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Outline of the Sediment Management Plan for the Sava River Basin

Report on Sediment Management in the Sava River Basin

November 2021

Prepared by

International expert:	Damir Bekić, PhD
National expert:	Florjana Ulaga, MSc (Slovenia)
	Dijana Oskoruš, PhD (Croatia)
	Emina Hadžić, PhD (Bosnia and Herzegovina)
	Marina Babić Mladenović, PhD (Serbia)

Published by:

International Sava River Basin Commission

Kneza Branimira 29

Zagreb, Croatia

Phone: + 385 1 488 6960

Fax: + 385 1 488 6986

E-mail: isrbc@savacommission.org

Web: http://www.savacommission.org

Supported by:

UNESCO Office in Venice

4930 Palazzo Zorzi- Castelo

Venice, Italy

Foreword

The main objective of this ***Outline of the Sediment Management Plan*** is to provide an analysis of existing sediment management practices in the Sava River Basin and define further steps for development of the full-fledged Sediment Management Plan for the Sava River Basin.

The Protocol on sediment management to the FASRB[1], in force since October 2017, regulates the procedures of mutual cooperation related to sustainable sediment management to protect the integrity of the water and sediment regime in the Sava River Basin.

The Protocol obliges the Parties to the FASRB to cooperate in development of the Sediment Management Plan for the Sava River Basin.

The Protocol emphasizes the importance of the sustainable sediment management for maintain the water regime, promote active international cooperation to enhance appropriate policies and to reinforce and coordinate action at all appropriate levels for promoting sustainable sediment management related to quality and quantity and to promote sustainable sediment management solutions, which carefully balance the socio-economic and environmental values to be set within the whole Sava River Basin.

In line with the provision of the Protocol the ISRBC accepted the Program for Development of Sediment Management Plan[2] in the Sava River Basin which provides a list of activities and actions required for the development of the Plan in line with the Protocol. In the Programme it is foreseen that the Plan will be developed through the technical assistance with support of the ISRBC's Expert Groups.

The two main contributions of this *Outline* are:

- An analysis of sediment management practices in the Sava River Basin (Slovenia, Croatia, Bosnia and Herzegovina and Serbia).
- A proposal of a detailed work plan for preparation of the full-fledged Sediment Management Plan.

[1] Protocol on Sediment Management to the Framework Agreement on the Sava River Basin, International Sava River Basin Commission, signed in 2010 and entered into force on 27 November 2015.

[2] Program for development of Sediment Management Plan in the Sava River Basin, accepted at the 55th Session of the International Sava River Basin Commission (29-30th September 2020)

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Abbreviations

a.s.l.	Above sea level
ADCP	Acoustic Doppler Current Profiler
ARSO	Slovenian Environment Agency
BA	Bosnia and Herzegovina
BLT	Bedload transport rate
DHMZ	Meteorological and Hydrological Service of Republic of Croatia
DIKTAS	Dinaric Karst aquifer System (project)
FASRB	Framework Agreement on the Sava River Basin
HPP	Hydropower Plant
HR	Republic of Croatia
ISI	International Sediment Initiative
ISO	International Organization for Standardization
ISRBC	International Sava River Basin Commission
IWM	Integrated Water Management
LT	Load transport rate
Q	Discharge
RB	River Basin
RBMP	River Basin Management Plan
RHMSS	Republic Hydrometeorological Service of Serbia
RS	Republic of Serbia
SI	Republic of Slovenia
SST	Suspended sediment transport rate
SMP	Sediment Management Plan
SSC	Suspended sediment concentration
WFD	Water Framework Directive
WMP	Water Management Plan

Introduction

1 Introduction

The Sava River Basin is the most significant sub-basin of the Danube River Basin with a total area of 97,272 km^2. It is located in South Eastern Europe between 13.67 ºE and 20.58 º E longitudes and between 42.43 ºN and 46.52 ºN latitude (Figure 1). The Sava RB area is shared among six countries: Slovenia, Croatia, Bosnia and Herzegovina, Serbia, Montenegro, and Albania. Except for Serbia and Albania, its watershed covers from 45 to 70% of the surface area of the other four countries. Its water resources constitute nearly 80% of the total freshwater resources in those four countries.

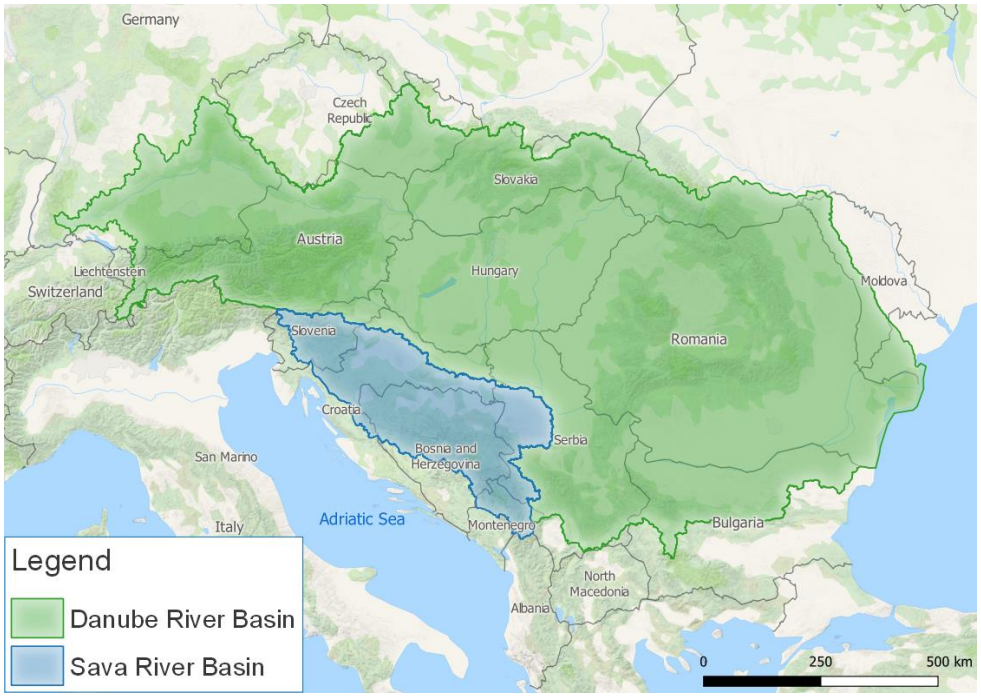


Figure 1 Location of the Sava River Basin within the Danube River Basin

Slovenia, Croatia, Bosnia and Herzegovina, and Serbia are Parties of the Framework Agreement on the Sava River Basin (FASRB). The implementation body of the FASRB is the International Sava River Basin Commission (ISRBC) which is responsible for development of joint plans and programs regarding the sustainable water management among others. ISRBC has developed the Protocol on Sediment Management to the FASRB which affirms the need for efficient cooperation among the Parties and for promotion of sustainable sediment management (SSM) solutions.

To respond to the above mentioned needs, the core expert group has been established upon the initiative of UNESCO Venice Office and ISRBC to analyse existing sediment monitoring system and institutional settings and to prepare this *Outline of the Sediment Management Plan for the Sava River Basin*. The existing national systems were analysed (Chapter 2) for a deeper understanding of the organisational and institutional settings on sediment monitoring systems and related activities (water regime management, reservoir management, biodiversity and ecosystem monitoring, etc.). The group conducted an in-depth overview of existing sediment monitoring systems and identified monitoring and sampling gaps (Chapter 3). Data uncertainties were recognised based on which a

proposal for sediment monitoring improvement was given (Chapter 4). Also, different sediment management measures (erosion control, water regime, navigability, preservation of wetlands and biodiversity, reservoir sedimentation) were considered and presented (Chapter 5) with a proposal for their improvement (Chapter 6). Collected information were basis on which a proposal for Sediment Management Plan was presented (Chapter 7).

1.1 Main characteristics of the Sava River Basin

1.1.1 Topography and land cover

The Sava RB covers a total area of 97,272 km^2. It encompasses 12% of the Danube basin and it is the second largest Danube tributary catchment by area size. The Sava represents the third longest tributary of the Danube and its largest tributary by discharge.

Terrain in the Sava RB significantly changes from the source in the west towards its confluence with the Danube River in the east (Figure 2). The elevation ranges between 71 m a.s.l. at the mouth of the Sava River in Belgrade (Serbia) and 2,864 m a.s.l. (Triglav, Julian Alps). The mean elevation of the basin is approximately 545 m a.s.l. The dominant slope in the basin is moderately steep. The mean value of the slope in the Sava RB is 15.8 %.

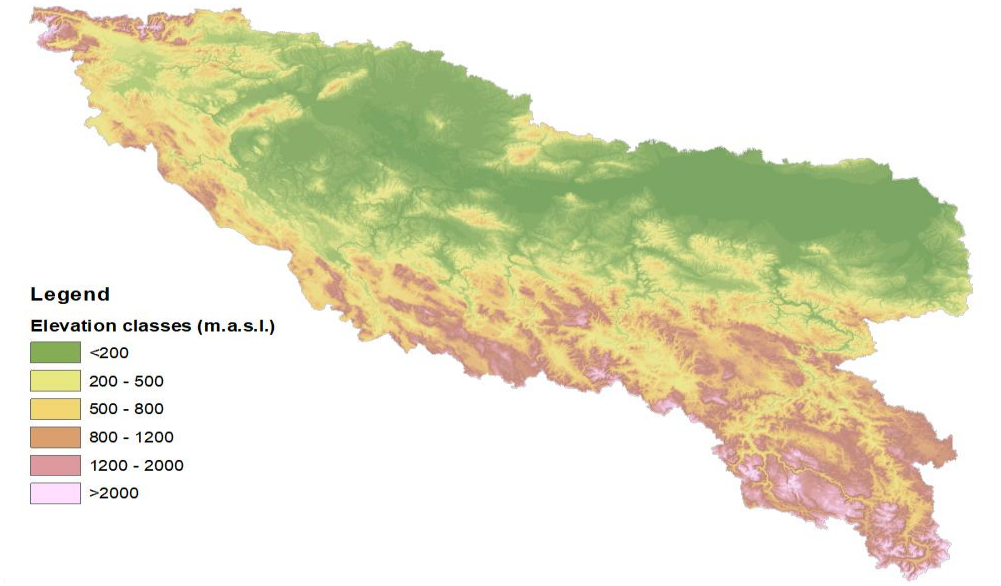


Figure 2 Relief of the Sava River Basin

High mountains dominate in the upper part of the basin which belongs to Slovenia. A remarkable distinction in landscape exists between the southern and northern part of the basin. The southern part is hilly and mountainous, with mountains up to 2,500 m a.s.l. high, particularly in Montenegro and Northern Albania. The northern portions of the middle and lower part of the Sava RB are characterized by low mountains and flat plains. This area is part of the Pannonian Plain, a low-lying, agricultural region.

Figure 3 represents slope gradient of the terrain in the Sava RB (derived from the Shuttle Radar Topography Mission), which is one of the main factors influencing the sediment yield and transport.

The two dominant land cover classes are forests and semi-natural areas (more than 50% of the basin area) and agricultural lands (40% of the area), while artificial surfaces, wetlands and inland waters cover 3,6% of the area (Figure 4).

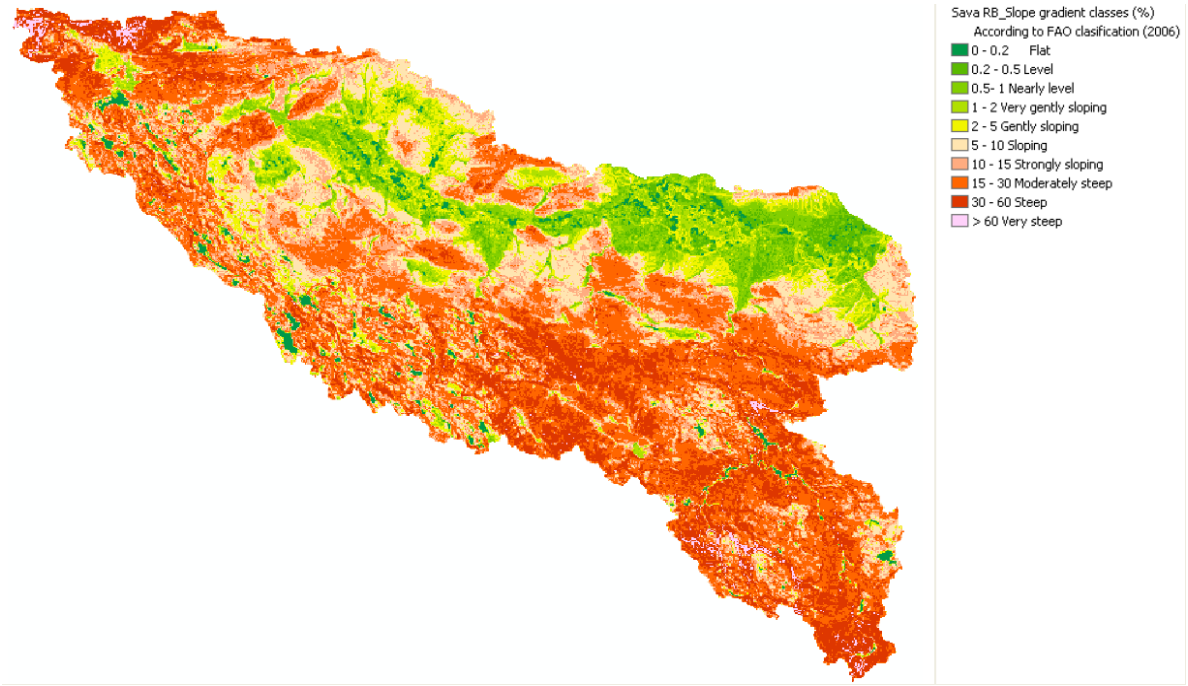


Figure 3 Slope gradient in the Sava River Basin

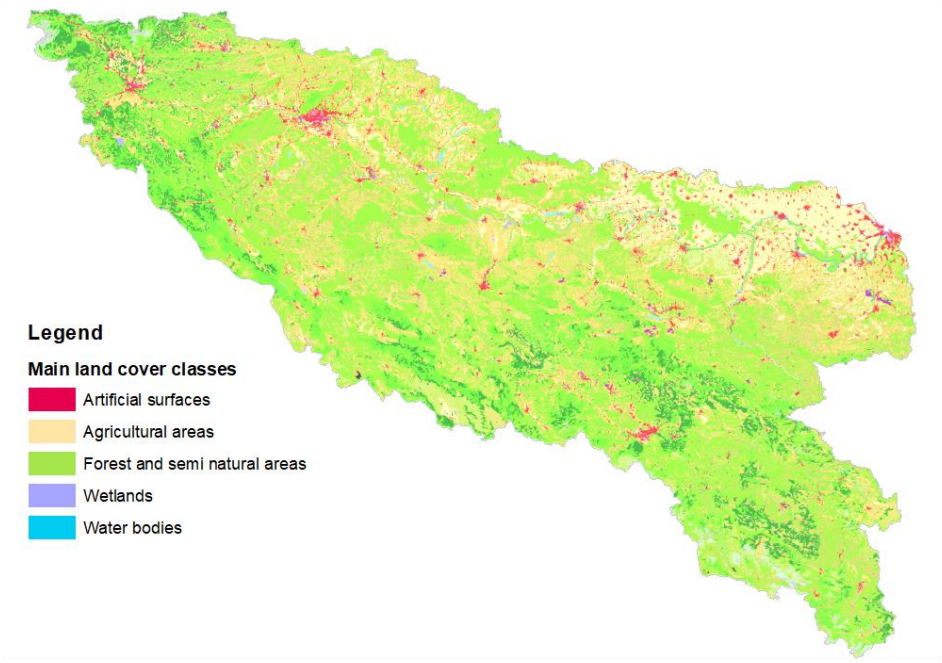


Figure 4 Land cover classes in the Sava River Basin

1.1.2 Climate

The Sava RB is situated within a region characterized by the dominant moderate climate of the northern hemisphere, which is modified by the influence of relief. Thus, mountainous zonal climate characteristics are present especially in the eastern and southern part of the area. Cold and hot seasons are clearly defined. The winter can be severe with abundant snowfalls, while the summer is hot and long. Average annual air temperature for the whole Sava RB was estimated to be approx. 9.5 °C. Mean monthly temperature in January falls to approx. -1.5 °C, whilst in July it can reach almost 20 °C.

There are three types of climate conditions within the basin:

- *Alpine or mountainous climate* is prevailing in the upper Sava Basin within Slovenia and also in Dinaric Alps at higher elevations;
- *Moderate continental climate* dominates in the right tributaries' catchment areas within Croatia, Bosnia and Herzegovina, Serbia and Montenegro;
- *Moderate continental (mid-European) climate* is dominating in lower elevations of the left tributaries' catchment areas that belong to the Pannonian Basin;

Dividing lines between these climate types are not sharp.

1.1.3 Precipitation and runoff

Average annual rainfall in the Sava RB is estimated around 1,100 mm. Precipitation amount is very variable within the basin (Figure 5). Precipitation is higher in mountainous parts of the basin (2,200-2,300 mm) than northern and eastern regions (600-700 mm). Most rainfall occurs in the late summer season or during autumn. A significant portion of precipitation falls in form of snow which then causes a relatively high spring runoff.

An average annual evapotranspiration for the whole catchment area is estimated to 530 mm.

An average discharge at the confluence to the Danube River is about 1,700 $m^3 \cdot s^{-1}$ which results in the long-term average unit-area-runoff for the complete catchment of about 17.5 $l \cdot s^{-1} \cdot km^{-2}$.

The runoff in the Sava RB is diverse – it is very high in the mountains, while being low in the north-eastern part of the catchment (

Figure 6). The runoff varies from 2,020 mm (the Sava Bohinjka catchment) to 218 mm (the Bosut catchment) giving the water yields of 64.2 $l \cdot s^{-1} \cdot km^{-2}$ and 6.87 $l \cdot s^{-1} \cdot km^{-2}$ respectively. All right tributaries (except the Kolubara and Tinja rivers) have high water yields (>15 $l \cdot s^{-1} \cdot km^{-2}$), while left tributaries (except the Savinja River) have lower average runoff.

Floods usually appear in the spring and in the autumn. Spring floods are the result of snow melting while autumn floods are caused by heavy rainfall. Depending on the cause, these types of flood exhibit different features. Spring floods are longer, while autumn floods have shorter duration and very high extreme flows.

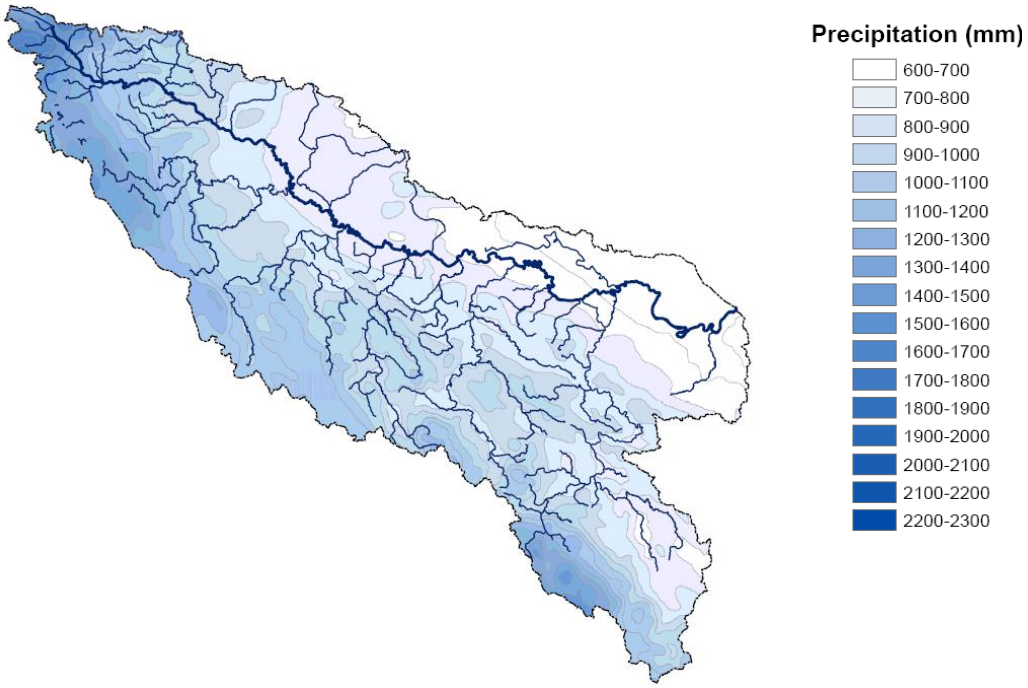


Figure 5 Mean annual precipitation in the Sava River Basin (The Danube and its Basin – Hydrological Monograph, 2006)

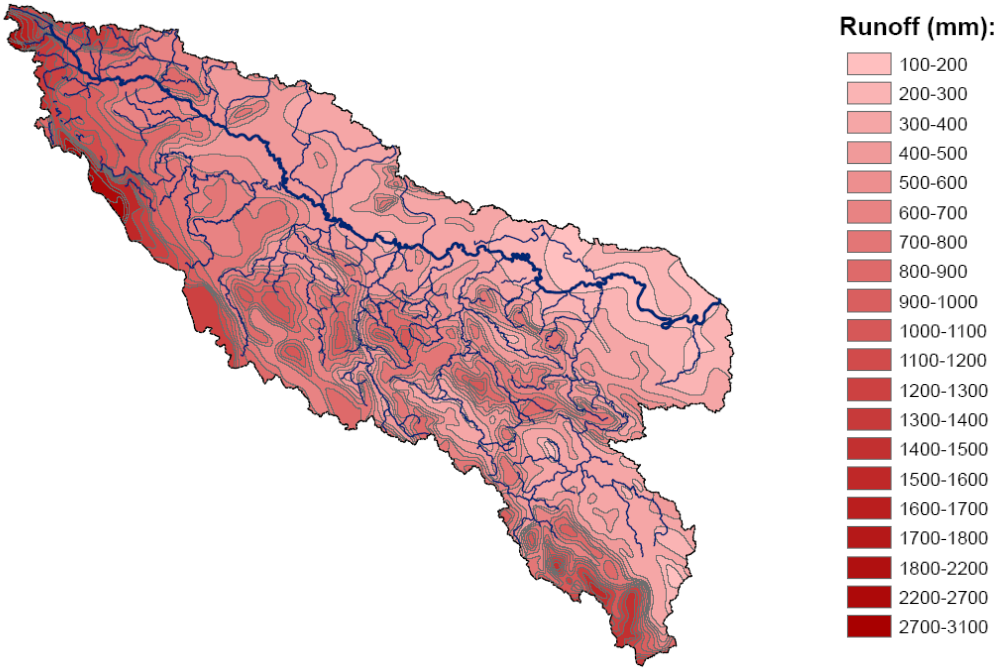


Figure 6 Mean annual runoff in the Sava River Basin (The Danube and its Basin – Hydrological Monograph, 2006)

1.1.4 Hydrography

The Sava River is formed by two mountain streams: the Sava Dolinka (left) and Sava Bohinjka (right) in Slovenia. Than it flows in direction NW –SE through Slovenia, Croatia, forming the border with Bosnia and Hercegovina, and on the lower stretch runs through Serbia. The total length of the watercourse is cca 945 km.

Table 1 Basic characteristics of the Sava River sections

Section	Upstream basin area A (km^2)	Specific flow q ($l \cdot s^{-1} \cdot km^{-2}$)
Upper Sava (at Rugvica, km 658)	12,680	31
Middle Sava (at the Drina River mouth, km 178)	86,154	20.1
Lower Sava (at the mouth to the Danube, km 0)	97,713	17.5

The longitudinal profile of the Sava River from its mouth into the Danube River in Belgrade to the hydrological station Radovljica (410 m a.s.l., river km 890) is shown in Figure 7. The most obvious detail on the longitudinal profile of the Sava River is the turn point around river km 660, close to the City of Zagreb. The average longitudinal slope of the Sava River between Radovljica (river km ~890) and Rugvica (river km 658) is ~ 2‰, upstream of the hydrological station Radovljica close to ~10‰ (this Sava River part is definitely of a pronounced torrential character). The average longitudinal slope in the Sava River between Rugvica (km 658) and Belgrade (km 0) is then only ~0.05‰.

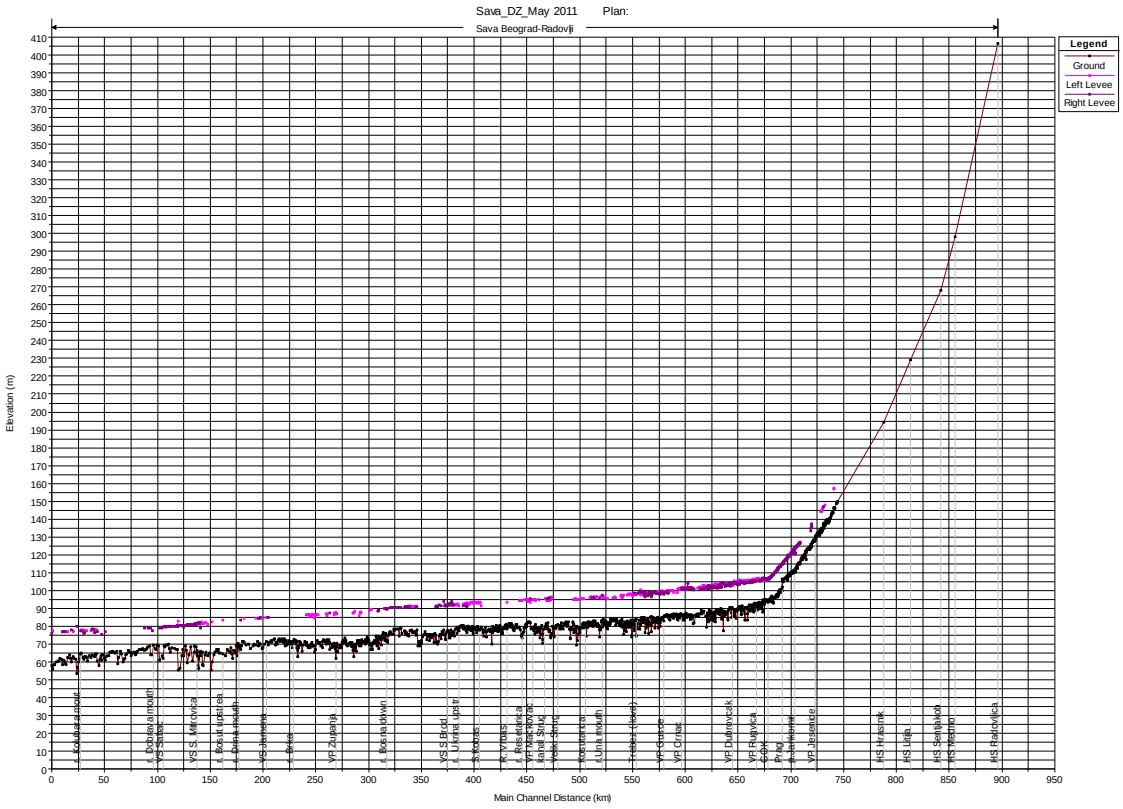


Figure 7 The longitudinal profile of the Sava River between the mouth to the Danube (RS) and Radovljica (SI)

There is a common understanding that the course of the river can be divided into 3 sections:

- *Upper Sava*, between the confluence of Sava Dolinka and Sava Bohinjka and Rugvica (km 658). The catchment area of the Upper Sava comprises mountainous and hilly relief;
- *Middle Sava*, between Rugvica and the mouth of the Drina River (km 178) is a lowland, alluvial section, characterized by wide floodplains, and mouths of numerous tributaries;
- *Lower Sava*, downstream of the mouth of the Drina River, is also alluvial section. There are no significant tributaries on this section. The most downstream, 100 km long section is under the influence of the Danube.

It should be noted that changes of the Sava River alignment due to fluvial erosion are not pronounced. The unstable banks were present in sharp river bands, but numerous river structures were built to prevent further bank erosion.

1.1.5 Overview of the Sava River tributaries

The river network in the Sava RB is well developed with 18 tributaries of the basin wide importance (Table 2), and of which 16 sub-basins have the catchment area >1000 km^2 (Figure 8). The basin is asymmetric with right tributaries covering approx. 70% of the area.

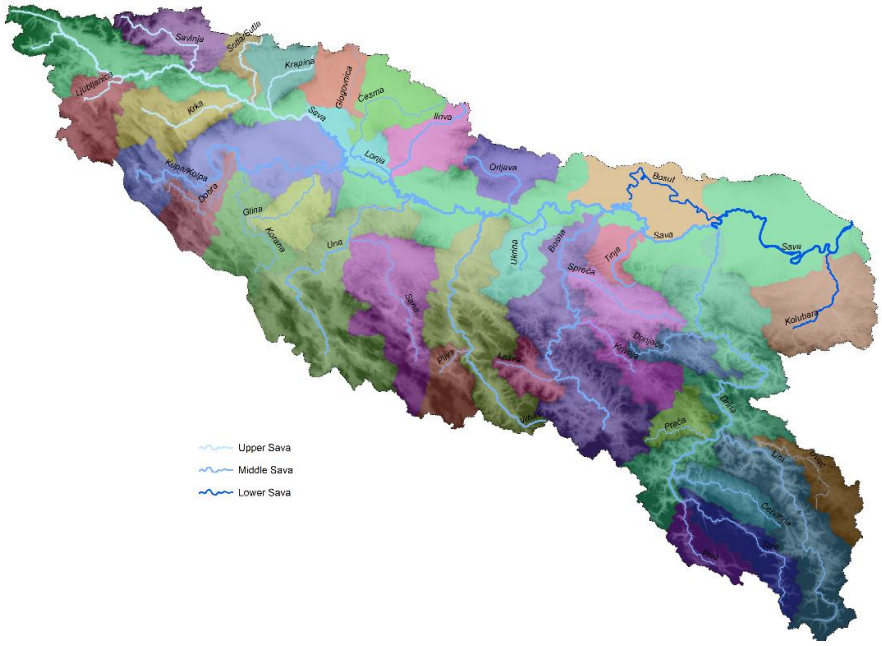


Figure 8 Tributaries to the Sava River

The most important **right tributaries** are: Ljubljanica, Krka, Kolpa/Kupa, Una, Vrbas, Ukrina, Bosna, Drina and Kolubara Rivers. Common feature of almost all right tributaries of the Sava River is their torrential behaviour, particularly in their upper sections. River channels are often deeply cut into the hard rocks, with very violent flow through gorges. Rivers Ljubljanica, Krka and Kolpa with karstic catchments, react on precipitation with the delay and also sediment transport is not as high as in some other tributaries of the Sava River.

The main **left tributaries** are Savinja, Sotla/Sutla, Krapina, Lonja, Orljava and Bosut Rivers. Except in Slovenia, left tributaries drain mostly flat areas and low hills of the Pannonian basin. Consequently, the slopes and flow velocities are smaller and the streams are meandering.

Longitudinal profiles of the main Sava River tributaries are presented in Figure 9. It can be noted that the slope increase in the upstream sections is a common feature for all tributaries.

Table 2 Rivers of basin-wide importance in the Sava River basin

River	Tributary order	Basin area	Countries sharing sub-basin
		(km^2)	
Sava		**97,713**	**SI, HR, BA, RS, ME, AL**
Ljubljanica	1	1,890	SI
Savinja	1	1,848	SI
Krka	1	2,315	SI
Sotla/Sutla	1	584	SI,HR
Krapina	1	1,237	HR
Kupa/Kolpa	1	10,226	HR,SI,BA
Dobra	2	1,428	HR
Korana	2	2,302	HR,BA
Glina	2	1,427	HR,BA
Lonja	1	4,259	HR
Česma	2	3,253	HR
Glogovnica	3	1,302	HR
Ilova (Trebež)	1	1,796	HR
Una	1	9,829	BA,HR
Sana	2	4,253	BA
Vrbas	1	6,274	BA
Pliva	2	1,326	BA
Orljava	1	1,618	HR
Ukrina	1	1,504	BA
Bosna	1	10,810	BA
Lašva	2	958	BA
Krivaja	2	1,494	BA
Spreča	2	1,948	BA
Tinja	1	904	BA
Drina	1	20,320	ME,AL,BA,RS
Piva	2	1,784	ME
Tara	2	2,006	ME,BA
Ćehotina	2	1,237	ME,BA
Prača	2	1,018	BA
Lim	2	5,968	AL,ME,RS,BA
Uvac	3	1,596	RS,BA
Drinjača	1	1,091	BA
Bosut	1	2,943	HR,RS
Kolubara	1	3,638	RS

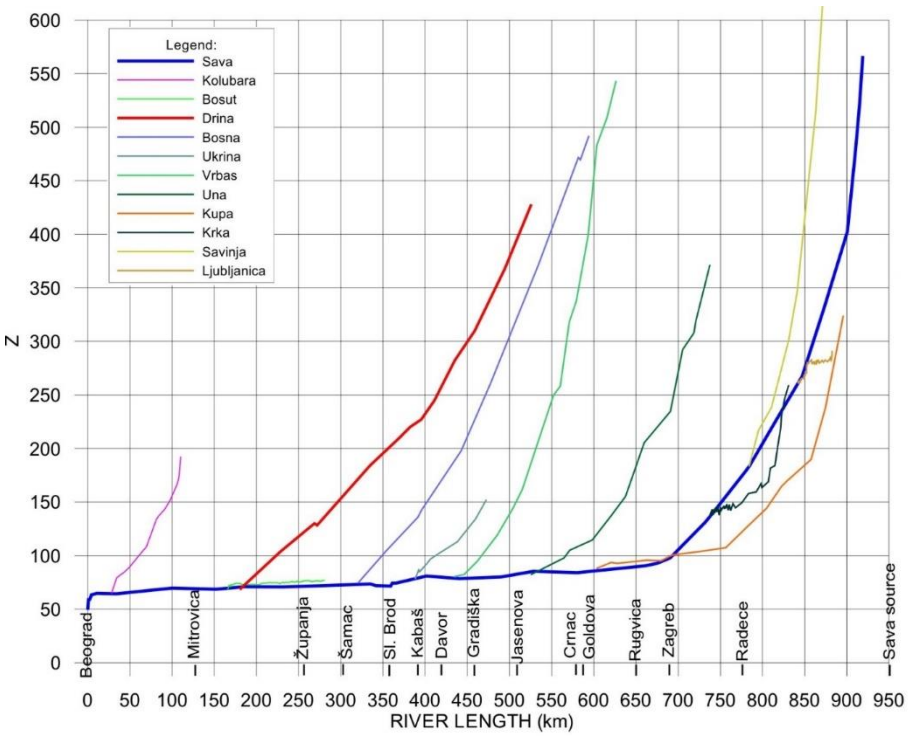


Figure 9 Schematic longitudinal profiles of the Sava River and its main tributaries

1.1.6 Geology and hydrogeology

The very important geological characteristic of the Sava RB, influencing the regime of water and sediment is the presence of the karst phenomena. Karst region spreads from the Italian to the Albanian frontier and covers in the southern part of the basin (Figure 10). Karst regions are present only in the southern part of the river basin. This terrain mostly belongs to the zone of the External Dinarides. The rest of the basin belongs to the Inner Dinarides zone and Pannonian basin. In this zone, limestone is less present with prevailing other lithological units: sandstone, marls, claystones, intrusive and extrusive igneous rocks (diabase, spilite, dacite, andesite etc), metamorphic rocks (serpentinite, phylite, argiloshist etc). The main aquifers are formed in alluvial deposits. The aquifers characterise large reserves of groundwater, especially alluvial deposits.

Figure 10 Dinaric karst regions in the Sava River Basin (overtaken from DIKTAS project)

1.1.7 Dams and hydropower plants

Five hydropower plants (HPPs) were built on the Upper Lower Sava in Slovenia: HPP Moste (1952), HPP Medvode (1953), HPP Mavčiče (1986) and HPP Vrhovo (1993). Five hydropower plants (HPP) have been built on the Lower Sava in Slovenia: HPP Boštanj (2005), HPP Arto-Blanca (2008), HPP Krško (2013), HPP Brežice (2017) and HPP Mokrice is still under construction (for which a National Spatial Plan was approved in August 2013). All hydroelectric power plants are of the run-of-the-river and reservoir type with daily flow regulation regime.

The most downstream section of the Sava River, between Šabac and the mouth to the Danube, is under the influence of the Iron Gate 1 HPP operation regime (HPP was built in 1970, 227 km downstream of the Sava River mouth, at km 943 of the Danube River). This section is a shallow part of the Iron Gate reservoir, where the water levels and flow velocity during low and average flows were changed, thus influencing the sediment regime of the Sava River.

A large number of dams and hydropower plants were built on the tributaries of the Sava River. Table 3 presents the most important ones. The most of reservoirs exist in the Drina River Basin.

Table 3 Reservoirs on the Sava River tributaries

Country	Subbasin	River	Name	Volume	Purpose	Year
SI, HR	Sotla/Sutla	Sotla/Sutla	Vonarje (Sutlansko jez.)	12.4	DW, IW, FP, IR	1980
HR	Ilova	Pakra	Pakra	13.3	DW, IW, FP	1996
BA	Vrbas	Vrbas	Bocac	52.7	EP	1981
BA	Drina	Rastosnica	Snjeznica	20.6	EP	1984
BA	Bosna	Spreca	Modrac	88	IW, DW, FP, EP	1964
ME	Drina	Cehotina	Otilovici	17	IW, DW, FP	1981
RS	Drina	Drina	Zvornik	89	EP	1955
BA	Drina	Drina	Visegrad	161	EP	1989
RS	Drina	Beli Rzav	Lazici	170	EP	1983
RS	Drina	Uvac	Uvac	213	EP	1979
RS	Drina	Uvac	Kokin Brod	273	EP	1962
RS	Drina	Drina	Bajina Basta	340	EP	1966
ME	Drina	Piva	Mratinje	880	EP, FP	1973
RS	Drina	Uvac	Radoinja	7	EP	1959
RS	Drina	Lim	Potpec	44	EP	1967
RS	Kolubara	Velika Bukulja	Garasi	6.27	DW	1976
RS	Kolubara	Kladnica	Paljuvi Vis	14	IW	1983
RS	Kolubara	Jablanica	Rovni	270	DW, IR	-

Legend on purpose: IR – irrigation; DR – drainage; DW - drinking water supply; IW – industrial water supply; R – recreation; EP – electricity production; FP – flood protection.

1.1.8 Bottom sediment

A rather sharp transition from a gravel-bed river (at the Upper Sava) to a sand-bed river (at the Middle Sava) is formed at Rugvica near km 680. The mean sediment diameter from the Sava source to the knickpoint close to Rugvica is of the order of several tens of mm. Riverbed material on the Middle and Lower Sava is finer (sand and find gravel), having $D_{50\%}$ mainly bellow 12 mm (Figure 11). It should be noticed that the main right tributaries (Vrbas, Bosna and Drina Rivers) bring coarse gravel material into the Sava riverbed, forming large and visible gravel bars at the mouths.

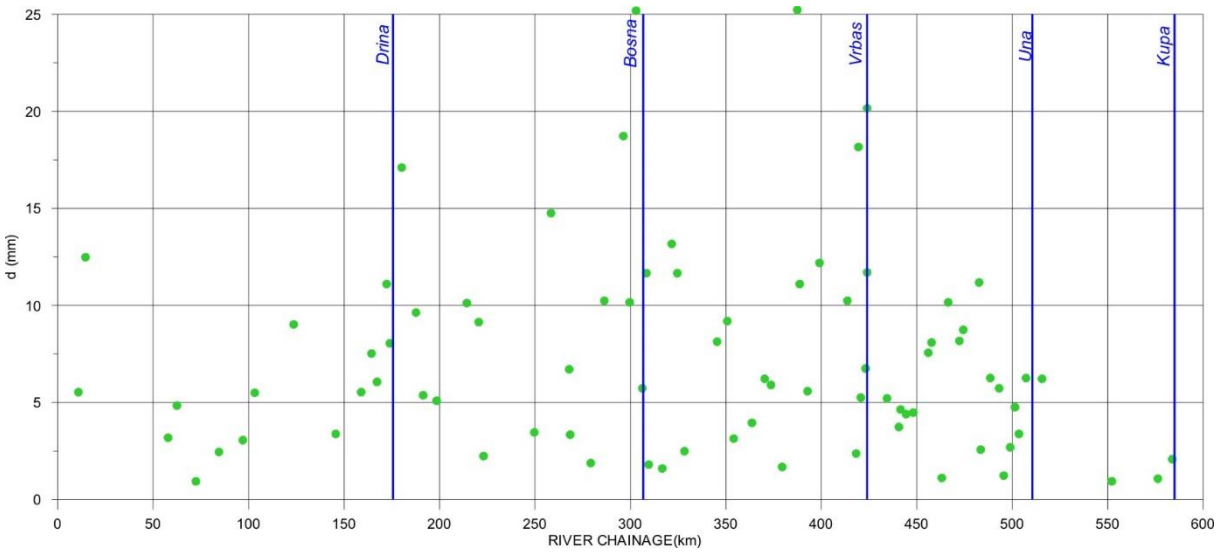


Figure 11 Longitudinal distribution of the Sava riverbed sediment diameter D50%

1.2 Background to the sediment transport in the Sava River Basin

The river sediment is a result of surface soil erosion caused by rainfall, temperature differences, wind, terrain slopes and rainfall water. Sediment transport accounts for the transport of material (clay, silt, sand, gravels, and boulders) in rivers and streams. Bedload is, according to its origin, a trough-forming sediment that settles at the bottom of the watercourse bed. The bed load characterizes grains rolling, sliding and saltating along the river bed, while suspended load refers to smaller sediment grains maintained in suspension by turbulence. Transported amounts are expressed as suspended sediment transport rate (SST) and bedload transport rate (BLT).

The Sava River is a typical large alluvial river, flowing mostly in its own alluvial deposits. Only in its upper course in Slovenia it has cut its channel into the mountains or hills. Elsewhere, the river flows on plains where it has deposited large amounts of coarse and fine-grained sediments, and where one can observe different river terraces and wide alluvial floodplains (formed in the past since the last glaciation). Without regulation works and anthropogenic interventions, the Sava River would mainly be a large meandering river in almost its entire course. However, the Sava and its tributaries have been experiencing major hydromorphological changes in the last two centuries.

The surface erosion is strongly present in the upstream parts of the Sava RB and the dominant sediment transport in rivers occurs during flood flows. The Sava River downstream of Zagreb and lower parts of its tributaries are typical alluvial watercourses with river channel formed by their own sediments. Bedload has a relatively small share in the total sediment transport in the Sava River (5-15 %), but it has an important role in morphological processes during flood events in particular.

An overview of sediment management practice in the Sava River Basin

2 An overview of sediment management practice in the Sava River Basin

In this chapter, the institutional and organisational framework are presented for different sediment management aspects, including:

- maintenance of water regime
- management of sediment monitoring network
- dredging
- management of reservoir sedimentation
- development and implementation of erosion control, torrent and other sediment processes
- protection of wetland areas and retention spaces
- protection of biodiversity of the ecosystems/areas

2.1 Maintenance of water regime

The water management system and maintenance of water resources and water regime is well established and regulated in the Parties to the FASRB (Table 4). The EU directives on water and nature conservation were transposed into the national legislations. The national Water Acts regulate the management of marine waters, inland waters and groundwaters as well as the management of water land and waterside land. The legislation also regulates the public good and public services in the areas of waters, water facilities and installations, and other water-related issues.

In Slovenia, the water management is regulated by Water Act. Environmental protection, water management and management of water land and waterside land should consider the principles of the integrity, which takes into account natural processes and the dynamics of waters, principles of the long-term protection of the quality and efficient use of available water resources, the principle of providing protection against the harmful effects of waters and the principle of public participation. For management of the hydrological network is responsible Slovenian Environment Agency.

Table 4 Overview of maintenance of water regime

Party	Regulated by	Managing institution	Management of hydrological network	Publicly available water information system
SI	Water Act	Ministry of Environment and Spatial Planning	Slovenian Environment Agency	+ (gis.arso.gov.si)
HR	Water Act	Croatian Waters	National Meteorological and Hydrological Service (DHMZ) and Croatian Waters	+ (preglednik.voda.hr)

BA	Water Act	Sava River Watershed Agency (Federation of BiH), JU Vode Srpske (Republic of Srpska), Department of Agriculture, Forestry and Water Management (Brčko District)	Sava River Watershed Agency and Federal Hydrometeorological Institute Sarajevo (Federation of BiH), Pablic Institution "Vode Srpske", Republic Hydrometeorological Institute (Republic of Srpska)	+ (isvportal.voda.ba/)
RS	Water Act	Public Water Management Companies Srbijavode and Vode Vojvodine	Republic Hydrometeorological Service of Serbia (RHMSS)	+ (geoportal.srbijavode.rs/visios/JavniPortal) (gis.vodevojvodine.com/visios/vodeVojvodineEksterna)

In Croatia, The Water Act regulates all activities in water management, organisation of institution(s) in performing these activities, and other issues related to waters and water status. Water management comprises all activities, measures and actions commenced by the Republic of Croatia and Croatian Waters, local and regional self-government units as well. The also regulates activities, measures and actions related to flood protection, detailed amelioration drainage, public irrigation and water services in Croatia.

In Bosnia and Herzegovina, the competencies on water management are under the jurisdiction of the Entities and the Brčko District. Water management includes water protection, water use, protection against harmful effects of water and regulation of watercourses and other waters. Water laws and other laws and bylaws regulate the issue of water management exclusively in the territories of the entities. The EU directives and principles were considered in the development of legislative documents on water (Water Act, Water Management Strategy, Water Management Plan).

In Serbia, maintenance of water regime is a responsibility of Public Water Management Companies Srbijavode and Vode Vojvodine, following the division of responsibilities set in Water Act. The EU directives and principles were considered in the development of legislative documents on water (Water Act, Water Management Strategy).

2.2 Management of sediment monitoring network

The establishment and management of sediment quantity and quality monitoring network is usually performed by dedicated agencies (Table 5, Table 6). The suspended sediment monitoring is partially present (in SI and HR), while there is no bedload monitoring in the Sava RB. The sediment quality monitoring is established in the Parties (except in BA).

Table 5 Management of sediment quantity monitoring

Party	Regulated by	Managing institution	Suspended sediment monitoring	Suspended sediment load	Bedload monitoring
SI	Water Act (Water Management Plan)	Slovenian Environment Agency	+	+	-
HR	Meteorological and Hydrological Activity Act	National Meteorological and Hydrological Service (DHMZ) and Croatian Waters	+	+	-

	Annual programme of monitoring of water status				
BA	-	-	-	-	-
RS	Annual programme of monitoring of water status	Republic Hydrometeorological Service of Serbia (RHMSS)	-	-	-

Table 6 Management of sediment quality monitoring

Party	Regulated by	Managing institution	Sediment sampling	Water sampling
SI	Annual programme of monitoring of water status	Slovenian Environment Agency	+	-
HR	Annual programme of monitoring of water status	National Meteorological and Hydrological Service (DHMZ) Croatian Waters	+	+
BA	-	-	-	-
RS	Annual programme of monitoring of water status	Serbian Agency for Environmental Protection (SEPA)	+	+

In Slovenia, the quantitative assessment of water is part of the River Basin Management Plan. Preparation and assessment of the quantitative and qualitative (ecological and chemical) status of all water bodies (surface and groundwater) are responsibility of the Slovenian Environment Agency. The suspended sediment monitoring in the past involved incomplete data sets and periodic sampling. The sediment quantity is currently assessed by monitoring of turbidity and suspended sediment concentration at two hydrological stations on the Sava River tributaries.

In Croatia, establishment and maintenance of sediment monitoring network is responsibility of two organisations: National Meteorological and Hydrological Service (DHMZ) and Croatian Waters. Long-term suspended sediment and bedload monitoring in Croatia is part of a regular hydrological monitoring which is carried out in accordance with the annual program of hydrological works. This sediment monitoring programme includes:

- Point measurements of sediment concentration on daily basis at 8 gauging stations in total on Sava RB (4 stations on the Sava River and 4 stations on the tributaries)
- Calculation of sediment load transport on the Sava River gauging stations on daily basis from the point sampling
- Integral profile measurements of sediment concentration and sediment load transport, at 3 stations on the Sava River, periodically
- Grain-size distribution of suspended load on 3 stations on the Sava River, periodically
- Grain-size distribution of bed load on 2 stations on the Sava River, periodically

On quality monitoring sites, Croatian Waters examines all qualities elements involved in the ecological and chemical status as well as suspended sediment concentration (mg/l) at some monitoring sites, which are not necessary located by the existing DHMZ hydrological gauging stations. This quality monitoring is carried out in catchment areas larger than 2500 km^2 as well as on transboundary water bodies.

In Bosnia and Herzegovina, systematic sediment monitoring in the Sava RB does not exist. Short-term measurements and calculations were performed for the purposes of technical documentation and plans or for the need of individual water management facilities (mostly hydropower plants). Sediment management in Bosnia and Herzegovina is not regulated by appropriate laws and bylaws, both in the part related to the establishment of sediment quantity and quality monitoring and in the part related to sediment dredging from watercourses and its subsequent use.

In Serbia, the Republic Hydrometeorological Service of Serbia (RHMSS) is responsible for sediment quantity monitoring. A regular monitoring of suspended sediment suppose to be undertaken at the main gauge stations in the Sava RB: Sremska Mitrovica on the Sava River, Prijepolje on the Lim River and Beli brod on the Kolubara River. Although the sediment monitoring is present in the Programme, it is not operative because the instruments and methodology should be updated. Monitoring of bedload sediment is not foreseen in the Annual programme of monitoring of water status. Sediment quality was monitored by the RHMSS by sampling of river and reservoir sediment in the Sava RB till 2010, when this became the regular task of the Serbian Agency for Environmental Protection (SEPA) within the Ministry of environmental protection. Currently, the river sediments are analysed at a number of locations on the Sava River and also at many locations on the Drina, Lim, Kolubara and Topčiderska River.

2.3 Management of dredging

The dredging from rivers and lakes is mainly regulated (Water Act) and managed by relevant authorities (Table 7). Dredging is allowed through a concession (SI, HR, BA) or by issuing water approvals (RS). In HR, BA and RS the dredging is undertaken for the waterway maintenance and safe navigation purpose, while navigability is restricted in SI.

In Slovenia, according to the Water Act it is necessary to obtain a concession for the removal of debris, except in the case of performing maintenance work on the public service. The law prohibits activities or interventions on riparian or coastal land that could endanger the existence or reproduction of aquatic and riparian organisms. According to the River Basin Management Plan for the Danube River Basin, the removal of sediment from the river is a hydromorphological pressure caused by industry, agriculture, and energetics. For a significant pressure, it is necessary to get a concession for the use of sediment removal. Annual amount of dredged material must be reported to the Ministry of Environment and Spatial Planning.

In Croatia, the Ministry of the Sea, Transport and Infrastructure - Waterways administration is in charge of waterway maintenance and monitoring. The activities of the Agency include, among others, the following:

- construction, technical improvement and traffic-technological modernization of waterways,
- technical maintenance of waterways,
- training of waterways and navigation safety facilities that are disabled due to natural disasters.

Table 7 Management of dredging

Party	Regulated by	Managing institution	Navigability allowed	Sediment abstraction mechanism	Regular river channel monitoring
SI	Water Act	Ministry of Environment and Spatial Planning	restricted	regulated (concession)	-

HR	Water Act	Ministry of the Sea, Transport and Infrastructure - Waterways administration	Yes	regulated (concession)	+
BA	Water Acts, Decree on the manner of allocating the right to extract material from watercourses (Federation of BiH) Rulebook on maintenance of riverbeds and water land (Republic of Srpska)	Sava River Watershed Agency, Cantonal Ministry (Federation of BiH), JU Vode Srpske (Republic of Srpska), Department of Agriculture, Forestry and Water Management (Brčko District)	Yes	regulated (concession)	-
RS	Water Act and Plan for extraction of river sediments	PWMCs Srbijavode and Vode Vojvodine	Yes	regulated (water approval valid for 1 year)	+

In Bosna and Herzegovina, the inland navigation is managed by Ministry of Transport and Communications of Bosnia and Herzegovina. Inland navigation is defined by the "Law on Inland and Maritime Navigation" (Federation of BiH) and by the "Law on Inland Navigation of the Republic of Srpska" (RS), which regulates, among others:

- conditions and use of inland waters and inland waters for navigation, such as waterways, locks, dams and others,
- problems of pollution of water resources caused by vessels,
- technical maintenance of waterways.

Works on watercourse maintenance are regulated by Water Act and include maintenance of banks, riverbed and inundation zones, removal of sediments, partial deepening of riverbeds, etc. The Water Act emphasizes that the dislocation and extraction of materials from watercourses is allowed to the extent that it does not significantly change natural processes, does not disturb the natural balance of ecosystems or does not enhance the harmful effects of water. For dredging activities in watercourses, it is necessary to obtain permits.

In Serbia, in order to achieve positive effects on the water regime and navigation the PWMCs Srbijavode and Vode Vojvodine provide water approvals every year for dredging at locations along the Sava, Drina and Kolubara rivers to interested business entities. Since 2017, dredging of sediments is executed according to the Plan for extraction of river sediments. The Plan provides the conditions for the lease of water land, locations for dredging and permitted annual quantities. The Plan is produced biannually. The Water Act stipulates that the extraction of river sediment can be carried at sites where it is of interest for conservation or improvement of the water regime to the extent that it will not disturb the water regime, the existing use of groundwater, coastal stability and the natural balance of aquatic and coastal ecosystems. Inland navigation in Serbia is responsibility of the Ministry of construction, transport and infrastructure, Directorate for inland waterways Plovput. Plovput performs river training works including construction of structures and river sediment dredging. Plovput participates in preparation of Plan for extraction of river sediments, providing data on obstacles for safe navigation on the Sava River based on the newest survey data. Plovput also manages river cross-sectional surveys along the Sava River on regular basis.

Pursuant to the Protocol on Sediment Management, the Parties to the FASRB are obliged to deliver information concerning sediment dredging performed in the previous year and data on

planned dredging for the next year. Based on the delivered data, the Sava Commission prepares reports and delivers them to competent institutions of the Parties.

2.4 Management of reservoir sedimentation

Maintaining and monitoring of reservoir sedimentation is implemented by the owners of hydropower plants (HPP), usually public organisations (SI – HESS; HR – HEP and Croatian Waters; RS - Public Enterprise Electric Power Industry of Serbia). The management of reservoir sedimentation is supervised only in Slovenia (by Ministry of Environment and Spatial Planning), see Table 8. In Serbia, cross-sectional surveys for reservoirs are prescribed in Water permits for the HPP operation.

Table 8 Management of reservoir sedimentation

Party	Regulated by	Managing institution	Supervised institution
SI	Water Act, concession permit	HPP owners	Ministry of Environment and Spatial Planning
HR	Water permits for reservoirs	HPP owners or Croatian Waters	-
BA	-	HPP owners	-
RS	Water permits for reservoirs	HPP owners	-

2.5 Management of soil erosion, torrents and other sediment processes

Management of soil erosion, torrents and other sediment processes is regulated by legislation as part of other water management measure for protection against harmful effects of water (Table 9). The management activities in the Sava RB include construction and maintenance of erosion control structures and monitoring of torrential flows without monitoring of soil erosion/production.

Table 9 Management of erosion control, torrents and other sediment processes

Party	Regulated by	Managing institution	Construction and maintenance of control structures	Torrential flow monitoring	Soil erosion/ production monitoring
SI	Water Act	Geological Survey of Slovenia	+	-	+
HR	Water Act	Croatian Waters	+	+	Empirical estimation only
BA	Water Act	Sava River Watershed Agency (Federation of BiH), JU Vode Srpske (Republic of Srpska), Department of Agriculture, Forestry and Water Management (Brčko District)	-	-	Empirical estimation only
RS	Water Act	Public Water Management Companies Srbijavode and Vode Vojvodine	+	-	Empirical estimation only

In Slovenia, identification of erosion hotspots is tasks of the Geological Survey of Slovenia. In the erosion area the activities are regulated, so it is prohibited: to encroach on space in a way that accelerates erosion and torrent formation, bare areas, clearing of those forest stands that prevent landslides and snow cover, regulate runoff conditions or otherwise protect lower lying areas from the harmful effects of erosion, backfilling of springs, uncontrolled collection or discharge of collected water on erosive or landslide lands, restriction of torrential water flow, acceleration of water erosion power and deterioration of equilibrium conditions, disposal or storage of wood and other materials, backfilling with excavated or waste material, collection and disposal, except to ensure the flow capacity of the torrent bed and the hauling of timber. Determination of erosion protected areas, measures and restrictions are part of the River Basin Management Plan (RBMP), prepared by the Ministry of the Environment and Spatial Planning. In order to protect against harmful effects of water, the government and local communities ensure the planning, construction and management of water infrastructure in the endangered area, especially high-water embankments, reservoirs, gravel barriers, bottom and bank stabilization facilities, pumping stations and backwater drainage.

In Croatia, the Water Act regulates legal status of waters, water status and water management facilities, management of water quantity and quality, protection from adverse effects of water. Determination of erosion protected areas, measures and restrictions are part of the River Basin Management Plan (RBMP). In order to protect against harmful effects of water, Croatian Waters and local communities ensure the planning, construction and management of water infrastructure in the endangered area, especially high-water embankments, reservoirs, gravel barriers, bottom and bank stabilization facilities.

In Bosnia and Herzegovina, the development and implementation of erosion control measures, control of torrents and other sediment processes are included in the Water Act of Federation BiH and Water Act of RS as part of other water management measure for protection against harmful effects of water. In the Sava RB in BiH, the assessment of sediment production (average annual production of sediments, average annual volume of suspended and bedload sediments) is done using empirical estimation. Torrential flows in Bosnia and Herzegovina are hydrologically ungauged and insufficiently explored. There is no official Cadastre (register of torrents). Even though torrential floods have an extremely destructive effect on the socio-economic sector, their monitoring is very often omitted.

In Serbia, the development and implementation of erosion and torrent control measures is a responsibility of Public Water Management Companies (PWMC) Srbijavode and Vode Vojvodine. These activities are present mainly on the right side of the Sava RB in Serbia (including the Drina and the Kolubara River Basins) due to characteristics of the area (hilly and mountainous part of the country). PWMC Srbijavode is responsible for construction, reconstruction, rehabilitation, maintenance and management of water facilities for protection against erosion and torrents in public ownership and execution of works and measures for protection against erosion and torrents, in accordance with the Water Act. Erosion and torrents on the left side of the Sava RB, which is the responsibility of PWMC Vode Vojvodine are not a pronounced problem. The actions towards control of sediment processes are related to torrents on the slopes of Fruška Gora and cleaning of drainage canals flowing towards Sava.

2.6 Protection of wetland areas and retention spaces

Wetlands in the Sava RB are protected and treated with special protection measures for nature conservation and biodiversity in accordance with the legal documents (Nature Conservation Act) and governed by international conventions (Ramsar).

Within the ongoing process of harmonizing the legal regulations in the field of environmental protection and nature conservation with the regulations of the European Union in BA and RS, the European and global standards are considered and applied in this field in all the Parties. Institutions dealing with the environment protection are either different to the ones dealing with the water management (BA - Federal Ministry of Environment and Tourism, Ministry of Physical Planning, Construction and Ecology, Department for Spatial Planning and Property Affairs; RS – Ministry for environment protection and Institutes for Nature Conservation of Serbia and Vojvodina Province) or it is within the same organisation (SI – Slovenian Environment Agency, HR - Ministry of Environment and Energy).

In the Sava RB, there are few important wetland areas of high importance (Ramsar sites): Lonjsko Polje Nature Park, Bardača and Obedska Bara. An important part of natural protected areas are also Natura 2000 sites. The Natura 2000 Management Programme (2015–2020) in Slovenia includes:

- water management measures, mostly measures to restore watercourses,
- measures to preserve or improve river dynamics, including flood regime and groundwater level,
- measure of reduced water runoff in certain areas,
- measures to improve the status of waters
- non-structural measures to reduce flood risk, such as the identification of key flooding areas and their suitable arrangement for more controlled flooding during major flood events - the guidelines are to seek synergies in these areas between establishing a favourable status of wetlands, marsh meadows and other important species and habitats, and reducing flood risk;
- measures to restore sources of pollution,
- measures related to the management of small dams.

In Croatia, the development of the Prioritized Action Framework (PAF) for the implementation of Natura 2000 protection measures was completed in January 2021 for the financial period 2021–2027. Prioritised action frameworks (PAFs) provided a comprehensive overview of the measures that are needed to implement the EU-wide Natura 2000 network and its associated green infrastructure and specified the financing needs for these measures. The report included measures:

- to establish the necessary conservation measures involving appropriate management plans specifically designed for the sites or integrated into other development plans;
- to establish appropriate statutory, administrative, or contractual measures that correspond to the ecological requirements of the natural habitat types in Annex I and the species in Annex II present on the sites.

The report also provided financial needs and priority measures associated with bird species in the Special Protection Areas (SPAs) designated pursuant to the EU Birds Directive 2009/147/EEC, as well as financing needs related to wider green infrastructure.

In Bosnia and Herzegovina, the Stabilization and Association Process to the EU was launched in May 1999. This process involves overtaking on all necessary commitments including the process of establishing/implementing Natura 2000 in BA. The implementation of Natura 2000 has involved governmental, non-governmental and EU actors in several projects such as the Emerald Network (2004-2006), Living Heart of Europe (2006-2011) and Cooperation for Natura 2000 (2012-2015). Although the entity laws on nature protection allow for the possibility to establish Natura 2000 areas, currently, no such areas have been officially created. [3] The protection is proposed for 122 areas (about 19% of the territory of BiH), including 200 species and 60 habitats, as well as establishment of an environmental network in BA, as shown in Annex F [4]. No subsidiary legislation on Natura 2000 has been adopted to date. [5]

In Serbia, Natura 2000 sites will be declared when Serbia joins the EU member states.

2.7 Protection of biodiversity of the ecosystems/areas

Different Nature/Environment Conservation/Protection acts were adopted by the Parties and together with the international agreements (Bonn, Bern, Ramsar conventions) they all govern biodiversity conservation measures and regulate environmental protection systems based on sustainable development principles. Many natural protection areas exist in the Sava RB as well as Natura 2000 and Ramsar sites.

The long-term goals and guidelines for the conservation of biodiversity and geodiversity are defined in Nature Protection Strategies:

- visions, principles, guidelines for the preservation of the situation
- analysis of threats, causes of threats and problems regarding the protection of ecosystems, habitat types, wild species and geodiversity, together with status assessment
- analysis of threats, causes of threats and problems regarding the protection of protected areas and the ecological network, together with status assessment.
- an analysis of the legislative and institutional framework, analysis of the implementation of the Strategy, and data on sources and use of funds for nature protection.
- goals and activities to eliminate harmful consequences for nature, as well as measures to mitigate the negative consequences.

[3] FBiH Law on Nature Protection (OG of FBiH, No. 66/13) recognizes Natura 2000 sites and affirms that certain areas may be designated for the European program Natura 2000 to be included in an international environmental network for conservation of natural habitats and habitats of species by a regulation of the FBiH Government.

[4] As available at: https://www.fmoit.gov.ba/bs/okolis/zastita-prirode/ekoloska-mreza-natura-2000.

[5] Bosnia and Herzegovina biodiversity analysis and addressing the biodiversity needs FAA 119 analysis February 2020, USAID/Bosnia and Herzegovina, February 2020.

An overview on the existing sediment monitoring system and data on sediment quantity and quality

3 An overview on the existing sediment monitoring system and data on sediment quantity and quality

3.1 General

The sediment monitoring system is organised by the national hydrometeorological services and comprises mainly sediment quantity, while sediment quality monitoring is present to a lesser extent. The sediment quantity monitoring includes suspended sediment monitoring with the determination of the concentration and load of suspended sediment at hydrological stations. Recent improvements in sampling techniques, laboratory analyses and software applications increased the quality and reliability of estimation of suspended sediment load.

Good understanding of sediment transport in rivers is, according to the Water Framework Directive (WFD), one of the most important hydromorphological elements, which are part of ecological status of the water body. The Directive requires implementation of river restoration measures and achievement of good hydromorphological conditions (close to undisturbed sediment regime). For a careful development and implementation of sediment management measures (for river channels and basin-wide measures) a more detailed understanding of the existing sediment condition and regime in the Sava RB is required.

3.2 Suspended sediment monitoring system

Suspended sediment monitoring is currently performed only in Slovenia by Slovenian Environment Agency (ARSO) and in Croatia by National Meteorological and Hydrological Service (DHMZ). Regular sampling of suspended sediments only exists in Croatia (8 stations), while in Slovenia it is performed during flood flows only (Table 10).

In Slovenia, the suspended sediment concentration (SSC) has been determined from turbidity data (continuously) and from point samples (occasionally) with 1 litre plastic bottle. The SSC from 1 litre samples is obtained in laboratory by using the standard filtration method (ISO 4365:2005). A continuous monitoring of turbidity is established since 2016 (at two stations), see Figure 12. The relationship between turbidity (measured in NTU, Nephelometric Turbidity Unit) and suspended sediment concentration is not uniform. The characteristics of a particular watercourse and other influencing factors (colour, size, structure of particles) have to be considered, as each watercourse has its characteristic type of suspended particle (related to geological structure of the rear area). The relationship between the two parameters needs to be tested and periodically checked for each hydrological station. The implementation of automatic turbidity sensors was recommended for better understanding of sediment transport in rivers. In period 2016–2021 monitoring of turbidity and suspended sediment in Slovenia was reliable at two location on the Sava tributaries: gauging stations Suha on the Sora River (Figure 13) and Veliko Štirje on the Savinja River. The SSC profile measurements and gran-size distributions are not performed.

Table 10 Overview of activities on suspended sediment monitoring

Party	Type of monitoring	Number of stations	Stations	Monitoring frequency	Since	Data availability
SI	Point sampling	4	Radovljica and Hrastnik (Sava River), Suha (Sora), Veliko Širje (Savinja River)	occasionally	1955	on-line and yearbooks
	Profile measurements	-	-	-	-	-
	Continuous (turbidity)	2	Suha (Sora River) and Veliko Štirje (Savinja River)	hourly	2016	on-line and yearbooks
	SST	2	Suha (Sora River) and Veliko Štirje (Savinja River)	annually	2016	on-line and yearbooks
	Grain-size distribution	-				
HR	Point sampling	8	4 locations on the Sava River (Podsused ž., Rugvica, Jasenovac, Slavonski Brod) and 4 on the tributaries (Krapina, Kupa, Bijela, Bjelovarska rijeka)	daily	1960	internal system and yearbooks
	Profile measurements	3	Podsused žičara, Rugvica and Jasenovac (Sava River)		2012	restricted
	Continuous (turbidity)	1	Slavonski Brod (Sava River)		2020	on demand
	SST	7	3 locations on the Sava River (Podsused ž., Jasenovac, Slavonski Brod) and 4 on the tributaries (Krapina, Kupa, Bijela, Bjelovarska rijeka)	annually	1978	on-line and yearbooks
	Grain-size distribution	3	Podsused žičara, Rugvica and Jasenovac (Sava River)		1978	restricted
BA	-					
RS	-					

Figure 12 Turbidity sensor Solitax_sc and SC1000 communication interface (left); sensor in a pipe on gauging station Suha on Sora River (right)

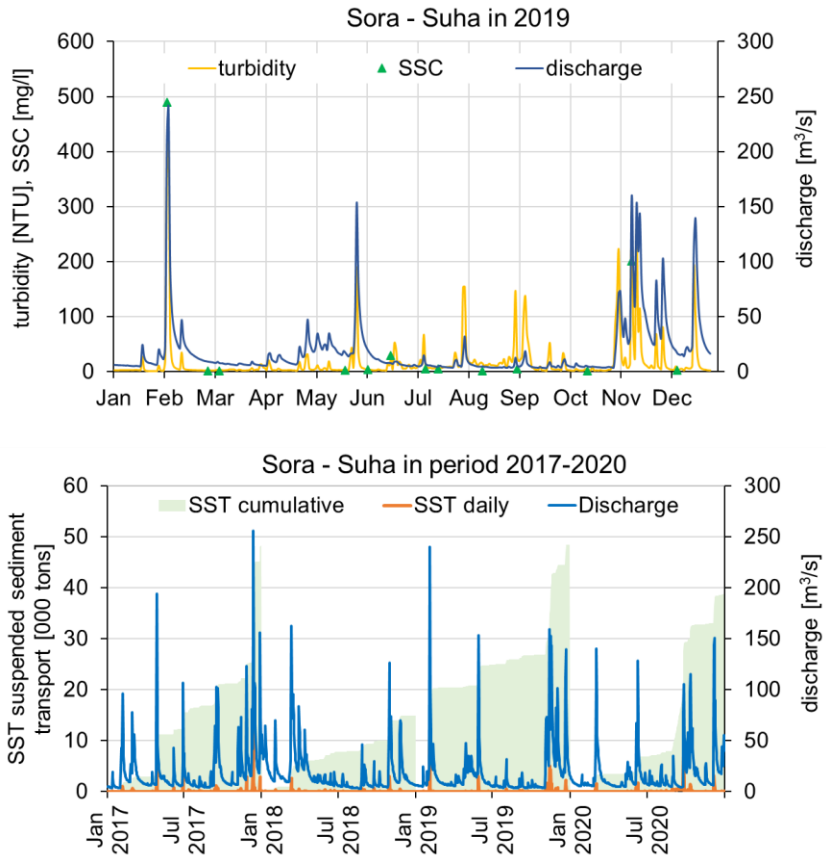
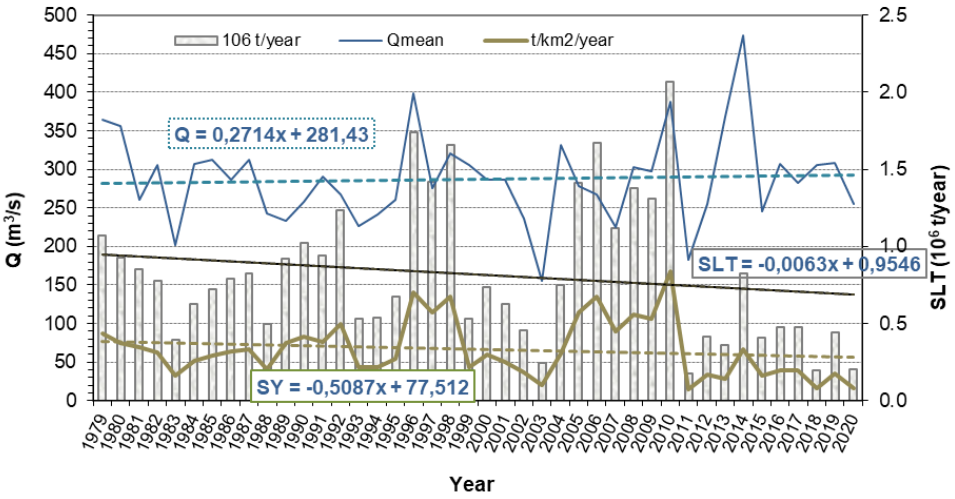


Figure 13 Mean daily discharge and turbidity together with periodic measurements of SSC (above) and daily and cumulative suspended sediment transport (below) at g.s. Suha on the Sora River

In Croatia, regular suspended sediment monitoring is carried out through daily point samplings of water from watercourses and lakes and as a continuous monitoring of turbidity since 2020 (at a single station). Determination of SSC is based on a weight difference between empty and full filter paper by standard filtration method (ISO 4365:2005). In period 1979-2020 at gauging station Podsused žičara (Figure 14) there were some specific years with extremely high annual suspended sediment transport (SST) (period 1996-1998; 2005-2010). According to the daily suspended sediment concentration (SSC) measurements a significant decrease of the annual suspended sediment transport (SST) and specific yield (SY) can be observed in the last decade (Figure 14). In contrast, mean annual flows show slightly increasing trend indicating anthropogenic influences in the upper part of the basin. Profile suspended sediment concentration is assessed on 3 stations mostly three times a year by using Acoustic Doppler Current Profiler (ADCP) together with point sampling of sediments in a water column. An acoustic surrogate technology takes into account raw acoustic data from a ADCPs and correlates the processed attenuation of the signal with manually sampled suspended sediment concentrations, and it obtains SSC for each measured ADCP cell. The aim of these measurements is to define profile sediment distribution and regression function between main hydraulic parameters (Q, SSC, SST), see Figure 15, as well as for correlation between point concentration and mean profile sediment concentration. Grain-size distribution of suspended sediment in performed at 3 stations. Suspended particle composition is undertaken during profile measurements by using integrated 200 litre samples along the entire flow cross-section. The sample is decanted and, based on a computation of still-water settling velocity, i.e. hydraulic coarseness of individual fraction, the suspended load grain-size distribution is determined in a laboratory.



Q – mean annual flow; SST – annual suspended sediment transport; SY – annual specific yield

Figure 14 Long-term suspended sediment transport (SST) and specific sediment yield (SY) for HS Sava - Podsused žičara, period 1979-2020

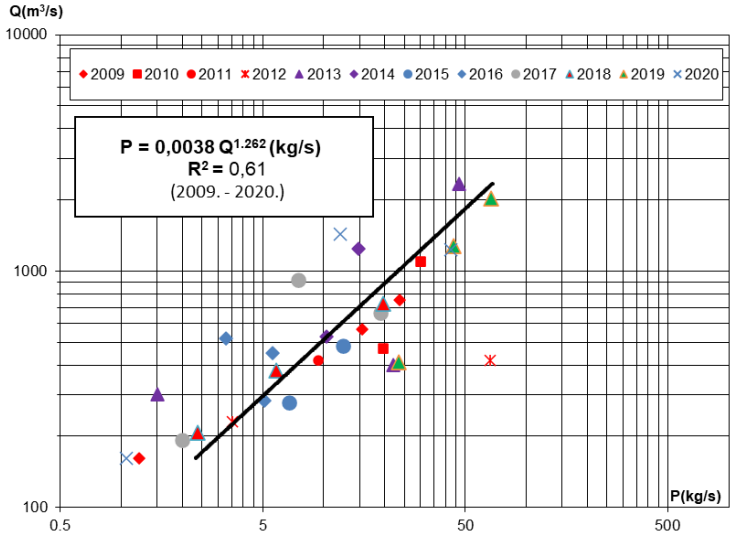


Figure 15 Sediment-rating curve for gauging stations Sava-Jasenovac in 2009-2020

Figure 16 Integrated 200 litre water sample at gauging station Sava-Podsused

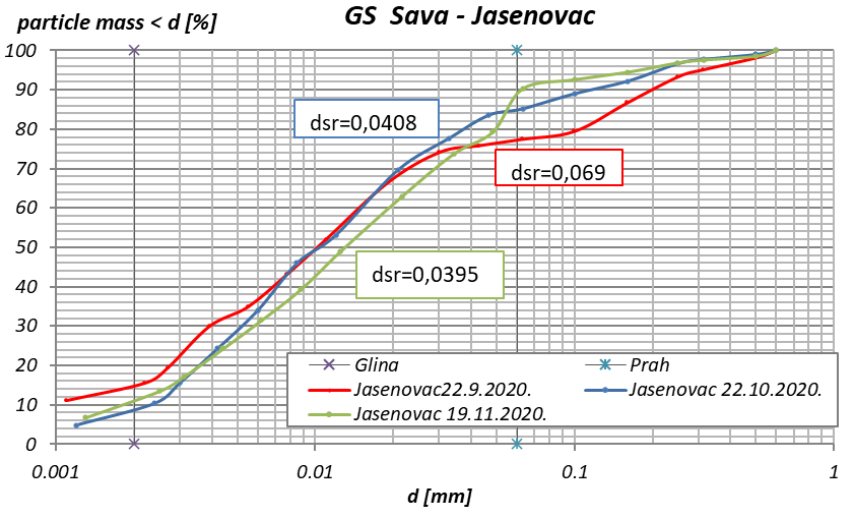


Figure 17 Suspended sediment grain-size distribution gauging station Sava-Jasenovac in 2020

In Bosnia and Herzegovina systematic sediment monitoring (sediment quantity and sediment quality) on the Sava River or its tributaries does not exist. Occasional monitoring of sediment is conducted for individual projects. The exceptions are some hydrological stations with continuous automatic turbidity measurement, such as gauging station Goražde on the Drina River.

In Republic of Serbia, RHMSS conducted suspended sediment monitoring in the past on the Sava river (3 stations), Drina river (4 stations), and Kolubara river (4 stations). The methodology included daily point sampling (1 l volume). In the frame of the UNESCO financed project, a turbidity sensor was installed on the left bank of the Sava river at gauge station Sremska Mitrovica in 2017. Correlation between water turbidity (NTU) and average concentration of suspended sediment (SSC) was established (Figure 18) and SSC was estimated during 2017 (Figure 19). Unfortunately, turbidimeter is out of function since March 2018.

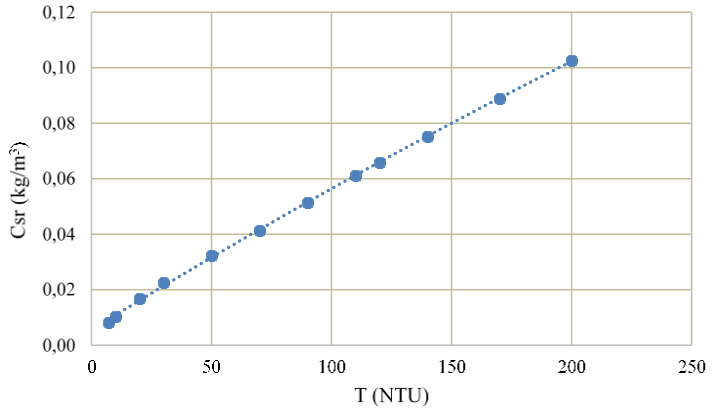


Figure 18 Correlation between water turbidity and average SSC at g.s. Sava - Sremska Mitrovica

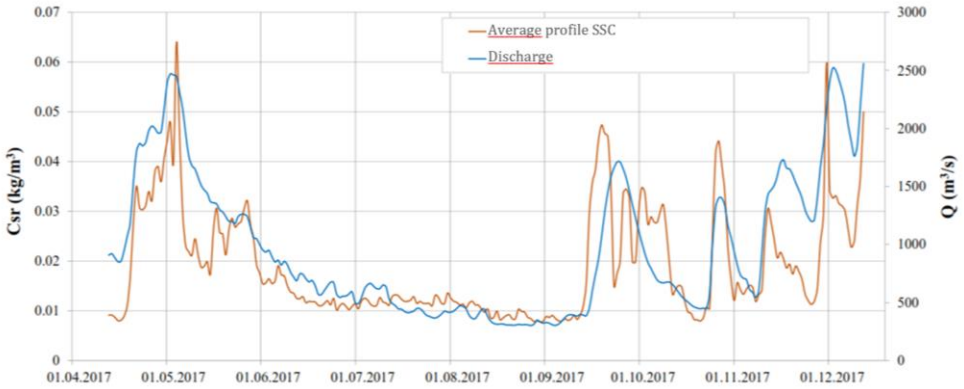


Figure 19 Data on river discharge and average SSC in 2017 at g.s. Sava - Sremska Mitrovica

3.3 Bedload monitoring system

Bedload transport measurements are currently not being carried out in the Sava RB (Table 11).

Table 11 Overview of activities on bedload monitoring

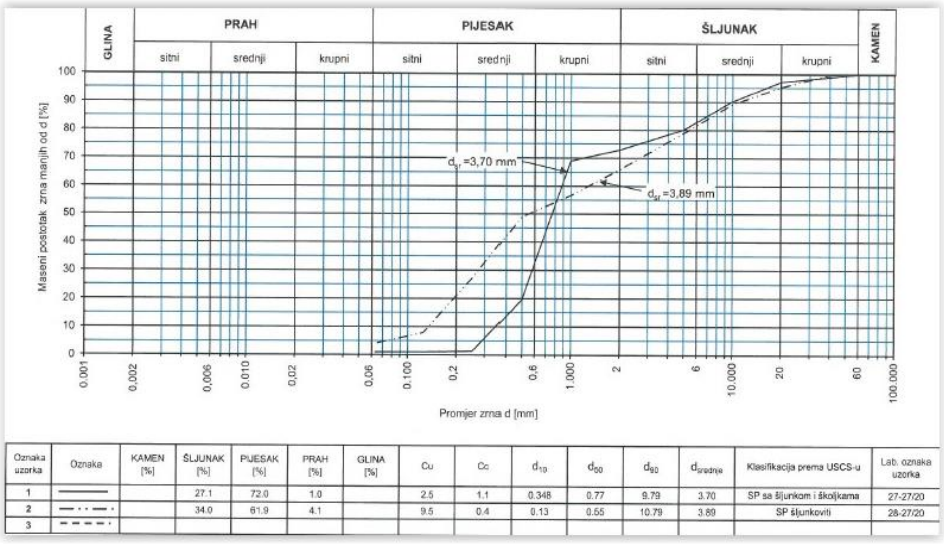
Party	Type of monitoring	Number of stations	Stations	Monitoring frequency	Beginning	Data availability
SI	-					
HR	Grain-size distribution	2	Rugvica and Jasenovac (Sava River)	every 6 months		restricted
BA	-					
RS	-					

In Croatia, the only systematic bedload measurements in the Sava River were performed at g.s. Sava - Podsused in period 1968-1986 with an addition of the grain-size curve determination on individual measuring verticals. Nowdays, the granulometric distribution of bedload is regularly monitored at two locations in Sava river (Rugvica and Jasenovac) twice a year. The determination of distribution is done by sowing and hydrometering in accredited geotechnical laboratory, according to HRN EN ISO 17892-4 (Figure 20). Changes in the granulometric composition and geometry of the river bed

are monitored over a longer period of time in order to detect erosion and deposition processes in the river bed.

In Bosnia and Herzegovina, during the project "Study of river sediment transport, Pilot project lower course of the river Bosna", the bedload measurements were performed at two sites (Maglaj and Bosanski Samac) on the Bosna river.

In Republic of Serbia, bedload measurements were previously conducted only for individual studies and projects, together with the bed material sampling along the Sava River and in reservoirs on the Drina River.



Oznaka uzorka	Oznake	KAMEN [%]	ŠLJUNAK [%]	PIJESAK [%]	PRAH [%]	GLINA [%]	Cu	Cc	d_{10}	d_{50}	d_{90}	$d_{srednje}$	Klasifikacija prema USCS-u	Lab. oznaka uzorka
1			27.1	72.0	1.0		2.5	1.1	0.348	0.77	9.79	3.70	SP sa šljunkom i šljunkama	27-27/20
2			34.0	61.9	4.1		9.5	0.4	0.13	0.55	10.79	3.89	SP šljunkoviti	28-27/20
3														

Figure 20 The bedload grain-size curve at g.s. Sava-Jasenovac in Sept 2020

3.4 River cross-sectional monitoring system

In Slovenia, regular river cross section monitoring is performed at hydrological stations of Slovenian Environment Agency (ARSO). Cross-sectional geometry measurement is performed either at individual points (shallow section) or along transverse profiles (deeper section) by using acoustic Doppler method (RDI ADCP meter) with real-time integration of velocity field and cross-sectional area (ISO / TS 24154: 2005). On average, 4 to 6 measurements of cross section are performed annually at each station. All facilities of the ARSO hydrological service are also entered in the Collective cadastre of economic public infrastructure (e-prostor), see Figure 21. Information about cross section on gauging stations are reachable by the demand on ARSO.

Table 12 Overview of activities on monitoring of river cross sections

Party	Responsible institution(s)	Type of monitoring	Number of sections	Monitoring frequency	Data availability
SI	Slovenian Environment Agency	individual points or transverse profiles	stations in hydrological monitoring network	4 to 6 times per annum	on demand
HR	National Meteorological and Hydrological Service (DHMZ) and Ministry of the Sea, Transport and	geodetic surveys	stations in hydrological monitoring	according to the annual plan	on demand

	Infrastructure - Waterways administration		network and waterways		
BA	Sava River Watershed Agency and Federal Hydrometeorological Institute (Federation of BiH), JU Vode Srpske and Hydrometeorological Institute of Republika Srpska (Republic of Srpska)	geodetic surveys	stations in hydrological monitoring network	periodically	on-line
RS	Ministry of Construction, Transport and Infrastructure - Directorate for Waterways (Plovput)	geodetic surveys	entire Sava river at 200 section distance	periodically	on demand

In Croatia, the river cross section monitoring is performed at hydrological stations by geodetical surveys in order to determine the river bed shape, the cross-sectional area or the degree of morphological changes, which affects the stability of rating curves defined for a certain period. The number and schedule of surveys is defined in the annual program for the hydrological works of hydrological monitoring networks (DHMZ network, CW network, HEPP network). The surveying frequency generally depends on changes in the flow profile. Graphical and tabular results of river channel surveys are archived in the local database (HIS2000), together with all other hydrological parameters measured at that station (see Figure 22). In addition, Ministry of the Sea, Transport and Infrastructure - Waterways administration (public institution in charge of waterway maintenance) conducts occasional or regular geodetic river surveys as part of their activities related to technical maintenance of waterways and navigation safety.

In Bosnia and Herzegovina, the river cross section monitoring is performed at hydrological stations by geodetic surveys in order to determine the riverbed shape, the cross-sectional area or the degree of morphological changes, which affects the stability of rating curves defined for a certain period. Geodetic observations of these places are performed periodically and as needed. Data on river cross section monitoring is available on the website of relevant institution.

In Serbia, the river cross section monitoring of the Sava River is performed for the needs of maintaining the Sava waterway. The Sava surveys at a 200 m distance were undertaken in 2009, 2014, 2016, 2017, 2018 and 2020. Surveys of other rivers in the Sava RB are performed only by the project basis.

Figure 21 Gauging station Hrastnik-Sava with station infrastructure (from the portal e-prostor)

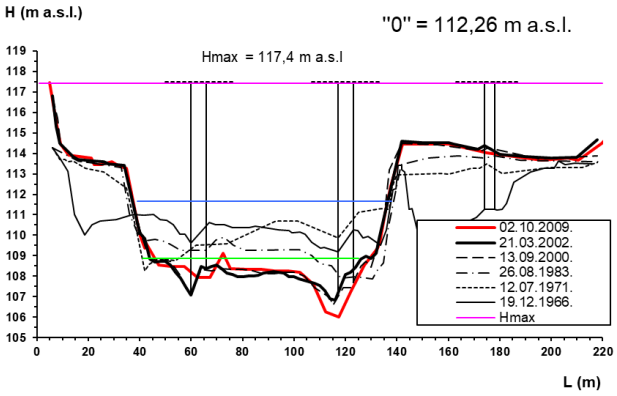


Figure 22 Monitoring of river cross-section at g.s. Sava-Zagreb

Based on decision 9/21 of the ISRBC adopted in March 2021, the Parties to the FASRB are obliged to deliver to the ISRBC the data collected by bathymetric surveys of the Sava River and its navigable tributaries on a regular basis. The bathymetric data would be collected for the purpose of regular updating of the geometry of the existing Sava hydraulic model, with main aim of increasing its accuracy of water level forecasting, especially in low-flow conditions.

3.5 Dredging monitoring system

In Slovenia, a yearly amount of dredged material must be reported to the Ministry of Environment and Spatial Planning, but the data are not publicly available.

In Croatia, in period 1990-2007 dredging in watercourses was allowed. It should be mentioned that in that period interventions were most often carried out without expert studies and assessments of the environment, water regime, flood risks or the balance of water systems. As such a practice paved the way for the grey economy, and in 2009 there was a complete ban on sediment extraction. With the new Water Act in 2009, dredging on rivers became legal again by obtaining concession permit. Concessionaires pay a free for each m^3 of extracted sediment and thus the official record of dredged amount is obtained. All data and information on dredging in Croatia are available at the Ministry of the Environment and Energy of the Republic of Croatia or Croatian Waters, Annual Reports on executed dredging. The Report contains information regarding type of dredging (capital or maintenance location of dredging sites, type of dredging, period of dredging, type and total amount of dredged material etc). Annual Reports of dredging can also be found at the Sava GIS Geoportal (ISRBC) in the Metadata catalogue for registered users.

Table 13 Overview of activities on dredging monitoring

Party	Type of monitoring	Monitoring frequency	Number of sections	Data availability
SI	-			
HR	Reports on dredging	annually	5 in 2019 and 1 in 2020	on demand
BA	Reports on dredging	annually	-	ISRBC portal (restricted)
RS	Reports on dredging	annually		on demand

In Bosnia and Herzegovina, there is no regular monitoring on dredging. The only collected data on dredging for the Sava RB are available through the ISRBC document "Report on executed dredging". The dredging in 2019 and 2020 was mainly executed in the Vrbas, Bosna and Drina rivers.

In Serbia, the Plan for extraction of river sediment is given together with maps (Figure 23). According to the conditions from relevant institutions (environmental protection, water management, navigation), the maps provide details on locations where dredging is allowed (light blue areas), not allowed (red areas) or should be done to enhance water regime (green areas). The maps for the Sava and the Drina are publicly available on web pages of relevant institutions (PWMCs Srbijavode and Vode Vojvodine). Dredging on the Sava is allowed only from the main channel, using floating dredging devices. Preferred locations are within navigation route, where dredging is needed to maintain or enlarge its dimensions. Dredging on the Drina should be done from sediment bars on convex banks of river bends or from water land if total designated volume is not exceeded. Both data from the Plan and data on water approvals for dredging are stored in Water Management Information system.

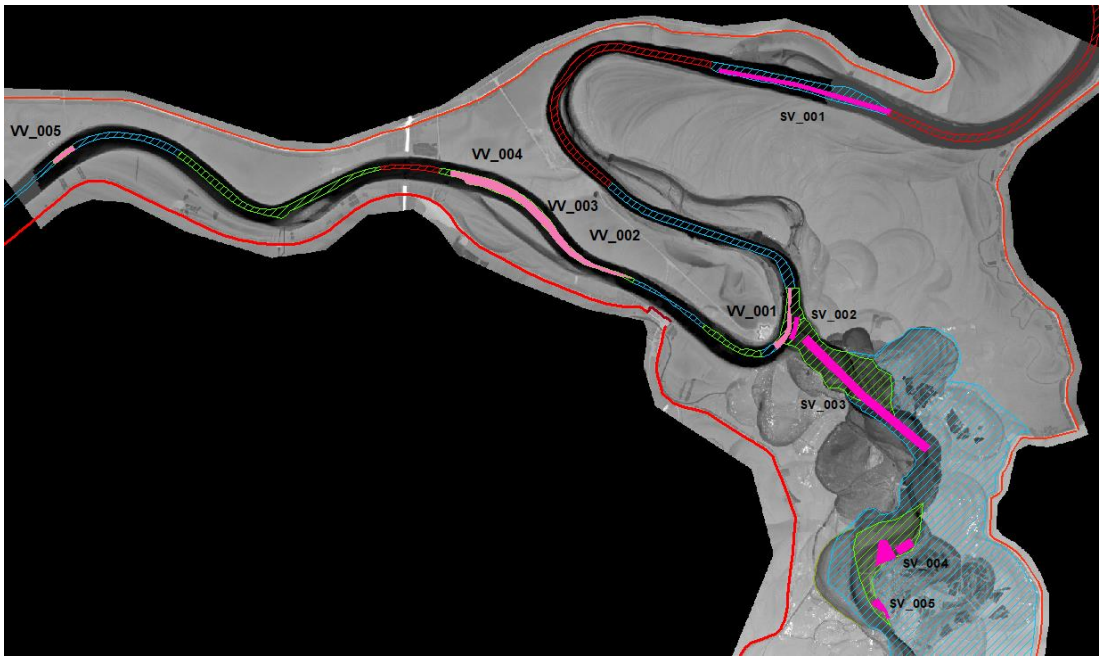


Figure 23 Map of the Drina mouth with dredging areas

At the basin level each Party should develop the Information on planned dredging on yearly basis in accordance with the Protocol on sediment management. The Information on planned dredging should contain at least the following:

- planned locations and types of dredging including assessment of quantity and quality of sediment to be dredged for Sava River and its main tributaries;
- methods for sediment disposal;
- methods for sediment treatment in case the sediment is polluted;
- summarized quantities of dredged sediment for the sub-basins of other tributaries.

The Parties should also report on executed dredging yearly for the previous year.

All the Parties are informed on planned and executing dredging through the Sava Commission which could organize consultations related to any issue of importance for development and implementation of the activities under the Information on Planned Dredging.

3.6 Reservoir sedimentation monitoring system

Currently there is no reservoir sedimentation monitoring system in the Sava RB. The monitoring of the hydropower plant reservoirs is carried out by the HPP owners, but occasionally and data are restricted. As there is no regular monitoring system in place, the data on reservoir sedimentation processes are missing.

Table 14 Overview of activities on reservoir sedimentation monitoring

Party	Type of monitoring	Reservoirs	Monitoring frequency	Data availability
SI	-			
HR	Cross-sectional surveys	Some small reservoirs in the river basin	-	restricted
BA	-			
RS	Cross-sectional surveys	Some reservoirs in the Drina river basin	occasionally	on demand

In Slovenia, the run-off-river reservoirs were built in the Sava main channel and thus have been affecting suspended sediment and bedload transport in the downstream sections. Sediment balance is estimated using river reservoir sedimentation data.

In Croatia, several small reservoirs and retentions were built on the Sava tributaries, but none of them performs systematic monitoring system on reservoir sedimentation. If any, the data are not publicly available.

In Bosnia and Herzegovina, only occasional monitoring of reservoirs is conducted for individual projects. According to the document "Established of sediment monitoring in ERB (2015)" monitoring of reservoir sedimentation was performed recently at "Modrac" reservoir by JP "Spreča".

In Serbia, reservoir monitoring (survey of cross-sections) and sedimentation estimations are done occasionally in the Drina River Basin, depending on the sedimentation problem severity perceived by the HPP operators.

3.7 Soil erosion monitoring system

The monitoring of soil erosion in the Sava RB is not present, but recently some useful information is becoming available (only in SI).

In Slovenia, for a better understanding of soil erosion processes the landslide warning maps are utilised (Figure 24). Information from geotechnical, geological, hydrogeological and geodetic surveys, together with landslides monitoring system are basis for development of landslide warning maps. The maps and their interpretation serve for an expert opinion for determination of soil erosion processes in river basins. Information about landslide hazard is publicly available at the GeoHazard portal (https://www.geohazard.geo-zs.si/)

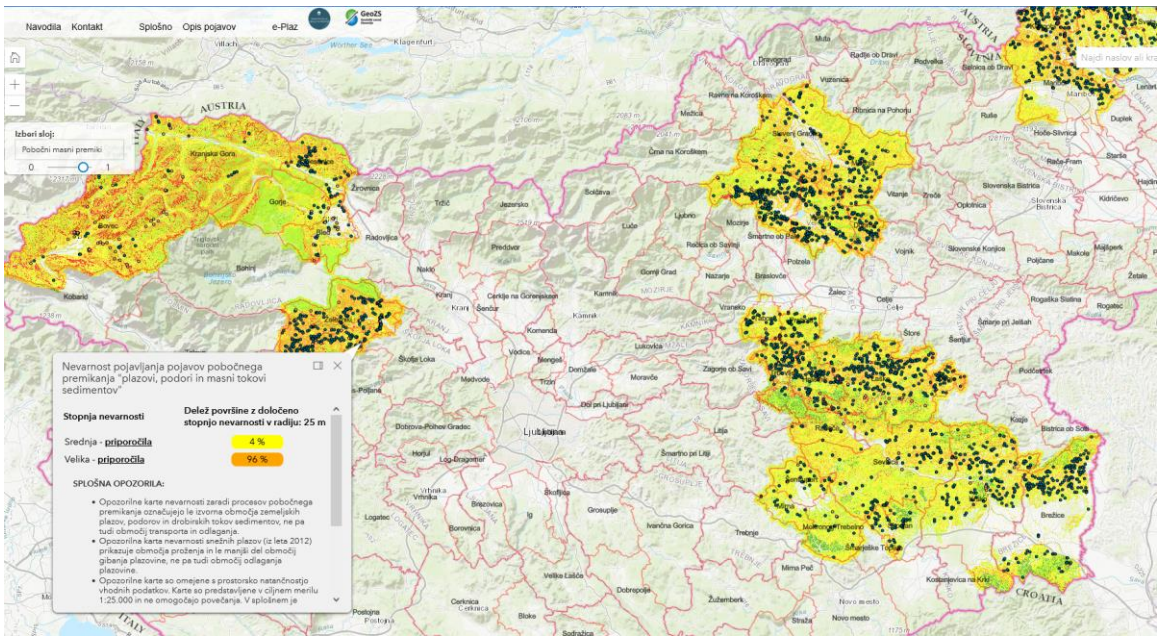


Figure 24 Landslide warning maps, which indicate the source areas of landslides, location of landslides and debris flows of sediments (Geological Survey of Slovenia)

3.8 Sediment quality monitoring system

In Slovenia, sediment quality monitoring is part of a regular monitoring system at 12 stations and is performed by the Slovenian Environment Agency (ARSO). Monitoring of priority and priority hazardous substances in sediments is the fraction less than 63 μm and it is carried out every three years. Investigations of the following parameters is performed: di (2-ethylhexyl) phthalate, C10-C13 chloroalkanes, brominated diphenylethers, cadmium, lead, mercury silver, hexachlorocyclohexane, pentachlorobenzene, hexachlorobenzene, hexachlorobutadiene, tributyltin compounds, anthracene, fluoranthene, polyaromatic hydrocarbons - benzo (a) pyrene, benzo (b) fluoranthene, benzo (g, h, i) perylene, benzo (k) fluoranthene, indeno (1,2,3-cd) pyrene and tributyltin compounds. Slovenia has established bilateral monitoring of transnational watercourses with neighbouring countries (Austria, Hungary, Croatia). Monitoring has been going on for a number of years, and after the introduction of WFD the programme was adapted. Some measuring points on the Sava River are also included in the monitoring within the framework of international conventions (TNMN - Trans National Monitoring Network under the Danube Convention). The data on sediment quality at measuring stations and the monitoring programme of the chemical and ecological status of water are available on-line.

In Croatia, chemical and biological monitoring is performed by Croatian Waters on a yearly basis. Monitoring stations are set up for catchments larger than 2500 km^2 and on transboundary watercourses. The chemical analysis of sediments includes total nitrogen, total phosphorus, cadmium, nickel, lead, mercury, mineral oil, polychlorinated biphenyls, organochlorine pesticides, alachlor, triazine pesticides, pentachlorobenzene. The results of water quality monitoring are published in the annual reports. In the year 2009, the quality monitoring was carried out at 31 measuring stations, and according to the investigated biological elements, 8 monitoring stations have good status, 11 moderate status, while 12 monitoring stations have poor status. Besides the regular monitoring, the periodic chemical analyses are performed by different institutions on a project basis.

In Bosnia and Herzegovina, systematic monitoring of sediment quality on the Sava River or its tributaries does not exist. Occasional monitoring is conducted for individual projects. The project results are usually not publicly available.

In Serbia, monitoring of sediment quality was performed between 2012 and 2017 on 17 locations in the Sava RB. Samples were analysed to detect heavy metals (Zn, Cu, Cr, Pb, Cd, Hg, Ni, As), and the organic pollutants as polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), organochlorine pesticides, and triazine-based pesticides.

A proposal for improvements of the existing sediment monitoring systems

4 A proposal for improvements of the existing sediment monitoring systems

4.1 Gap analysis

General remarks

Regular monitoring of sediment transport and sediment quality on a sufficient number of gauging stations is prerequisite for a sustainable sediment management at the river basin level and for achieving a good water status. The general gaps in the existing sediment monitoring system in the Sava RB include: (a) poor density of monitoring stations, (b) limited sediment monitoring data availability for a reliable basin-wide sediment assessments, (c) lack of monitoring data on reservoir sedimentation, and (d) lack of appropriate storage and manipulation of datasets.

Gaps in suspended sediment monitoring system

In general, the number of suspended sediment monitoring stations is insufficient with a continuously decreasing trend.

The SSC monitoring on the Sava main channel is performed only at 4 stations (all are in HR), and no monitoring on the Sava main channel exists in other Parties (see Table 5). There are additional 6 stations on the Sava tributaries (2 stations in SI, 4 stations in HR) with the SSC monitoring.

The SST on the Sava main channel is assessed only at 3 stations (all are in HR), and at 6 additional stations on the Sava tributaries (2 stations in SI, 4 stations in HR).

Even though some SSC monitoring systems are in place (SI, HR), the sediment measurement techniques and frequency differ and, therefore, do not form a coherent basin-wide sediment quantity (SST) dataset. The SSC and SST are obtained from continuous turbidity measurements (in SI) or from daily point samples (in HR).

The suspended sediment monitoring data are available either on-line (SI) or on demand (HR).

Gaps in bedload monitoring system

The bedload monitoring includes only a grain-size distribution at 3 stations (all are in HR). The BLT is not assessed in the Sava RB. The grain-size distribution monitoring data are available on demand (HR).

Gaps in river cross-sectional monitoring system

The river cross-sectional monitoring in the Sava RB usually includes the river channel surveys at hydrological stations (SI, HR, BA, RS). Entire reaches of the Sava river are being surveyed in HR and RS (at regular intervals) for the purpose of technical maintenance of waterways and navigation safety. Geodetic surveys on transboundary river section is subject to protocols on the utilisation of

the banks of another Party. Therefore, cross sections on the interstate flow of the Sava and its tributaries have not been recorded in full width in some sections (HR, BA). The river survey monitoring data are available on demand only.

Gaps in dredging monitoring system

The status of dredging from rivers and lakes is well managed in the Sava RB. In all the Parties the dredging is regulated by law and managed by competent authorities. Annual dredging amounts are being reported to competent authorities and the data is shared with the ISRBC. However, the quality assessment of the dredged material is not undertaken.

Gaps in reservoir sedimentation monitoring system

Currently there is no reservoir sedimentation monitoring system in the Sava RB. The monitoring of the hydropower plant reservoirs is carried out occasionally by the HPP owners, but still unregular and data are restricted. Reservoir monitoring is prescribed in the Water permits for the HPP operation (in RS) and it is supervised (in SI). As there is no regular monitoring system in place, the data on reservoir sedimentation processes are missing.

Gaps in soil erosion monitoring system

The monitoring of soil erosion in the Sava RB is not present, but some spatial information is emerging (only in SI).

Gaps in sediment quality monitoring system

The sediment quality monitoring system is established only in some Parties (SI, HR), while in other parts the monitoring it is either not present (BA) or it is occasional (RS). As the programme is not harmonised among the Parties, the monitoring parameters are not common.

4.2 Proposals for improvements

The existing sediment quantity monitoring in the Sava RB is inadequate and there are many avenues for improvement.

Proposal 1.1: Increase the number of sediment monitoring stations

The number of monitoring sites in the Sava RB is below the WMO recommendations (The Guide to Hydrological Practices, Vol.I 4Th ed., 1981). According to the WMO recommendations, the sediment transport should be monitored on 15 % to 30 % of the hydrological stations (in minimum hydrological network). Considering the minimum density of hydrological stations, the following minimum density of sediment monitoring stations is required:

- In flat regions of temperate or Mediterranean zones: 1000-2500 km^2/station.
- In mountainous regions of temperate or Mediterranean zones: 300-1000 km^2/station.

In the identification of stations for sediment monitoring the following should be considered:

- stations should experience a dominant sediment yield from the upstream basin (on the Sava river and main tributaries),
- locations near country borders,

- locations before and/or after the confluence with main tributaries.

Proposal for few sediment monitoring stations is given in the national reports (annexes).

Proposal 1.2: Establishment of efficient data storage and exchange

For improvement of the sediment monitoring system the following is recommended:

- Systematic and reliable storage of all data and information on sediment sampling and transport.
- Regressions between all relevant variables (SSC = $f(Q)$; SST = $f(Q)$; $SSC_{profile} = \boldsymbol{R}\ SSC_{point}$) should be archived in the same way as discharge rating curves (graphical and analytical presentation for the period).
- Annual SST and BLT as well as cross-sectional surveys should be part of regular reports and should be available on demand.

Proposal 1.3: Establishment of cross-border cooperation and data exchange

- It is recommended to improve the cross-border cooperation on water and sediment management between the Parties with the closer exchange of experiences, common methodology and data.
- Periodic common SST and BLT measurements on at least three control cross-border profiles are recommended (Sava – Medsave, Sava - Jasenovac/Drenje Brdovečko and Sava - Gunja/Jamena).
- Data on sediment sampling and transport on common cross-border profiles should be exchanged between the Sava RB countries.

Proposal 1.4: Improvements in suspended sediment monitoring

To allow for more comprehensive SSC and SST measurements, and especially during flood events, the following measurements should be included in the monitoring programme:

- Regular: SSC, SST and grain-size distribution of SS on all stations
- Harmonisation of SSC monitoring among the Parties.
- Periodic: Profile SSC on all stations
- The SSC monitoring should combine all three measurement techniques:
  - Daily point sampling on all stations.
  - Periodic profile measurements (profile sampling + ADCP) on all stations and establishment of relationship between point and profile concentration ($SSC_{profile} = \boldsymbol{R}\ SSC_{point}$).
  - Continuous turbidity monitoring on all stations.

Proposal 1.5: Establishment of bedload monitoring

The following measurements should be established in the monitoring programme:

- Regular: Grain-size distribution of BL on all stations
- Periodic: BLT measurements on all stations

- The BLT monitoring should combine different measurement techniques:
  - Point sampling.
  - Estimation from ADCP bottom tracking.

Proposal 1.6: Improvements in river cross-sectional monitoring

The following improvements are recommended:

- River surveys should account also main Sava tributaries, besides the Sava main channel.
- To allow for basin-wide analysis of morphological changes (at least for some years), the river survey frequency should be harmonised among countries.
- Bilateral agreements between the Parties on the utilisation of water and land for surveys of common sections.
- The monitoring data should be stored in digital format (graphical and tabular) and available on demand.

Proposal 1.7: Improvements in dredging monitoring

The following improvement is recommended:

- Establishment of sediment quality monitoring system of dredged material.
- Data and reports on locations and type of dredging should be publicly available.

Proposal 1.8: Improvements in reservoir sedimentation monitoring

The following improvements are recommended:

- Annual reservoir bed surveys should be performed on all HPPs.
- Annual grain-size distribution of BL should be performed on all HPPs.
- Establishment of sediment quality monitoring system of sedimentation material.
- Data should be stored in a dedicated database.

Proposal 1.9: Improvement of soil erosion monitoring

The following improvements are recommended:

- Production of soil erosion maps on the entire basin.
- Regular terrain surveys are recommended.
- Regular update of soil erosion maps is recommended.
- Data and maps should be available on-line.

Proposal 1.10: Improvements in sediment quality monitoring

The following improvements are recommended:

- Establishment of sediment quality monitoring system in BA.
- Harmonisation of monitoring programme and parameters among the Parties.
- Common monitoring of the two Parties on the joint profiles.

- The monitoring data and reports should be available on-line.

An analysis of the existing sediment management issues

5 An analysis of the existing sediment management issues

5.1 General remarks

5.1.1 Background documentation

The intention for this report was to collect information on various water and sediment management measures in place in the Sava RB. However, the reports and studies do not provide detailed and comprehensive basin-wide information on issues related to management of sediment quantity and quality. The knowledge and information on the sediment management issues in the Danube River Basin were also analysed and collected as well as other relevant documentation. The status of the EU WFD implementation in the Sava countries is also analysed.

In Slovenia, the two national RBMPs have already been adopted: the first for period 2009-2015 and the second for period 2016-2021. The 3rd plan for period 2022-2027 is under preparation. All suggested measures from the previous plans have not been realised.

In Croatia, the two national RBMPs were adopted: for period 2013-2015 and for period 2016-2021. The third plan for the period 2022-2027 is under development and will be finalized in the fourth quartal of 2021. The availability and quality of background information on sediment management issues are limited and differ by area. The information are collected by the owners and managers of water management structures (Croatian Waters, a national power company Hrvatska elektroprivreda, and Waterways Agency) as well as local government. The major hydromorphological issues are identified as physical changes along river channel and floodplains, transversal river structures and hydrological alterations.

In Bosnia and Herzegovina, the EU WFD is partially transposed through provision of the existing Water Acts in the Federation of Bosnia and Herzegovina and Republika Srpska. The three entities' RBMPs were adopted: (a) Sava RBMP for Federation of Bosnia and Herzegovina for period 2016-2021, (b) Sava RBMP in Republika Srpska for period 2017-2021 together with Strategy of IWM of the Republic of Srpska (2015-2024), and (c) RBMP for the Brčko District (2016-2021). The development of the 2nd RBMP in Republika Srpska is ongoing, while in Federation of Bosnia and Herzegovina the 2nd RBMP is drafted and is in public consultation process.

In Serbia, the development of the 1st RBMP is ongoing. The plan will be available for the public consultation in 2021.

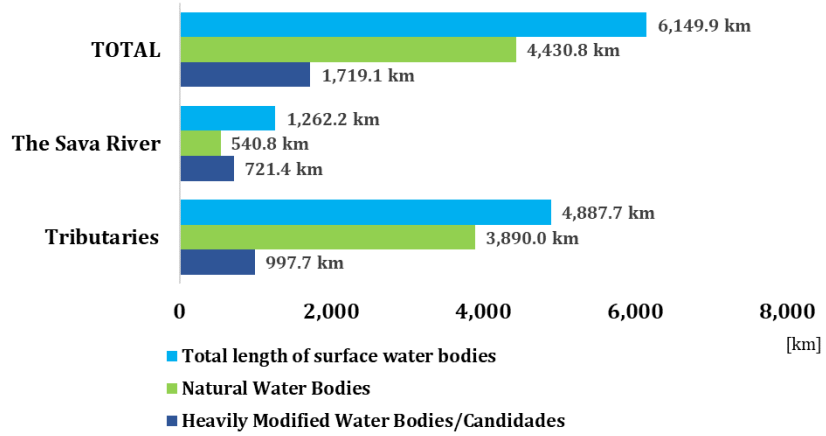


Figure 25 The length (in km) of the delineated natural WBs, HMWBs and candidates for HMWB for the Sava River and its selected tributaries, source [6]

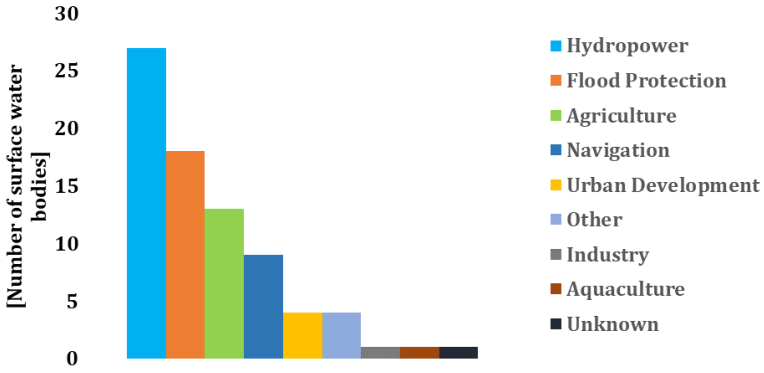


Figure 26 Drivers for HMWB designation per number of the affected surface water bodies in the Sava River basin

The basin-wide information on the existing sediment management issues for the Sava RB are the EU WFD implementation reports by ISRBC: the 1st Sava River Basin Management (accepted in December 2014), the 2nd Sava River Basin Analysis (accepted in June 2017) and the 2nd Sava River Basin Management Plan (drafted), from August 2021.

Preliminary data in the draft 2nd Sava RBMP (from August 2021) shows that out of a 1.262,18 km of total length of the Sava River surface water body, a 56% (721,42 km) is designated as heavily modified. On the selected tributaries of total surface water body length of 4.887,72 km as heavily modified/provisionally heavily modified are designated 20% (997,69km), see Figure 25. The main drivers for identification of HMWBs in the Sava River are hydropower production, flood protection, navigation, agriculture, and urban development (Figure 26).

The Sava and Danube rivers share similar sediment transport and management issues. A comprehensive hydromorphological assessment for the Danube River was reported in the document "Integrative study on hydromorphological alterations on the Danube", by Habersack et al. 2010. The study shows that *sections of the Danube River feature totally disturbed systems (e.g. sediment balance) due to the combined impacts of flood protection, navigation and hydropower. The sediment continuum in the Danube does not exist any more (torrent control, hydropower etc.), leading to a lack of bed load*

[6] ISRBC, 2nd Sava River Basin Management - Plan Draft, August 2021

and suspended load in free flowing sections. For the purpose of navigation, flood protection, sediment extraction and hydropower generation, large sections of the Danube River have been narrowed, channelised, disconnected from floodplains and morphologically degraded. This has led to increased shear stresses, sediment transport capacities, lack of lateral sediment transport and reduced morphodynamics in unimpounded sections. As a consequence of limited sediment supply and channelisation, the free flowing sections show river bed degradation. Such degradation leads to a loss of instream structures, especially a disappearance of gravel bars and changes to sand bars.

Similar to the Danube River, the continuous alterations of sediment transport in the Sava River disturbed the morphodynamics and natural sediment balance. There is generally decreasing trend in sediment yield from the upstream sections which, in combination with the strengthening of the river banks and construction of flood embankments, resulted in a continuous river bed degradation of the Sava channel around Zagreb (Figure 27) followed by the decrease of water and groundwater levels. Such trends have shown negative impacts on status on the Sava waters, such as:

- increased flood risk
- riverbed degradation
- reduced navigability
- deterioration of the ecological conditions

Figure 27 The railway bridge Jakuševac in Mičevac on the Sava River that collapsed on March 30, 2009

5.1.2 Key sediment management issues

According to available information, the most important sediment management issues in the Sava RB are identified as:

1. Longitudinal continuity interruptions and hydrological alterations
2. Morphological alterations
3. Dredging and sediment excavations
4. Soil erosion

5.2 Longitudinal continuity interruptions and hydrological alterations

Longitudinal continuity and hydrological alterations refer to pressures resulting from interruption of longitudinal river continuity, impoundment, water abstraction and hydropeaking which can block sediment transport and altered flow regime.

The longitudinal continuity interruptions (dams, weirs, raps, sluices, sills, etc.) in the 2nd Sava River Basin Analysis 2016 were defined based on the ICPDR's criteria as: (a) for rithral rivers, height > 0.7 m, and (b) for potamal rivers, height > 0.3 m. Based on defined criteria the 38 barriers were identified in the Sava RB: 14 on the Sava River and 24 on its tributaries (Bosut, Ćehotina, Dobra, Drina, Kolubara, Kolpa/Kupa, Lašva, Lim, Lonja, Piva, Pliva, Sotla/Sutla, Spreča, Una, Uvac and Vrbas rivers). Out of the 38 barriers 35 are dams, two are ramps and one is classified as "other type of interruption".

The criteria for hydrological alterations were defined following the ICPDR's criteria with the specific provoked alterations and criteria for assessment (Table 16). In Slovenia, there were reported 56 km of impoundments caused by 7 dams and 18 hydrological alterations affecting 14 water bodies on the Sava River and tributaries, and which relate to all three pressures (impoundment, water abstraction and hydropeaking). In Croatia, 20.1 km of impoundments create 4 reservoirs and the two HPPs reported to cause hydropeaking. In Bosnia and Herzegovina, there are 8 impoundments. In Serbia, there are 9 hydrological alterations, one on the Sava River (impoundment by the Iron Gate I reservoir) and others on tributaries, as well as 249.3 km of impoundments caused by 7 dams, a gate and water intake.

Table 15 Summary of reported hydrological alterations in the Sava RB, from 2nd Sava River Basin Analysis 2016

Hydrological pressure	SI	HR	BA	RS
Impoundment	56 km caused by 7 dams	20.1 km caused by 4 reservoirs	163.0 km caused by 8 reservoirs	249.3 km caused by 7 dams
Water abstraction	18 alterations	-		
Hydropeaking	18 alterations	2 HPPS		

The presence of transverse structures on the Sava River and its tributaries are interrupting the longitudinal continuity and therefore hinder the natural sediment dynamics, reflecting as riverbed incision/aggradation due to the interruption of sediment transport. The HPPs represent 92 % of all interruptions in the Sava RB, and are a key driving pressure the basin, as reported in the 2nd Sava River Basin Management Plan (drafted), from August 2021. There are 20 hydropower plants in the Sava RB larger than 10 MW. In Slovenia, most of the plants are located on the Sava River, while in the other Sava countries the plants have been built on major tributaries (Drina, Vrbas, etc.). There is also a large number of small and micro hydropower plants and barrages.

In Croatia, the obligations for the HPP owners include provision of the minimal discharges and the sediment withdrawal. The Environmental Impact Study for the HPPs envisages the artificial transfer of sediments from the upper to the downstream section as a measure to protect the downstream riverbed. However, there is no documented evidence on the implementation of the measure. The sediments extracted from the regular maintenance works (watercourses, retentions, reservoirs), and other water structures where there is a surplus of material, should be disposed at the dedicated site and not in the immediate vicinity of watercourses in order to preserve a good condition of the surrounding soil.

In Serbia, the main measure to control reservoir sedimentation is monitoring. The dislocation of sediments from the operational reservoir volume has not been undertaken. The Potpeć on the Lim River was emptied several times, in order to clean the gates (1979, 1980, 1988 and 1999), but due to an extremely high suspended sediment concentration, the reservoir flushing had catastrophic environmental consequences in the downstream river reaches (Figure 29). The deposition of sediments in the Sava river in Belgrade is a long-lasting problem, and PWMC Srbijavode dredged about 39000 m^3 of polluted sediment in spring 2021, but details on sediment disposal and treatment are not available. In January 2021, the reservoirs of the HPP Potpeć on the Lim and the HPP Višegrad on the Drina were heavily polluted with floating debris (Figure 30) and about 7500 m^3 of material was dispatched to dumping site. The problems of "floating sediment" in this area, contributes to development of reservoir sedimentation and pollutes the water. This should in the near future be resolved by common action of riparian countries.

Figure 28 River and habitat continuity interruptions, from 2nd Sava River Basin Analysis 2016

Table 16 The criteria for the hydrological pressure assessment, from 2nd Sava RBMP 2016-2021

Hydrological pressure	Provoked alteration	Criteria for pressure assessment
Impoundment	Alteration/reduction in flow velocity of the river	Impoundment length during low flow conditions > 1 km
Water abstraction	Alteration in quantity of discharge/flow in the river	Flow below dam < 50% of mean annual minimum flow of a specific time period (comparable with Q95)
Hydropeaking	Alteration of flow dynamics/discharge pattern in the river	Water level fluctuation > 1m /day

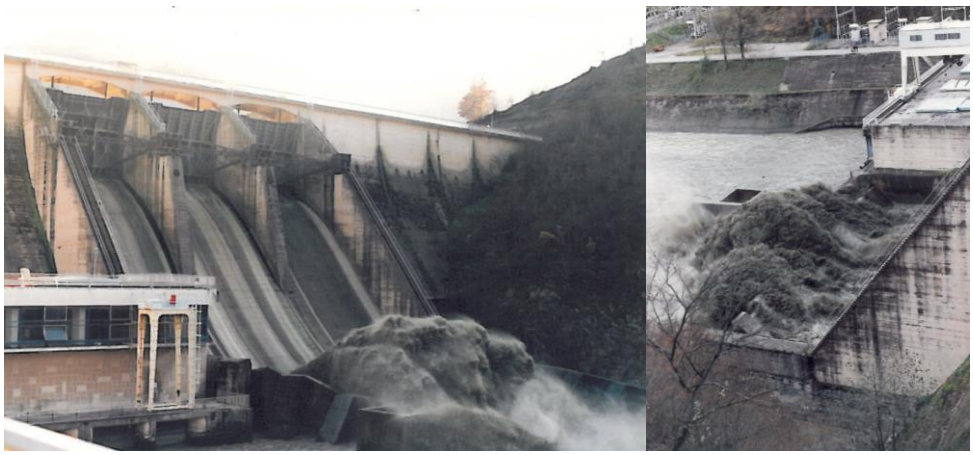


Figure 29 Discharge from the bottom outlets of the HPP Potpeć in 1999

Figure 30 Floating debris on Potpeć lake, 2021

5.3 Morphological alterations

Longitudinal water management structures and interventions (embankments, bank stabilisation and reinforcement, lining of river channel with stone or concrete, channelization and deepening of river channels, etc.) lead to the disappearance of natural variations in river widths and depths, but also in a number of physical habitat features, substrate types, course, sedimentation and erosion properties, etc. In addition, the interaction between aquatic and terrestrial components of the river valley may be disrupted, especially in floodplains, which play an important role in controlling erosion, sediment transport and deposition, etc.

The flood defence in the Sava RB comprises complex systems of river channel training, bypass channels, flood embankments, detention and retention reservoirs. The flood protection is selected as the second largest driving pressure in the Sava RB, as reported in the 2nd Sava River Basin Management Plan (drafted), from August 2021.

In Slovenia, majority of flood embankments were built along the Sava and Savinja River, while retention and detention reservoirs were built mostly on smaller rivers. Construction of hydropower plants on the lower section of the Sava River in Slovenia involved restoration and construction of new structural flood defences (dikes, detention reservoirs).

In Croatia, the flood protection systems in the Sava RB is rather complex and comprise of a large number of flood protection structures. There are around 1,600 km of flood protection embankments, with additional 200 km of different flood defence structures. A major flood protection system "Srednje posavlje" comprises multipurpose reservoirs and partially also five large lowland retention storages. It is located between the Upper and Middle Sava sections and attenuates flood hydrographs in the downstream river sections.

In Bosnia and Herzegovina, besides flood protection embankments along the Sava River and its tributaries the flood protection system comprises also polders (on lower river sections of tributaries). The total length of the Sava River dikes is 202.85 km. Protection against external upland waters and inland waters is provided by pump stations, main boundary canals and main canal network.

In Serbia, the flood protection system along the Sava River also comprises flood protection embankments. However, construction of the flood defence lines along the Sava River and its tributaries in the mouth sections has not been completed so far.

River training structures are present along many river sections (mainly in Middle and Lower Sava) and generally include bank stabilisation and groynes in the river bed.

5.4 Dredging and sediment excavation

Navigation is one of the significant pressures in the Sava RB from an ecological point of view, mainly due to pollution caused by navigation, as well as due to dredging and river training works aimed at improvement of navigability condition. Commercial dredging and excavations are also executed through concessions or special permits. All these activities impair downstream conditions in the Sava River, such as bedload transport, alteration of sediment transport balance, groundwater regime, and others).

The sediments from the Sava River and its tributaries have been dredged for decades to maintain and provide safe navigation and for commercial purposes (construction of highways). In the future, the intentions are on upgrading the Sava River waterway from Belgrade to Sisak to a Class IV (or Class Va), which should account for additional river training works.

In Serbia, the Water Management Strategy sets the measures on navigable rivers by ensuring that navigable dimensions and river training structures for navigation do not significantly affect alterations of hydromorphological parameters and aquatic and riparian ecosystems. Navigation conditions on identified critical sections of the Sava river, especially in the vicinity of the Drina River mouth, should be enhanced by construction of new river structures (groins) and limited dredging in the navigation channel.

5.5 Soil erosion

Land erosion and torrents create significant and long-term damages which impact multiple sectors: agriculture, forestry, water management, traffic, communications, communal infrastructure, settlements, etc. Management activities and implementation of measures on control of erosion and sediment processes have been undertaken in parallel in different sectors other than water management, such as environmental protection, agriculture, mining, forestry, construction, spatial planning or energy.

Anti-erosion measures are actions that affect the cultivation, maintenance and management of land, forests and water, and the ways in which they are exploited. These include various legal regulations

and administrative, economic, educational and propaganda measures, as well as other measures that have a socio-economic character. The following group of measures can be distinguished: technical works, biological and biotechnical works, agro-technical works, economic and management measures, administrative measures, and educational and propaganda measures.

In Slovenia, a part of the River Basin Management Plan 2010-2015 was also recognition of the most vulnerable regions according to landslides. The maps show erodibility of areas, erosion hotspots (classified by strength into five categories), and landslides. Larger rock falls and hill falls are also marked. The content of maps was analysed in a meaningful way and translated into the warning maps (Figure 31).

In Croatia, the data on soil erosion measures are spread among different institution and are incomplete. There are some general guidance on the management and maintenance measures:

- Maintenance work in the watercourse bed should be performed in the upstream direction, in order to avoid secondary preserve all larger ponds in the area or near the project in their natural status.
- Anti-erosion measures are actions that affect the cultivation, maintenance and management of land, forests and water, and the ways in which they are exploited. These should be accompanied with various legal regulations and administrative, economic, educational and propaganda measures, as well as other measures that have a socio-economic character.

In Serbia, the intensity and surface erosion were irregularly monitored and studied in the past. The soil erosion map, which shows identified erosion-prone areas or at risk, used “erosion potential” method for erosion classification in five categories. The last update of the erosion maps was made 30 years ago. For the areas at risk (erosion areas) the constraints and conditions of land use are defined, preventive measures are prescribed and required anti-erosion measures are implemented as a priority. Anti-erosion measures were applied in the Drina and Kolubara River basins. Large amount of work on anti-erosion land management and torrent control measures was done till 1991. This led to significant reduction of the average erosion intensity, but the investment in new works and maintenance were significantly reduced in the last decades. As a consequence, frequent torrential floods occurred, the most catastrophic consequences in May 2014 on a large territory of Western Serbia (Figure 33). After 2014, investments in anti-erosion work have increased significantly. In the Drina River Basin, at the Jadar tributary Likodra, where the town of Krupanj was flooded and jammed with large quantities of sediment, emergency anti-erosion works included construction of 12 sediment retention dams on torrents flowing towards the city (Figure 34). The effects of these works proved to be good in 2017 event with heavy rainfall and torrential flood. In Serbia, the three main goals to be achieved till 2034 were defined in Water management strategy with a number of planned measures for the overall country.

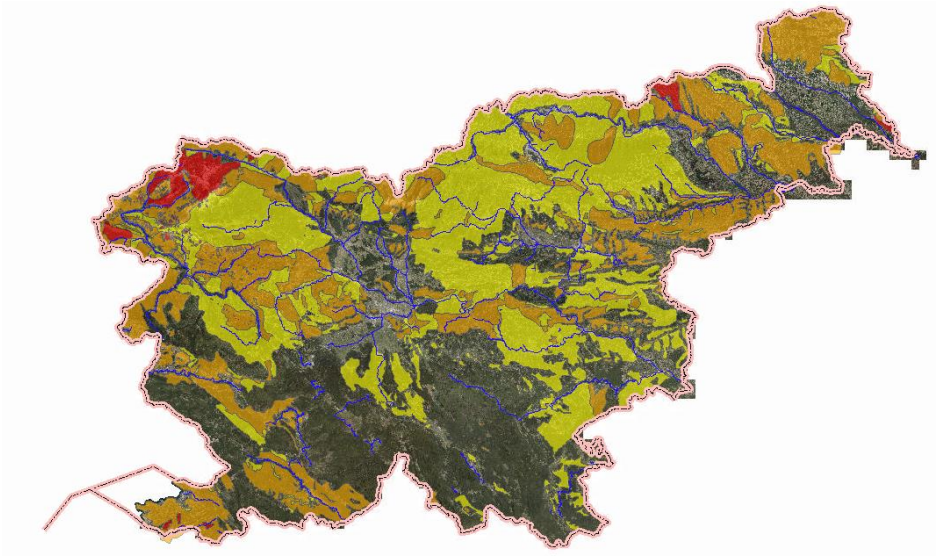


Figure 31 Erosion areas - erosion warning map, Geoportal ARSO

Figure 32 Soil erosion and debris flow destroyed the GS Trepča - Traverza, during the 2014 flood

Figure 33 Landslides and soil erosion during the 2014 flood

Figure 34 Sediment retention dam in the Jadar River Basin

A proposal of the improvements of existing sediment management issues

6 A proposal of the improvements of existing sediment management issues

6.1 Integration of sediment management in River Basin Management – the WFD perspective

Sediment is an essential, integral and dynamic part of our river basins, so sediment management is linked to river basin management and the Water Framework Directive (WFD). The causes and effects of sediment issues are spread across multiple spatial and temporal scales. Sediment issues may affect various environmental and legal objectives, and many different uses and interests. Also, direct interrelationships between sediment management measures and their effects may sometimes be difficult to determine. Although it is clear that good environmental status in a water body also requires a good sediment status, more knowledge is required to enable the various linkages between sediment management and WFD objectives to be properly understood.

The effective sediment management requires a holistic approach taking into account:

- system understanding
- the integrated management of soil, water and sediment
- upstream-downstream interrelationships

At river basin level, the assessment should identify relevant aspects of sediment management where there would be clear mutual benefits associated with integration. In some cases this may extend only to discrete aspects, for example particular win-win opportunities. In others, the comprehensive integration of a wide range of sediment management opportunities may be justified. In either case, the sediment management plan should enable managers to take appropriate steps to ensure the necessary early engagement and true dialogue.

The implications of sediment management are often integral to the management of water and vice versa. As the natural processes which determine the movement of water or sediments (or both) do not respect administrative boundaries, a holistic, river basin-wide approach is frequently more appropriate than a local or national approach. Improved integration between relevant sediment management and water management objectives is therefore an important aim and opportunities which contribute to both sets of objectives should be identified and exploited. Another area in which there are potential practical synergies between the WFD and sediment management is in recognising the need to deal not only with current pressures and impacts but also with past (i.e. 'legacy') issues - for example contamination caused by previous activities, or historic physical modifications, and with future challenges such as climate change.

6.2 Proposals

Proposal 2.1. Inventory of interventions

it is recommended to establish an inventory (database) of interventions that would include details on:

- Location and physical parameters of intervention (size, length, etc.)
- Year of completion and owner/manager
- Inventory on maintenance and monitoring activities

The database of intervention should include the structures on the Sava river and its tributaries:

- Dams, weirs, sluices, reservoirs
- Flood protection and river training structures
- Erosion and torrents protection measures and structures

Proposal 2.2. Improved sediment management at the HPPs

The general sediment management measures against sedimentation in reservoirs are available in the "Danube Sediment Measures" from DanubeSediment project. Appropriate measures should be addressed in the next Sava Sediment Management Plan. However, as the HPP's have been identified as a key barrier for sediment transport, the following measures can be implemented before the development of the Sava SMP:

- Analysis of the existing measures at the HPPs to control reservoir sedimentation, sediment disposal, treatment and use, and identification of deficiencies.
- Considering the operation of the HPPs in Slovenia and planned HPPs in Croatia, it is suggested to establish a standard operating procedure (SOP) in the HPPs' operation which would allow unobstructed passage of sediment in the downstream river sections.
- Relocation of sedimentation areas into non active parts of the reservoir and re-introducing of sediments downstream of a dam by removing it from reservoir is recommended to ensure/restore the longitudinal continuity of sediments and reduce erosion downstream of the dam.
- Reservoir flushing must respect fish spawning periods and critical suspended sediment concentration downstream for not silting up the river bed and not harming fish gills and benthos, thus flushing should be done in a controlled and planned way.
- Establishment of quality monitoring of accumulated sediments in reservoirs. If the sediments are polluted they must not be flushed but should be dredged out and technically treated as special solid waste according to Best Available Techniques (BAT).

Proposal 2.3. Improvement of discussion and exchange of information between HPP owners and all relevant stakeholders

It is proposed to organise a discussion process between the hydropower owners and all relevant stakeholders with the aim of agreeing on guiding principles for integration of sediment transport (dis)continuity and environmental aspects into the utilisation of the HPP reservoirs. Particular consideration should be given to the impact of the operation of the HPPs on the downstream water

regime (e.g. on the Sava water regime in Croatia and where there is a transboundary impact of the HPPs in Slovenia).

Proposal 2.4. Improvement of morphological alterations

WFD implies that flooding has to occur in order to maintain or enhance the ecological status of aquatic systems. Flood management practice needs to develop an understanding of how it can improve the ecological processes and functions within a catchment. Therefore, the synergies between river basin management and flood risk management have to be achieved through the following concerted actions:

- Floodplains need to be conserved and restored; self-forming processes (morphodynamics) need to be allowed and initiated; river bed incision should be stopped by adding gravel; and longitudinal, lateral and vertical connectivity should be restored.
- Flood risk assessment and management should follow integrated approach to ensure flood protection and the good status of water bodies.
- Ensuring a coordinated approach in land-use planning.
- Reactivation of former wetlands and floodplains to achieve increased water retention along with good surface water status. Initially, available data should be collected on e.g. inventory of floodplains; floodplains which are dis- or reconnected to their rivers; potential flood retention areas; future flood infrastructure projects etc.;
- Dredged material downstream should be refilled (such as in case of yearly ford dredging) and dredging activities (particularly concerning discharges and seasons) should be harmonised with ecological needs. In general, measures to improve navigation should also repair or restore hydromorphology.
- An adapted land use should prevent the input of fine sediment and fertiliser emissions into the river and should avoid agricultural activities along adjacent areas of the river. Buffer zones are needed between agricultural areas and floodplains (nature reserves).

Proposal 2.5. Improvement of erosion control measures

It is suggested to improve the protection against erosion and torrents by introducing the following measures:

- Establish a harmonised methodology for identification of erosion-prone areas.
- Develop an erosion map in the Sava RB and provide the map updates in a regular 6-year period.
- Integrate erosion protection issues in the water and sediment management plans.

A proposal for preparation of the full-fledged Sediment Management Plan

7 A proposal for preparation of the full-fledged Sediment Management Plan

7.1 Aim and scope

The aim of the Sediment Management Plan is to quantify and propose mitigation of key sediment transport issues in the Sava RB in a cost-effective way while providing continuous benefit to people and the environment to the highest possible extent.

The **overall objectives** of the Sediment Management Plan are as follows:

- Establish a balanced water and sediment regime with undisturbed sediment continuity.
- Establish sustainable good sediment quality.
- Establish long-term sediment management strategies for sediment continuity provision while accounting for flood risk management, hydro power production and water conservation.
- Emphasize sustainable measures that balance environmental, social, and economic impacts.
- Include public inputs and transparency in the development of the Plan and implementation of measures.

The Plan should identify key sediment transport and quality hotspots in the Sava RB and propose long-term mitigation strategies for improvement of sediment balance regime. The sediment balance within the Sava RB can be characterised as disturbed or severely altered. Besides, high direct pollutant inputs into waters and diffuse pollutant discharges from the watershed continue their negative impact on sediment quality in the Sava RB. Older polluted sediments in lower sediment layers can partly be remobilised by floods or be dredged and thus get into the flowing water and impact downstream river sections. Attention should be given to ensuring the sediment continuum (improving existing barriers), improving hydrological and morphological alterations and ensuring sustainable sediment excavation. However, the availability of sufficient and reliable data on sediment transport, sediment quality and knowledge on sediment hotspots are prerequisites for any sustainable decisions on sediment management in the Sava RB. Hence, additional investigations and quantification of sediment balance and sediment quality are needed to identify the key hotspots of sediment management on the Sava basin-wide scale and to propose appropriate measures for improving the situation.

7.2 The steps towards the Sava Sediment Management Plan

In order to meet the overall objectives and to fill the information and knowledge gaps on the sediment transport on the basin-wide scale, the development of the Sediment Management Plan for the Sava RB should include the following **stages**:

1. Harmonized monitoring system along the Sava River and its tributaries.
2. Scoping of sediment balance problems and identification of hotspots.

3. Scoping of sediment quality problems and identification of hotspots.
4. Identification of optimal sediment management solutions.
5. Integration of the suggested measures in subsequent RBM cycles.

7.2.1 Harmonized monitoring system along the Sava River and its tributaries

In order to evaluate the prevailing sediment processes, a harmonized monitoring system should be implemented with the following recommended steps:

- Step 1: Strategic action plan on harmonized sediment monitoring system
    - Define harmonized monitoring methods/techniques for sediment transport/quality monitoring (suspended sediments, bedload sediments, river channel surveys, sediment quality programme, bed material) taking the temporal and spatial variability of sediment transport and sediment quality into account.
        - The sediment transport monitoring methods should consider the recommendations in chapter 4 as well as suggestions in the ISRBC's document "Joint Sava River Basin Sediment Monitoring Programme" and monitoring strategy from the "Handbook on Good Practices in Sediment Monitoring" derived in the DTP project DanubeSediment [7].
        - The sediment quality should include river bed sediment, suspended sediment, overbank sediment. For the harmonization of plan and programme of sediment quality monitoring the suggestion from the SIMONA DTP project should be considered.
    - Define stations for sediment transport/quality monitoring on the Sava River and its tributaries. It is proposed to establish at least two stations at each major confluence of the Sava River, one station on the tributary and another station on the Sava River downstream of the confluence.
    - Define programme for regular river channel survey campaigns with definitions of reaches (Sava River, tributaries, reservoirs) and common timing (all surveys performed at the similar time window) for surveys.
    - Define programme for exchange of dredging information.
- Step 2: Implementation of regular monitoring system
    - Implement regular sediment transport/quality monitoring at stations/reaches as defined in the Strategic action plan (Step 1).
- Step 3: Development of common information platform
    - Establish common database for storage and exchange of all sediment transport/quality information.

7.2.2 Scoping of sediment balance problems and identification of hotspots

Current information in the Sava RB on the status of sediment transport and sediment balance are unreliable for developing efficient mitigation measures. Sometimes engineering measures are implemented to fix a perceived problem rather than a real problem, such as removing sediment from an area where sediment deposition is not increasing. Therefore, there is an urgent need to fill the

[7] Habersack H., Baranya S., Holubova K., Vartolomei F., Skiba H., Schwarz U., Krapesch M., Gmeiner Ph., Haimann M. (2019): Sediment Manual for Stakeholders. Output 6.2 of the Interreg Danube Transnational Project DanubeSediment co-funded by the European Commission, Vienna.

knowledge gap. Quantifying the problems and identifying hotspots will ensure that any considered mitigation measure is proportionate to the magnitude and scale of the problem.

The scoping phase should include the following key components:

- Quantification of river channel evolution (erosion/deposition), sediment depositions and excavations and soil erosion. A few recently completed projects in the Sava and Danube RBs examples of efficient methods for sediment data analysis and information gathering.
- Quantification of sediment transport and sediment balance for the Sava River and its major tributaries by numerical sediment transport models. 1D sediment transport models are suggested for longer river reaches and time scales (decades and more) and individual 2D and 3D sediment transport models for shorter or critical river reaches and shorter time scales (years to events). Models should be considered as important supplements to the monitoring data and should be used to close data gaps in the measurements or for spatial and/or temporal inter- and extrapolation of sediment data.

The need to determine the status of the sediments of the Sava River has already been mentioned in many studies and projects, such as BALSES[8] from ISRBC. One of the goals of the ČIGRA project[9] was also the development of technical possibilities for transfer of sediments across the HPP dams to improve sediments transport. The proposal for further works is expertly supported.

7.2.3 Scoping of sediment quality problems and identification of hotspots

In order to achieve objectives of water and soil protection and to enable the disposal of dredged material without causing harmful consequences (land deposit, deposit under water or re-deposition in the river), the identification of sediment quality hotspots is required. The priority aim of the scoping phase is to localize those sediment areas which pose the greatest risk for achieving good water quality.

The scoping phase of sediment quality should include the following components:

- An assessment and classification of contaminated sediments.
- An inventory of relevant amounts and relevant sediment contaminations in the areas of investigation.
- An assessment of the risk of re-mobilisation due to floods, wind and anthropogenic impacts (dredging, re-deposition, navigation).

For these areas posing a risk of great importance in the Sava RB, proposals for measures will be developed which are meant to serve as recommendations for actions for the authorities in charge of the further treatment of the sediments in these river sections.

7.2.4 Identification of optimal sediment management solutions

Development and evaluation of measures with identification of optimal solutions is a key step of the Sediment Management Plan. The development of strategies and measures in the Plan should be guided by the following **specific objectives**:

- Provide a balanced sediment regime with undisturbed sediment continuity.

[8] BALSES, ISRBC, December 2013

[9] https://www.info.hazu.hr/upload/Image/interreg_cigra/CIGRA_izvjesce_web_HR.pdf

- Maintain flood risk management and water conservation.
- Recognise opportunities for increased environmental benefits.
- Reduce social impacts associated with sediment management.
- Identify opportunities to use sediment as a resource.
- Ensure cost effectiveness fiscal responsibility in decision-making.

A **proposal for alternative measures** should focus primarily on mitigating the identified hotspots. A catalogue of measures has been proposed for the Danube RB in the Danube Sediment project [10]. The alternatives should consider:

- Measures to mitigate riverbed erosion
- Measures to manage of sedimentation
- Measures at the catchment, reach and local scales
- Measures for treatment of contaminated sediments

It is recommended for the plan to consider the following sediment and debris management measures:

- As a rule, gravel material is not removed from the riverbed, but is redistributed within the riverbed to areas with a deepening trend or to erosion areas in such a way that natural permeability is at least partially preserved.
- Gravel and sand should not be removed from the riverbed in order to preserve habitat structures (e.g. spawning grounds, habitat types of gravel) and hydromorphological processes. Exceptionally, withdrawal is possible if the flow of the riverbed is significantly reduced and facilities or infrastructure are directly or indirectly endangered as a result.
- Gravel material and debris should not be removed from the riverbed under HPP in order to preserve habitat structures (e.g. spawning sites) and hydromorphological processes. Exceptionally, dredging is possible if the conveyance is significantly reduced and facilities or infrastructure are directly or indirectly endangered as a results.
- Consideration should be given to the possibility of transporting some of the gravel debris from the upstream river sections below the HPP dam in order to reduce the decreasing trend of the riverbed downstream of the dam.
- All gravel in reservoirs should be regularly excavated to prevent accelerated backfilling.

Alternatives for sediment management measures should be **evaluated** based on the following criteria:

- Feasibility of implementation
- Impact on floods
- Environmental impacts
- Performance of alternatives
- Cost

[10] Habersack H., Baranya S., Holubova K., Vartolomei F., Skiba H., Schwarz U., Krapesch M., Gmeiner Ph., Haimann M. (2019): Sediment Manual for Stakeholders. Output 6.2 of the Interreg Danube Transnational Project DanubeSediment co-funded by the European Commission, Vienna.

In the development of Sava SMP, the process should include regular consultation with agencies, HPPs owners, companies, the public and environmental groups that play a role in sediment management of are directly affected by the sediment management process.

7.2.5 Integration of the suggested measures in subsequent RBM cycles

In order to achieve a good water status introduction of sediment management measures is recommended in the RBMPs, the national water management plans (WMPs) and planning documents. The Plans should prepare an overview of existing sediment monitoring system and studies in this field and interstate obligations related to the transboundary movement of sediments and should prepare a proposal for effective measures for the next plan taking into account and in accordance with the suggested measures from Sava SMP.

Conclusions

8 Conclusions

The transport of water and sediment is an essential component of a natural hydromorphological regime in a catchment. As part of the update of the Danube RBMP 2021, the alteration of the sediment balance has been identified as a new sub-issue of the "Hydromorphological alterations", which shows that an effective management of sediment transport is becoming increasingly important from an economic, social and environmental perspective. The Sava River and its tributaries have been subject to significant changes in sediment transport and water regime caused by energetics, flood protection, navigation and industry. The consequences are serious for the river, groundwater and bank stability. The processes controlling sediment transport and sedimentation are dynamic and highly variable, so the consequences are usually not immediately visible, but they become more severe over time, and subsequent remediation measures are time-consuming and very costly. Therefore, effective sediment management must be site-specific, by acting on the level of each significant pressure and understanding the dominant spatial and temporal processes operating by the pressures at the basin-wide level. A balanced sediment regime also allows for the long-term provision of appropriate habitats for type-specific aquatic communities and water-dependent terrestrial ecosystems. The development of the Sediment Management Plan for the Sava River Basin is urgently needed to develop sustainable water management strategies and achieve good water status. In developing and implementing the Sava SMP development and implementation, a stepwise approach is recommended initiating with filling of the information and knowledge gaps before developing sediment management measures and strategies.

In the preparation of this Outline, a successful workshop was organised with the participation all relevant stakeholders in the Sava RB. The main conclusions from the workshop are the steps that can be initiated even before the development of the Sava SMP.

- The analysis and definition of existing sediment transport/quality issues is required;
- It was suggested that the first steps should be the development of a harmonized monitoring system, including the development of a common information platform (data on SSC, SLT);
- The development of a common inventory platform for exchange of data relevant for sediment transport/sediment quality is also recommended (data on morphological alterations, river channel surveys, reservoir monitoring data, erosion maps, etc.).

Annexes

9 Annexes

9.1 Annex 1 - Status on Sediment Management in Republic of Slovenia

9.2 Annex 2 - Status on Sediment Management in Republic of Croatia

9.3 Annex 3 - Status on Sediment Management in Bosnia and Herzegovina

9.4 Annex 4 - Status on Sediment Management in Republic of Serbia