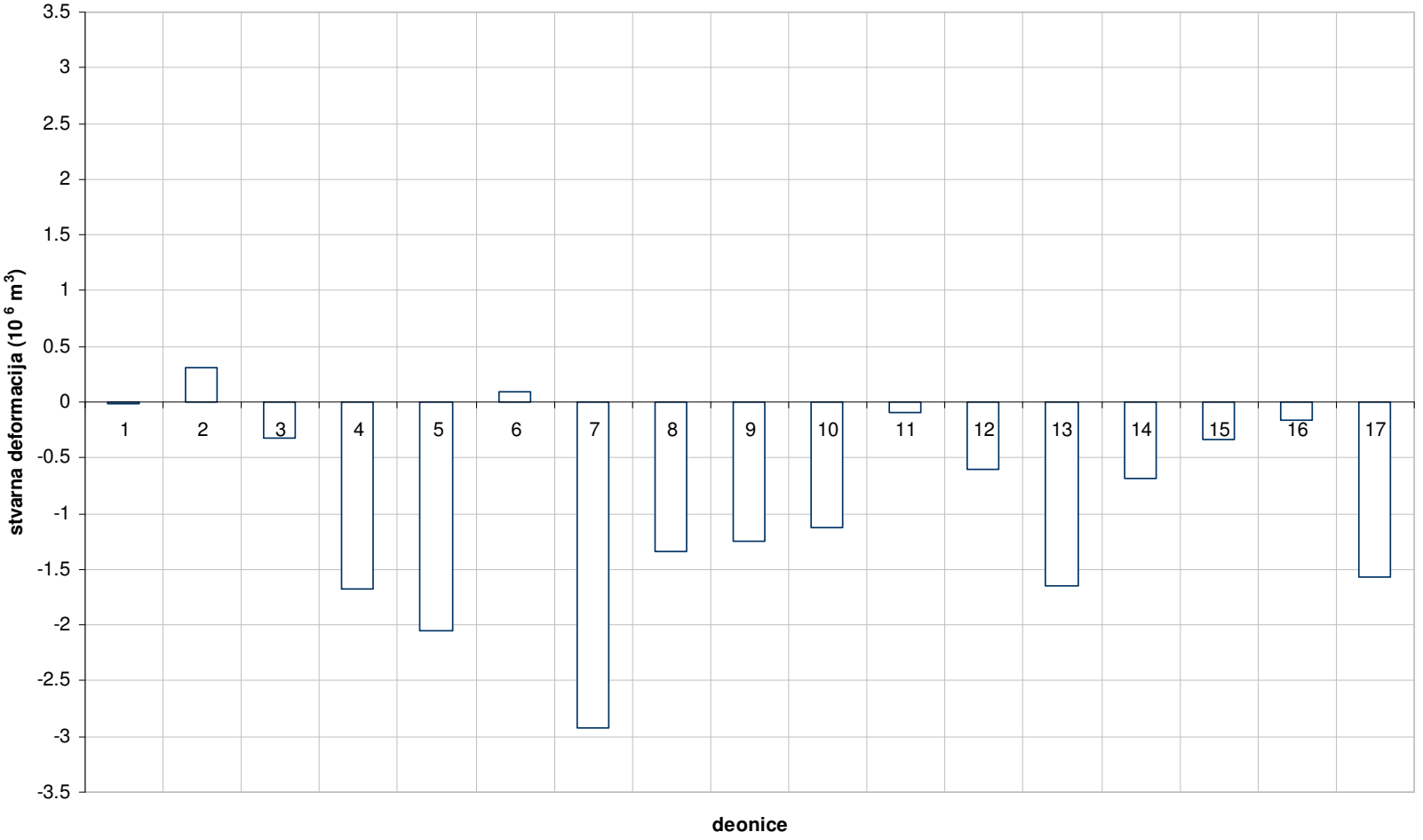
Sava River

Survey of permanent cross-sections, 1 km distance



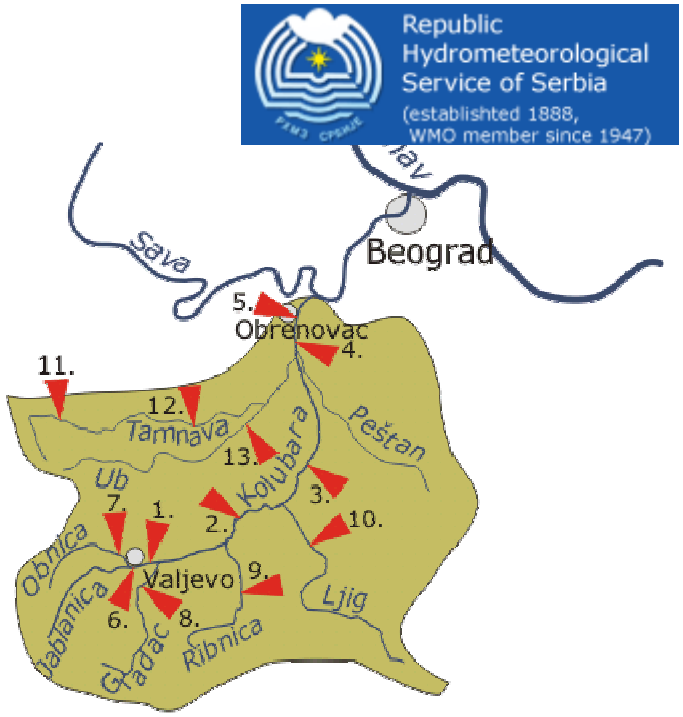
Sava River

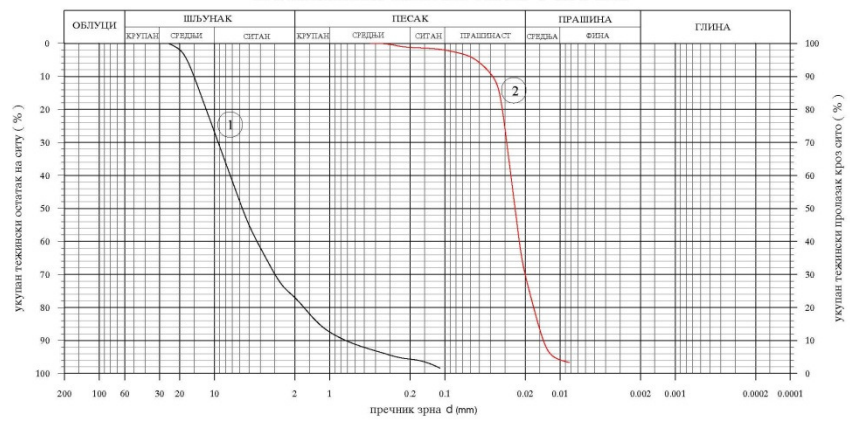
Morphological changes in the river bed 1982-2004 = dominant erosion
Volumes of dredged material taken into account



Kolubara River

1. Measurements of suspended sediment – Republic hydrometeorological service of Serbia, at:
   - Slovac (1958-1992)
   - Beli Brod (1986-2001)
   - Drazevac (1958-2002)
   - Stuborovni (1983-1993)
2. Institute Jaroslav Cerni & other - Various studies, designs etc.
   - Morphological changes in the river bed
   - Bed material sampling along the river





Monitoring of quality of sediment in rivers and reservoirs

Republic hydrometeorological service of Serbia


Република Србија
РЕПУБЛИЧКИ ХИДРОМЕТЕОРОЛОШКИ ЗАВОД

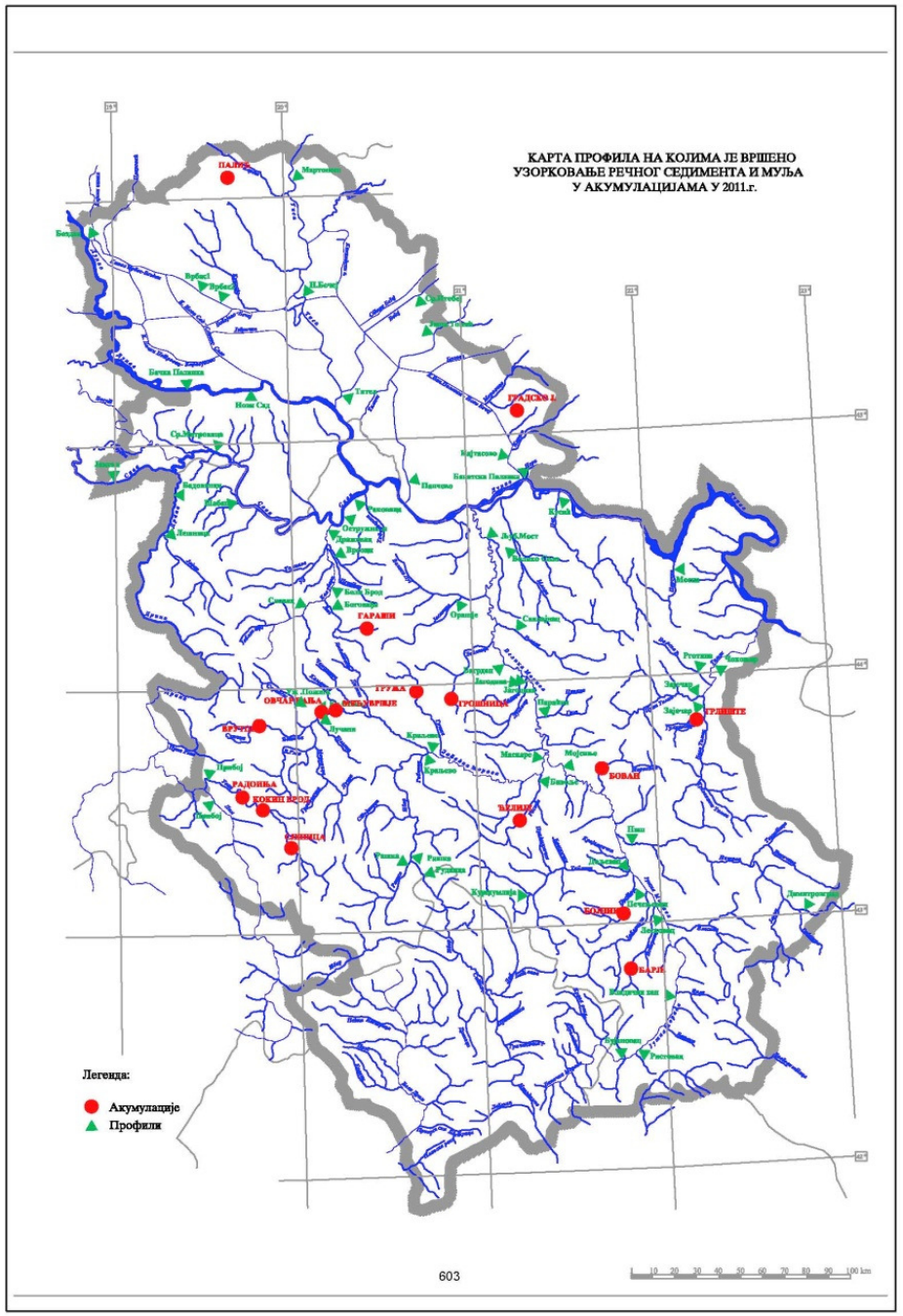
ХИДРОЛОШКИ ГОДИШЊАК

3. КВАЛИТЕТ ВОДА
2010.

Београд, 2011. година

Agency for Environmental Protection – since 2011

Monitoring of sediment quality



River sediment

Sava: Jamena, Sremska Mitrovica, Šabac, Ostružnica

Drina: Badovinci, Lešnica (Jadar)

Lim: Priboj, Priboj (Uvac)

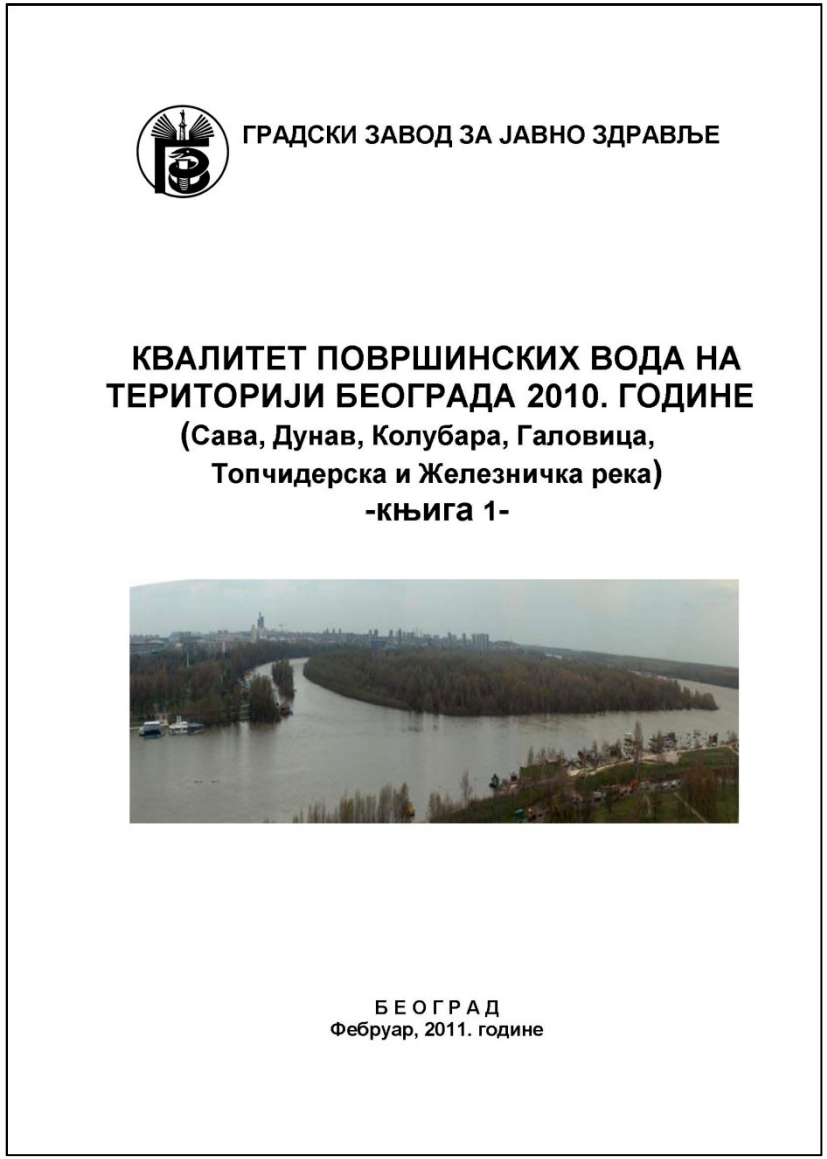
Kolubara: Slovac, Beli Brod, Draževac, Bogovađa (Ljig), Vreoci (Peštan)

Other tributaries: Rakovica (Topčiderska r.)

Reservoir sediment

Uvac: Kokin Brod, Radoinja, Sjenica (Uvac)

Monitoring of sediment quality

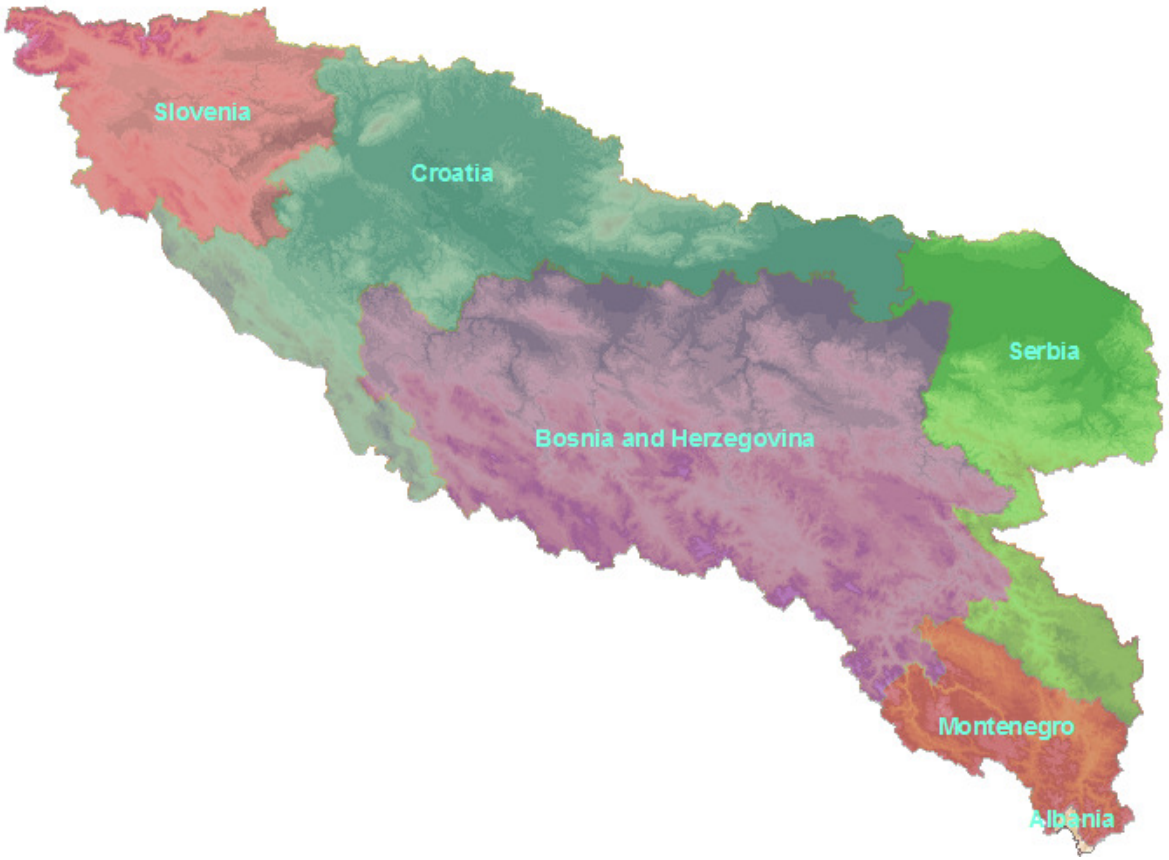


Detailed examination of sediment quality on the Sava river and its tributaries within the limits of the Belgrade city:

- **Sava:** Zabran (30km), Duboko (24km), Makiš (10km)
- **Kolubara:** 2 profiles + its tributaries Peštan, Turija, Beljanica, Lukavica (1 profile)
- **Galovica channel:** 2 profiles
- Other small tributaries of Sava r. (Topčiderska r., Železnička r., Barička r.)

Cleaning of hot spot in Belgrade

Mouth of Topciderka River – inflow of polluted water and sediment into the Sava



3. EVALUATION OF SEDIMENT QUANTITY AND QUALITY

Some proposals for the future monitoring

- Present scope of sediment monitoring in Serbia is not sufficient – only partial investigations of sediment parameters for different purposes
- Sediment monitoring is envisaged in Program of Republic hydrometeorological service of Serbia, but instruments/methodology should be updated
- Transboundary rivers - Sediment monitoring profiles and methodology of sampling and laboratory testing should be agreed between countries
  - Upper Drina and Lim – B&H, MNE, Serbia
  - Lower Drina - B&H (RS), Serbia
  - Sava – Slovenia, Croatia, B&H, Serbia
- National rivers – the same methodology as for transboundary rivers

In SSM plan national/international issues should be distinguished

The minimum scope of monitoring should cover:

- Suspended sediment transport
- Sedimentation of reservoirs
- Mapping of erosion processes (pluvial erosion, torrents, fluvial erosion)
- Investigations of sediment quality (WFD)

Is Sava a navigable river?

Sava River near Sabac, Serbia, August 2012

Thank you.