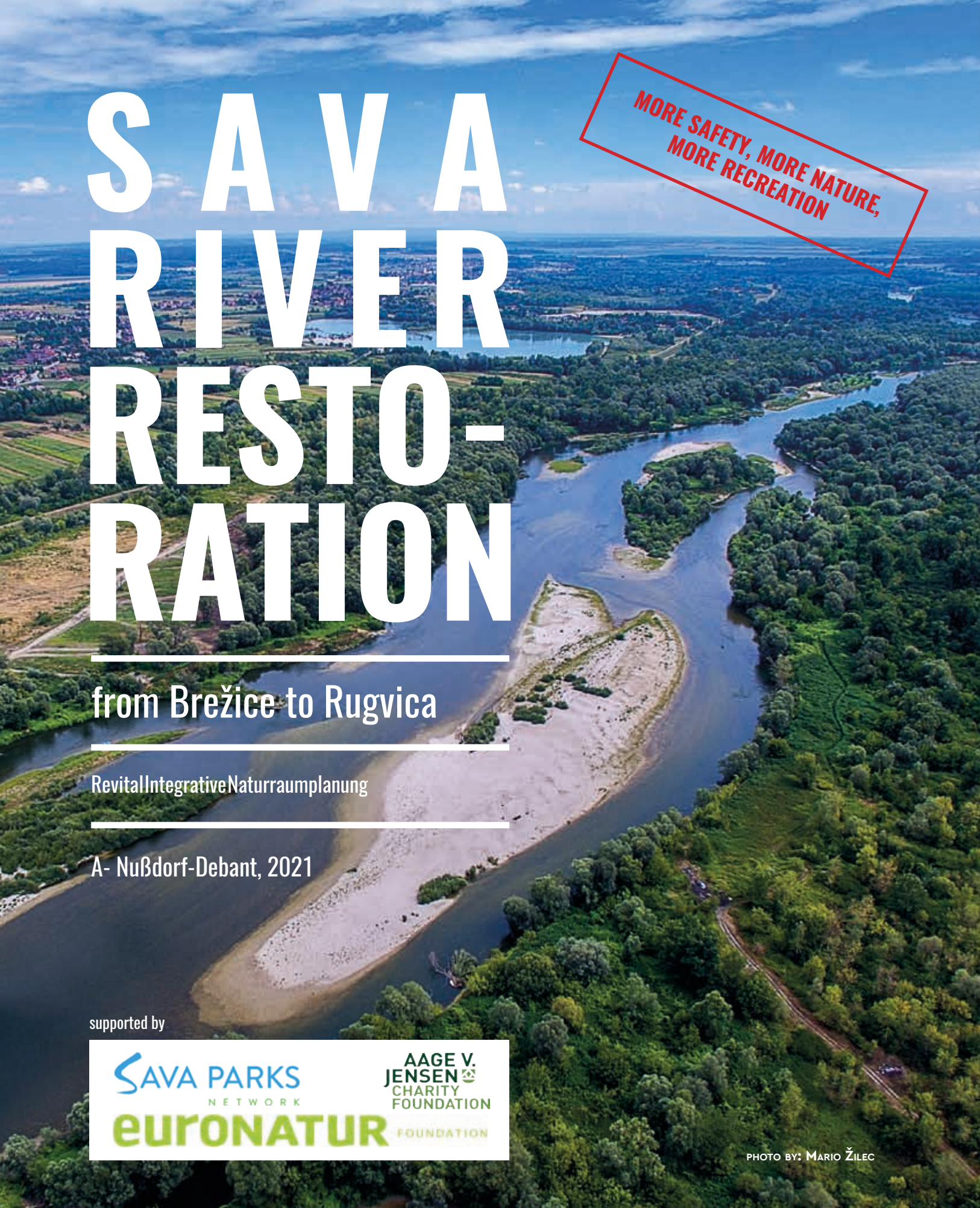
SAVA RIVER RESTO-RATION

MORE SAFETY, MORE NATURE, MORE RECREATION

from Brežice to Rugvica

RevitalIntegrativeNaturraumplanung

A- Nußdorf-Debant, 2021



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Summary

The Sava White Book (Schwarz, U. 2016) describes threats and restoration potentials for the river Sava. Based on the facts and information listed in the Sava White Book, the Austrian company "REVITAL Integrative Naturraumplanung" prepared this feasibility study, on behalf of EuroNatur - European Nature Heritage Foundation. Riverbed incision is a huge problem, especially in the river stretch around Zagreb. This feasibility study describes possible causes of the depression and near natural measures to stop riverbed deepening.

The river Sava is a typical alluvial river. Without regulations of the riverbed, the river Sava would be in a transition zone between a braided multi-channel river system (upstream of Zagreb) to a meandering river (downstream of Zagreb). Due to human influence, morphology and the geometry of the river and its riverbed have changed in the last centuries and decades.

From the Slovenian border to downstream of Zagreb the river Sava is completely channelized. Around the city of Zagreb, the channel has the form of a double trapezoidal profile. The width of the riverbed is about 100 m. Continuous dikes and wide river forelands are typical for this river stretch. The distance between the dikes is about 300 m.

Downstream Zagreb, from Hrušćica to Rugvica (rkm 675) there is the last remaining braided and anabranching stretch of the river Sava in the project area, but it is also severely suffering from the bedload deficit.

Canalization and river regulation lead to poor or very poor hydro morphological status of the river Sava. The hydro morphological condition within the project area ranges from slightly modified (downstream of Zagreb) to severely modified in the river stretch through the City of Zagreb.

Another factor for riverbed incision is the lack of sediment coming downstream, caused by dams of Hydro Power Plants upstream the project area.

This feasibility study describes one possibility to stabilize the riverbed in a nature friendly way.
In a first step the optimal river width to stop riverbed incision was calculated based on different variables like channel geometry, discharge, mean slope and granulometry.

In a second step the project area was divided in five sections, to which similar measures can be assigned. In addition, two intervention areas to stabiles the riverbed with technical measures were defined.

The feasibility study shows that it is possible to stop riverbed incision with some initial measures like:
- building "initial channels"
- restoring soft banks
- widening the river
- flattening or lowering areas
- reinforce and reset bank protection

After implementing these measures integrative goals like riverbed stabilization, increased discharge capacity, improvement of the ecological situation and discard capacity as well as new recreational sites, can be reached.

Best practice: River landscape as a recreational oasis in the middle of the city. *Isar in Munich.*

PHOTO BY: REVITAL

PHOTO BY: MARIO ŽILEC

Content

PROJECT AREA

The project area includes the Sava and its surrounding area in the section between Rugvica in Croatia (river kilometre 673,8) and Brežice in Slovenia (rkm 738,0). The considered river section is around 53 kilometres long.

In the middle of the project area is Zagreb, the capital city of Croatia.

The project area is extended by a small area around the derivation channel Sava-Odra, that is an important flood protection measure for the city of Zagreb.

FIGURE 1 BY: REVITAL

RIVERS IN DISTRESS

Sava on its way *through Zagreb.*

PHOTO BY: MARIO ŽILEC

CURRENT SITUATION OF RIVERS IN EUROPE

In the 19th and 20th century, when the demands for cultivatable land, infrastructure and settlements increased and flood protection gained importance, many European rivers underwent systematic regulations. The channelisation works straightened the river course and constrained the flow into a narrow channel between protected riverbanks.[1]

Accordingly, the capacity of sediment transporting was strongly decreased by river regulations, and hence caused massive riverbed incisions.

The incision was accelerated by decreased sediment supply from upstream. The missing sediment is the result of barriers like hydro power plants. The technical and ecological consequences of river regulation were noticed in the late 20th century, as they are:

- Decrease of habitat diversity and availability and hence a loss of biodiversity and biomass
- Decoupling of the riparian floodplain
- Drop of the groundwater level
- Aggravation of flood risk downstream due to less dampening highwater peaks
- Scouring of bridge piers and bank protections, etc.

These consequences of river regulations necessitate the implementation of countermeasures.[2]

[1] Habersack, H., Piegay, H. (2007): River restoration in the Alps and their surroundings: past experience and future challenges. In: Habersack, H., Piegay, H., Rinaldi, M. (Eds.), Gravel-bed rivers 6 "From process understanding to river restoration", Developments in Earth Surface Processes 11, 703-735; Elsevier

[2] Klösch, M. et al. (2019): HyMoCARES Project - WPT2. Integrating hydromorphological assessment and management at different scales D.T2.3.1. Technical notes on tools to support planning and design of hydromorphological management and restoration measures. Interreg Alpine Space. Report, 206 pp; www.alpine-space.eu/hymocares

CURRENT SITUATION OF RIVER SAVA IN THE PROJECT AREA

The river Sava, with a length of 926 km and a catchment area of over 97,800 km², the largest tributary of the Danube by discharge, could not escape this development either.

The middle and lower Sava is internationally recognised for its huge hardwood forests, the large near-natural flood retention system around the famous Lonjsko Polje Nature Park in Croatia. The river attracted international attention due to a historic flood in 2014. The alpine upper Sava in Slovenia crosses several breakthroughs stretches and small basins, and today is partially impounded by hydropower dams. Below Zagreb, the Sava valley is broad, and the river continues with a small gradient all the way to the confluence with the Danube in Belgrade.[1]

The approximately 53 km long Sava stretch from Brežice (rkm 738, Slovenian) to Rugvica (rkm 673,8 Croatia) is considered in more detail in this feasibility study.

RIVER REGULATION

The Sava river was heavily regulated during the 60-ties and 70-ties of the 20th century after the 1965 flood. Upper and middle Sava was regulated upstream Krško but with the construction of Hydropower plant (HPP) Brežice this section has been completely flooded by the hydropower reservoir since 2018.

The section downstream of Brežice to Podsused is regulated but regaining meandering power. Active and former floodplain areas are partly protected as a special ornithological reserve and a Natura 2000 site, which offers some space for reconnection with the river Sava.

Through the city of Zagreb, the river Sava is completely channelized in the form of a double trapezoidal profile. Continuous dikes and wide river forelands accompany the river. The distance between the dikes is about 300 m (Figure 3). However, in the river surroundings some floodplain areas still exist, which offer space for reconnection with the river Sava. The derivation channel Sava-Odra was built in late 60-ties for flood protection and starts in Zagreb around the Lučko area.

Downstream Zagreb, from Hrušćica to Rugvica (rkm 675) there is the last remaining braided and branched stretch of the river Sava within the project area. It is protected as a Natura 2000 site.

[1] Sava White Book, p.5

***Figure 2: Current alterations and threats** along the Sava around Zagreb.*

Map by: Revital

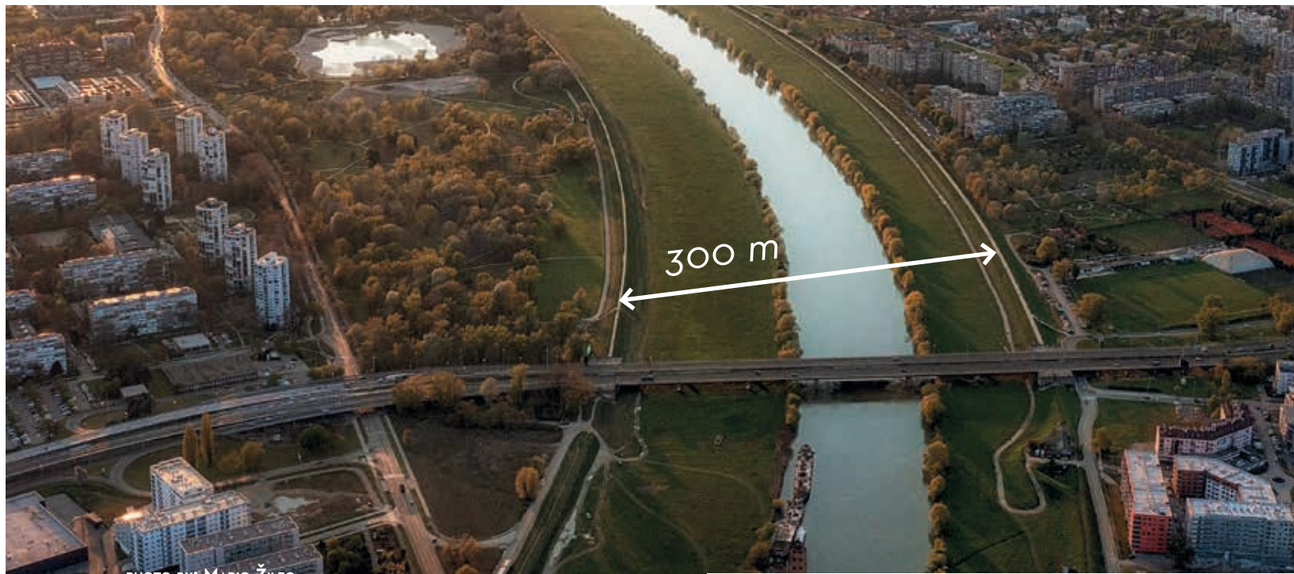


PHOTO BY: MARIO ŽILEC

***Figure 3:** Current situation of the river Sava in Zagreb, 2019. - Huge potential for river restoration and recreational area.*

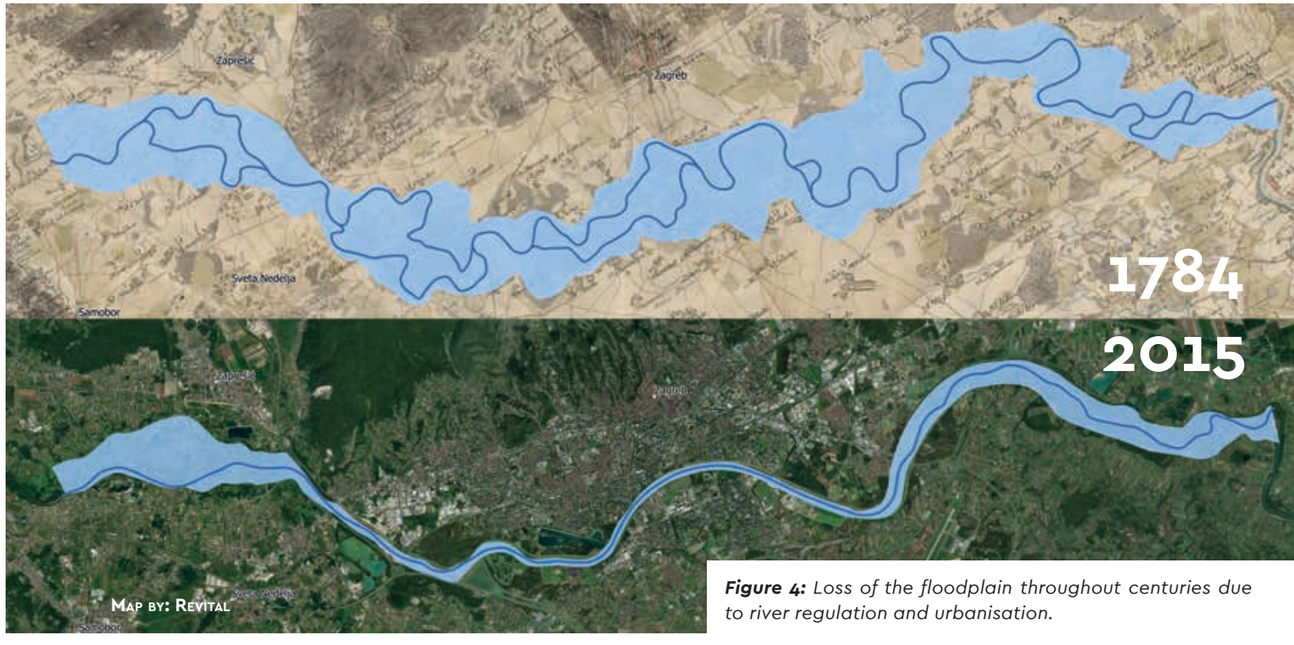


***Figure 4:** Loss of the floodplain throughout centuries due to river regulation and urbanisation.*

HYDROMORPHOLOGY

Hydromorphological conditions in the project area are diverse (Figure 7).
Whereas the stretches belonging to the Hydropower plant (HPP) Brežice or the river Sava throughout Zagreb city are extensively modified (Figure 8), in some areas even severely modified, other stretches are moderately but also slightly modified, especially in the area Hrušćica to Rugvica in the east of Zagreb (Figure 9).

Figure 5: *Extensively modified*

Figure 6: *Moderatly modified*

Figure 7: *Hydromorphological assessment of the river Sava around Zagreb.*

Source: Sava White Book / SWB, 2016

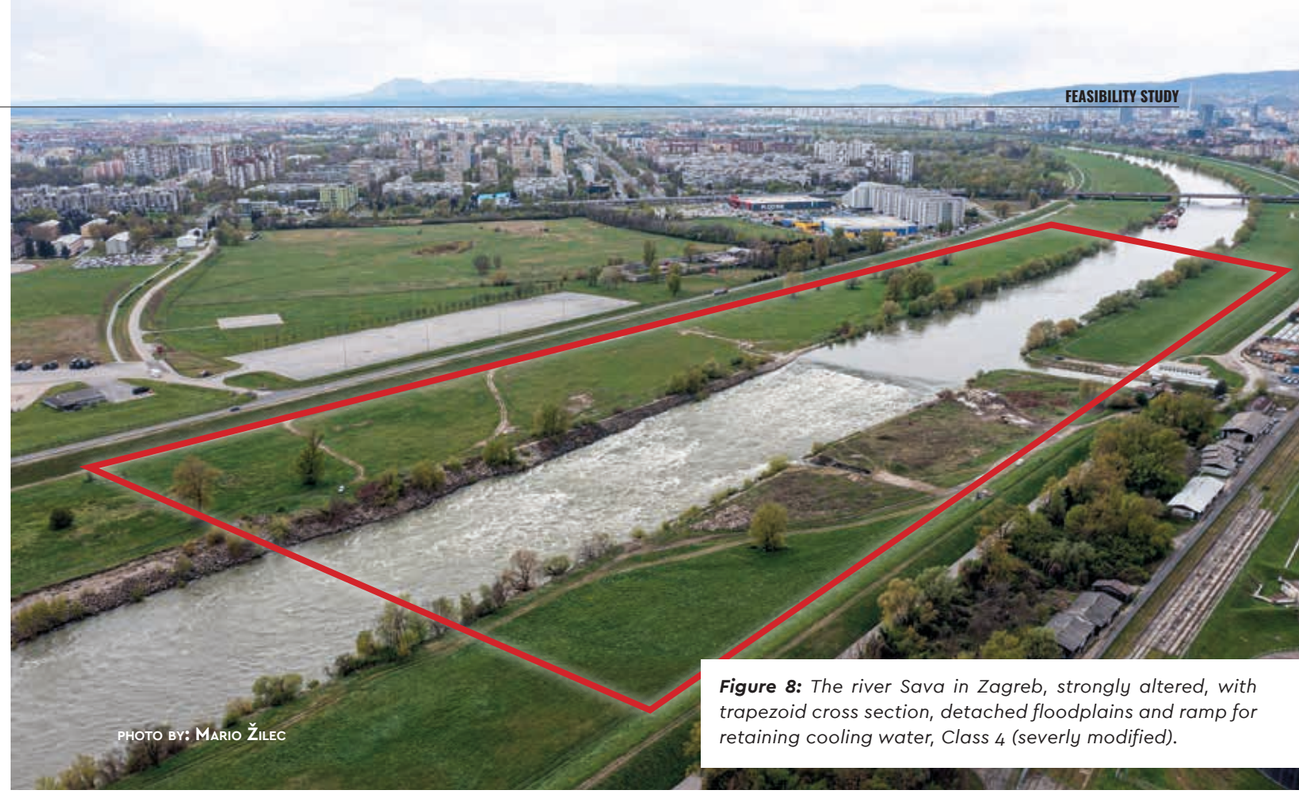


Figure 8: *The river Sava in Zagreb, strongly altered, with trapezoid cross section, detached floodplains and ramp for retaining cooling water, Class 4 (severly modified).*

Figure 9: *Slightly modified stretch* (Hrušćica to Rugvica).

SEDIMENT BALANCE AND RIVERBED STABILITY

A key element of the natural dynamic river ecosystem of the river Sava is sediment transport and river bed stability.

Normally gravel and sand is transported constantly along the river. In order to transport material along the river, the water loses its power. In case there is no material the water has no possibility to lose power, this leads to river bed incision and fast currents.

Regular water level measurements at the river Sava gauges drew attention to the riverbed deepening due to river regulations and HPP construction, which is still ongoing.

Geodetic surveys of the Sava riverbed in the section from rkm 673.00 to rkm 728.52 km were done in the period from 1985 to 2003. The survey of the profiles at water gauging stations show the following picture:[1]

- In the section from Jesenice to gauging station Zagreb (rkm 702), the riverbed deepened by about 2,5 m in the period 1985-2009.
- In the section from gauging station Zagreb to the riverbed sill at TE-TO Zagreb there are no significant changes in the riverbed height due to the influence of the sill.
- Downstream from the sill at rkm 682.0, the riverbed deepens significantly, due to the influence of the sill and the increased removal of gravel.
- In the section of the gauging station Rugvica (rkm 673,8), there is deposition of bedload and a rise in the riverbed of the Sava.

Dams and reservoirs, that are built upstream, cause these effects for riverbed development. In addition to a dozen dams and barriers already built in Slovenia, HPP Krško was completed in 2013 and HPP Brežice in 2018 on the lower reaches of the Sava River in Slovenia. Compared to the period before their construction, these facilities caused a significant reduction in sediment transport and thus significant morphological changes in the riverbed, i.e. strongly erosive processes in the Sava riverbed and lowering of the bottom level with simultaneous deposition of fine sediment (sand) and silt on the banks, as observed in Rugvica.[2]

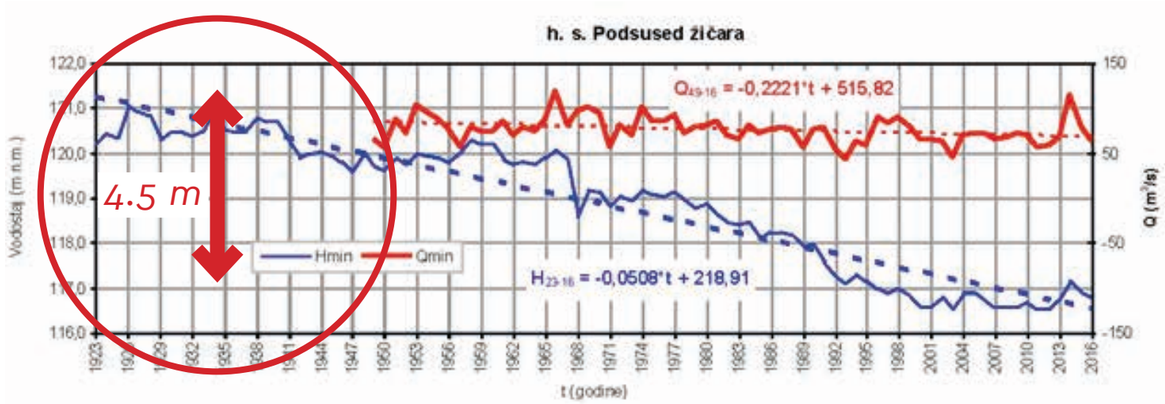


Figure 10: *Comparison of minimum annual water levels and flows in the period 1923-2016 at the Podsused gauge shows that the river bed has deepened by almost 4.5 m in the last 100 years.*[3]

All this results in an increasingly riverbed incision. Local erosion processes and deepening of the riverbed are very dangerous phenomena that can endanger the stability of flood protection structures.

[1] PROJEKT DANUBE SEDIMENT - Okvirna procjena sedimenta rijeke Dunav i većih pritoka, p. 91ff)

[2] as above, p.144ff

[3] as above, p.92, p.102

Figure 11: *River bed incision required drastic countermeasures such as the construction of the ramp in Zagreb.*

PHOTO BY: REVITAL

LAND STRUCTURE

Figure 12 gives an overview of the land structure within the morphological floodplain. It is defined as maximum area originally influenced by floods, including the active floodplain.

It is nowadays dominated on the one hand by large meadow areas within the dikes, and on the other hand, above and below Zagreb, by riparian forests and remnants of wetlands. The originally typical landscape elements of the river Sava - large gravel banks or pioneer sites - are largely absent. Due to the lowering of the groundwater level, the still existing floodplain waters are drying up more and more and are silting up due to fine sediments.

Large meadow areas dominate the foreland. They offer high potential for river restoration.

Among others, these habitats suffer from riverbed incision and the lack of river dynamic.

Figure 12: *Land structures within the morphological and active Floodplain of the river Sava in the project area (Source: Sava White Book, Ulrich Schwarz, FLUVIUS).*

BIODIVERSITY - BIRDS

Downstream of Zagreb the river Sava is rich on gravel or sediment bars and islands and host further downstream meander bends with steep banks that are home to several flagship bird species. Figure 13 shows the distribution of characteristic species in this section.

Gravel bars and islands downstream to Rugvica (660 rkm) support breeding of up to 150 pairs of common terns *(Sterna hirundo)*. They also represent the only breeding site along the whole Sava for the threatened little tern *(Sterna albifrons)*, which has a population of up to 20 pairs (detection status 2012, later no detection), as well as for the little ringed plovers *(Charadrius dubius)* with up to 14 pairs. A few pairs of common sandpiper *(Actitis hypoleucos)* can also be found there.

The first steep banks, resulting from dynamic hydromorphological processes, appear downstream of the Slovenian-Croatian border. Freshly eroded steep banks provide home for another indicator species, the sand martin *(Riparia riparia)*. The total breeding population along the river Sava is estimated at 3,000 pairs, the section upstream of the Una confluence hosts two thirds of the total breeding population. Particularly important sites are located downstream of Zagreb and upstream of Sisak, with colonies holding up to 270 pairs. Another charismatic species that lives in steep sand banks is a solitary nesting kingfisher *(Alcedo atthis)*.

In contrast, there are currently only isolated small-scale habitats for typical bird species of dynamic rivers in the urban stretch of Zagreb (see map below).

Figure 13: *Selected indicator species of breeding birds along Sava in the project area.*

Sterna hirundo

Charadrius dubius

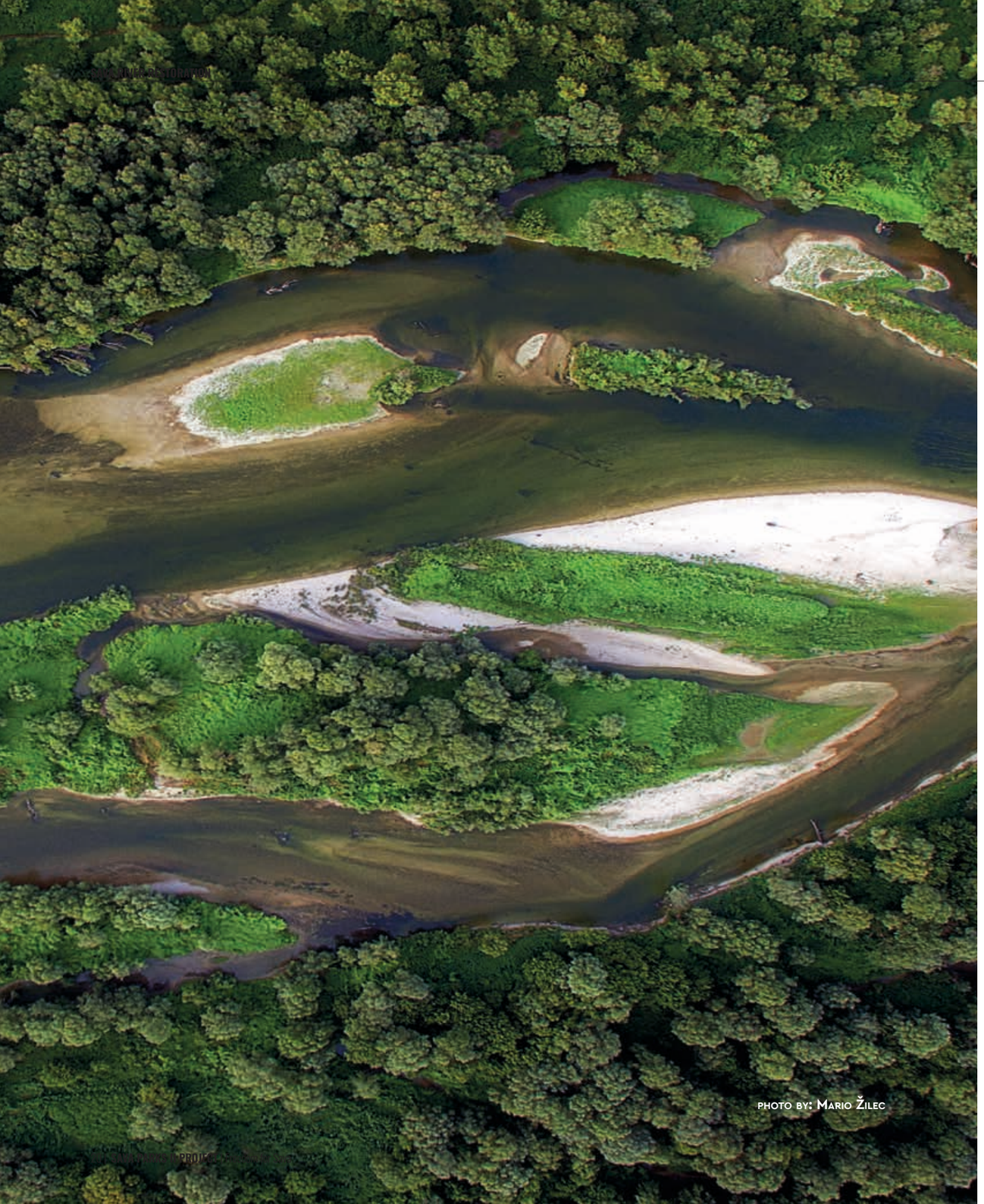
Breeding pairs *Riparia riparia*

- 1 - 50
- 50 - 100
- 100 - 300

Actitis hypoleucos

Breeding pairs
Merops apiaster
- 4 - 10

Alcedo atthis



PROTECTED AREAS

Within the project area most of the river Sava and its remaining floodplain is protected as Natura 2000 site under Birds and Habitat directive (Figure 14):

Birds directive Natura 2000 sites:

- Sava kod Hrušćice sa šljunčarom Rakitje
- Krakovski gozd - Šentjernejsko polje

Habitat directive Natura 2000 sites:

- Spodnja Sava
- Krka s pritoki
- Sotla s pritoki
- Vrbina
- Sava uzvodno od Zagreba
- Medvednica
- Sutla
- Potok Dolje
- Sava nizvodno od Hrušćice

Particularly important are Sava river stretches at Spodnja Sava (SI), Sava uzvodno od Zagreba (HR) and Sava nizvodno od Hrušćice (HR) that are covering free-flowing river areas suggested for restoration.

Additionally, upstream of Zagreb one Special ornithological reserves, covering Sava former floodplain is designated: Sava – Strmec (269,92 ha).

Within Zagreb reach Savica protected landscape (79,54 ha) covers the former Sava branch on its left bank.

Figure 14: *Natura 2000 sites touching the project area (Source: Open Geoportal EU).*

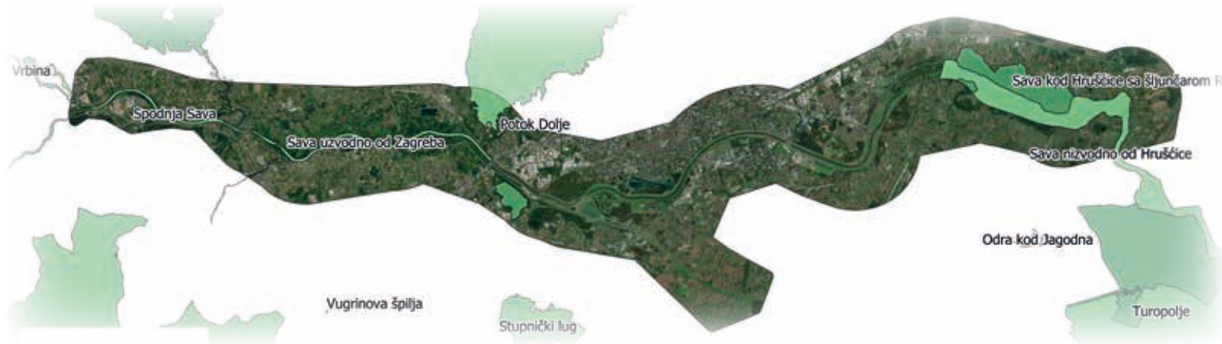


PHOTO BY: REVITAL

CONSEQUENCES AND CHALLENGES

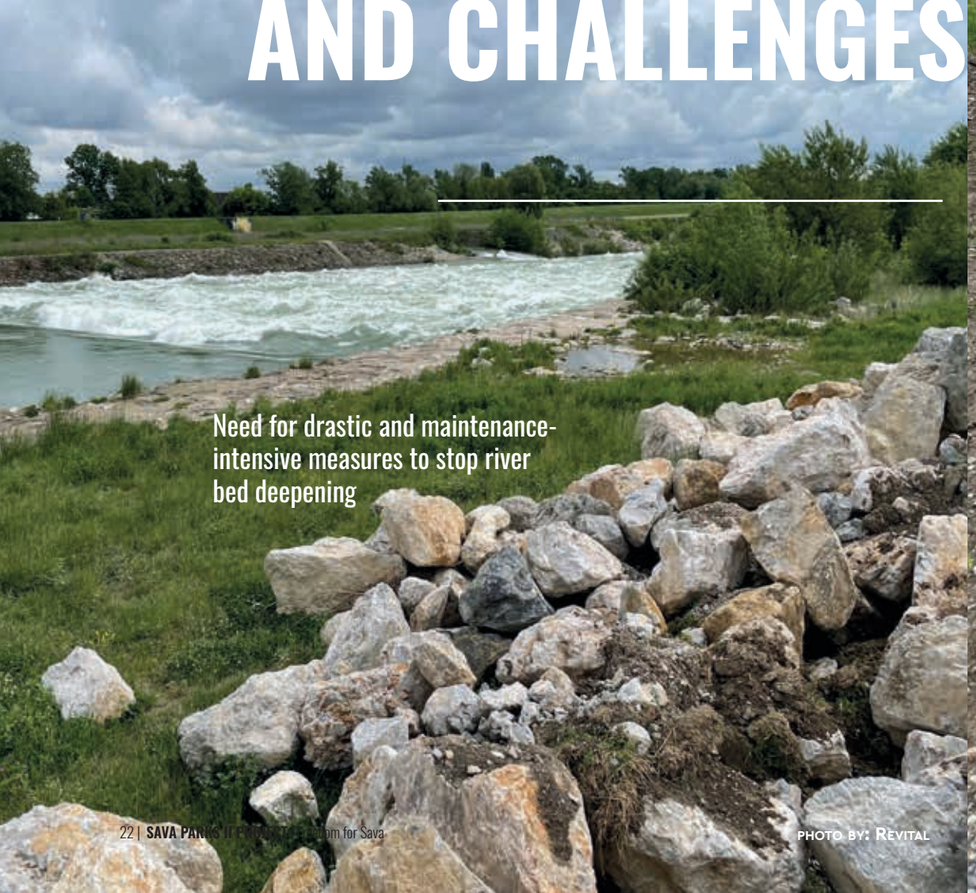


PHOTO BY: REVITAL

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PHOTO BY: REVITAL

CONSEQUENCES

Within the project area anthropogenic activities like riverbed regulation with dikes and embankments, gravel and sand extraction from the riverbed or trapped by hydro power plants upstream, caused enormous riverbed incision up to 4 m in the last decades. Consequently, various impacts on the flood protection as well as on the river and alluvial forest ecosystem can be observed:

- Risk of **instable fundaments** of bridges and riverbank protections within Zagreb and thus **uncontrolled morphological processes** during a flood (risk of dike breach)
- **Declining ground water level** with consequences on drinking water supply, agriculture and forestry use
- **Loss of biodiversity** due to the loss of river dynamic processes and lost connection between river and floodplains
- **Higher risk for flooding downstream** due to **less water retention** upstream
- **Loss of river-related recreational areas** that will increase in importance specifically due to climate change.

CHALLENGES

Unfortunately, like so many other European rivers, the river Sava within the project area faces enormous challenges:

- **Stopping riverbed incision** in an environmentally friendly way: This is crucial to maintain flood protection, to stabilize the groundwater level, to ensure the drinking water supply, enable agricultural use and preserve alluvial forests in the surrounding area.
- **Improving the ecological condition** of water bodies (e.g. hydromorphology) according to defined goals of the European Union.
- Pressure due to **increasing recreational use**.
- Finding sustainable solutions that require **low maintenance effort**.
- Finding solutions and commitments especially for **flood risk reduction and sediment management**, which are broadly supported. Considering that all changes to the river in the upper stretches have implication for the lower course.

CONCEPT FOR RIVER RESTORATION

Isar in Munich.
PHOTO BY: REVITAL

GOALS

This feasibility study shows first ideas and concepts to make the river Sava safer, related to flood protection or water supply and more alive, in relation to biodiversity and recreational use. The river restoration concept therefore specifically pursues different integrative goals:

- stabilize riverbed by riverbed widening, side erosion and increased bedload input (instead of ramps or hydropower stations)
- increase discharge capacity
- maintain and restore retention areas
- improve the ecological status
- create a unique recreational sites, that are within the city of Zagreb

MEASURE TYPES

To achieve these improvements for the river Sava, it is necessary to implement the following essential measures or a combination of these measures:

- building "initial channels"
- restoring soft banks
- widening the river
- flattening or lowering areas
- reinforce and reset bank protection

With these measures, the river Sava is not only getting a "new, attractive face", step by step in a generation project, but is also becomes more secure and livelier.

SPECIFICATIONS FOR PLANNING

Based on **available data and hydraulic calculations** according to approaches by Bledsoe & Watson, Henderson, Griffiths, Ashmore and DaSilva-Diagram the framework conditions for riverbed stabilisation of the river SAVA between Brežice and Rugvica are defined as follows:

- River width

rkm	*river stretch / location*	*Optimal target river width*
719	*upstream city of Zagreb*	*400 m*
714	*city of Zagreb*	*310 m*
711	*city of Zagreb*	*340 m*
706	*city of Zagreb*	*230 m*
695	*downstream of Zagreb*	*260 m*
681	*ramp HEP – Toplinarstvo*	*570 m*

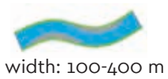
- Minimal length of the revitalisation sites: 1,5 km
- Width of initial channels: 10-40 Meter
- Longitudinal slope of the ramps 1:30-1:50

Intended morphological system
(Determination of the natural river widths)

current state (plane bed)
$w_{bf} = 3{,}36 \times Q_a^{0{,}49} \times \varepsilon_w$

width: 90-100 m

alternate bars
$w_{bf} = 4{,}86 \times Q_a^{0{,}49} \times \varepsilon_w$



width: 100-400 m

multiple bars and braiding
$w_{bf} = 2{,}61 \times Q_a^{0{,}49} \times d_{50}^{-0{,}76} \times \varepsilon_w$

width: >400 m

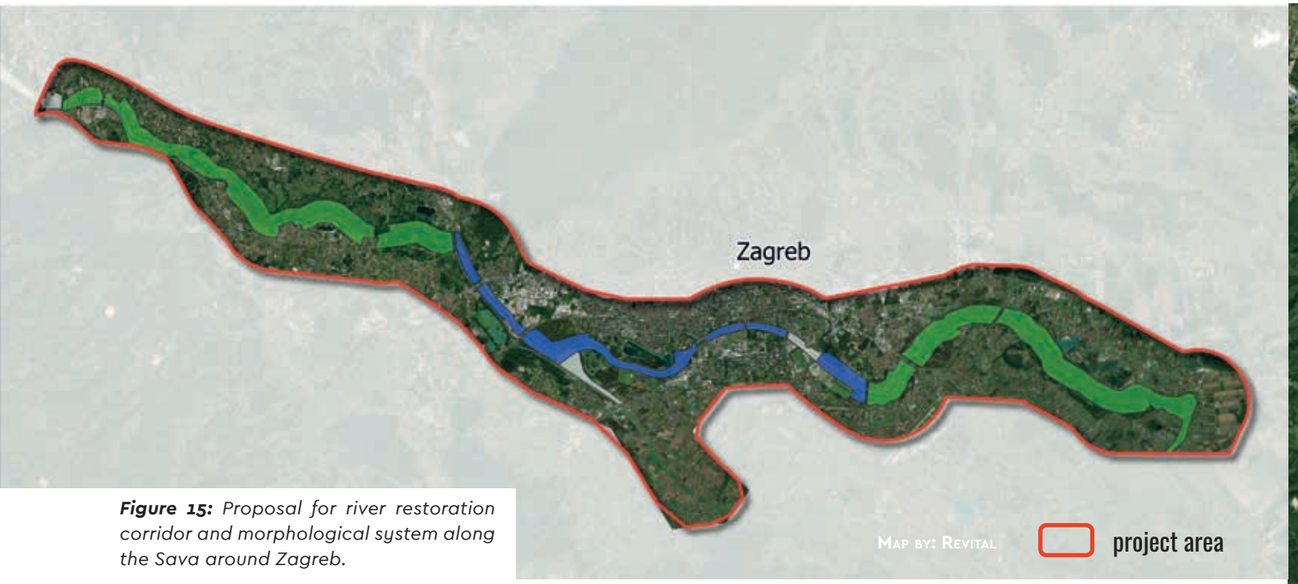


Figure 15: *Proposal for river restoration corridor and morphological system along the Sava around Zagreb.*

RIVER RESTORATION CONCEPT

From the point of river restoration, the river Sava from Brežice to Rugvica can be divided into 5 sections, to which similar measures can be assigned (see Fig. 16):

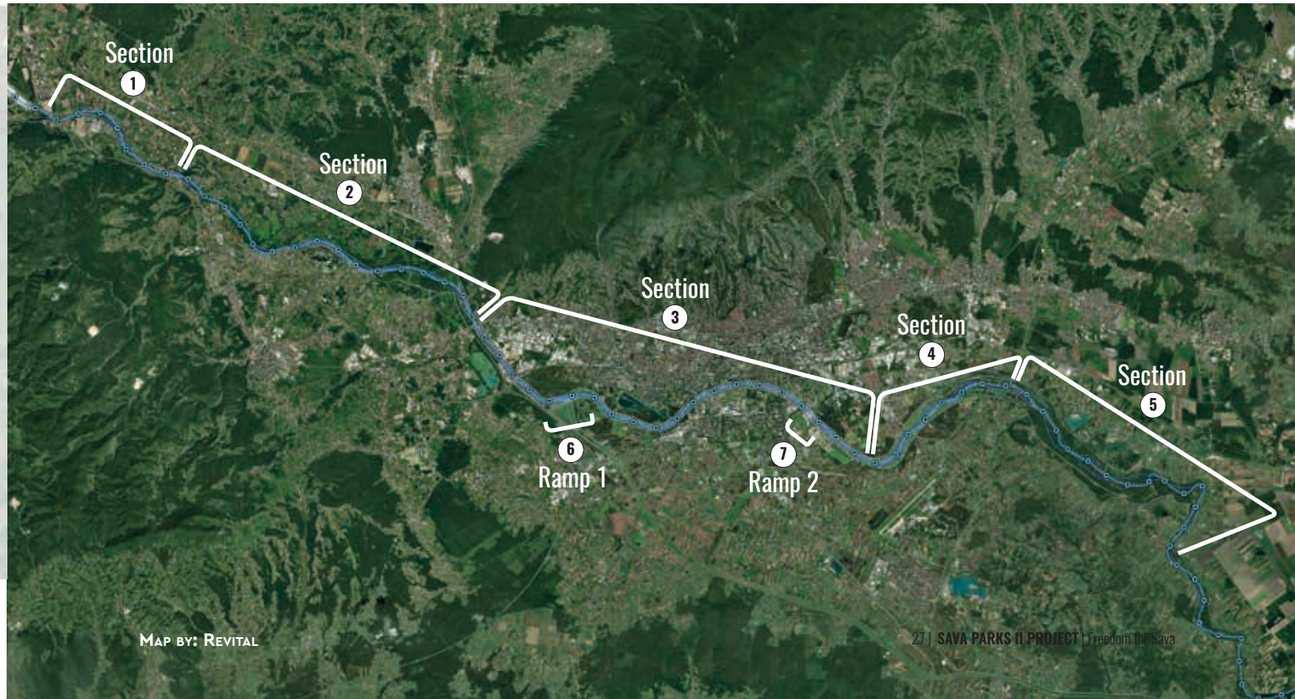
- Section (1): from Brežice (rkm 737) downstream till the dikes end on both sides (rkm 730)
- Section (2): upstream the city of Zagreb, from rkm 730 to rkm 715
- Section (3): river stretch through the city of Zagreb from rkm 715 to rkm 695
- Section (4): downstream of Zagreb from rkm 695 to rkm 687
- Section (5): from the Bridge at rkm 687 down to Rugvica (end of project area at rkm 672)

In addition, two other areas are required selectively to implement measures:

- Ramp and flood protection measures at rkm 693 (at the derivation channel Sava-Odra) (6)
- Ramp between rkm 681 and rkm 682 (existing ramp at HEP – Toplinarstvo) (7)

Five river sections and two selective intervention areas are proposed for Sava restoration around Zagreb. More details see following pages.

Figure 16: *Proposed river restoration stretches along Sava within the project area.*



SECTION 1· DOWNSTREAM BREŽICE

RKM 737 - RKM 730

Current situation:

The section is about 7 km long with an average river width of around 100 meters. The riverbanks are very steep, the bank protection is covered with wood. The river Sava is bounded on both sides by dikes, that are on average approximately 200 meters away from the water body. The foreland is covered by wet grassland or softwood (Fig. 17).

Transformation:

From the monotonous canal to the braided river with gravel banks and islands.

After the implementation of the described measures the average target river width will be around 230 m, including gravel bars, water body, soft and hardwood, grassland and flat embankments.

Initial measures:

- Building initial channels: see Fig. 18 and 19
  - Main initial channel 30 m wide
  - Small initial channel 15 m wide
- Restoring soft banks with flat embankments
- Reinforce and reset bank protection next to main initial channel (see Fig. 19 and 20)

Benefits:

- More discharge capacity
- Riverbed stabilisation
- Potential for bed load input
- Natural dynamic processes lead to a good ecological status of the river Sava
- New gravel banks
- New recreational sites

Figure 17: *Current situation of section 1 with aerial photo.*

Figure 18: *Cross section at rkm 735 of section 1 with current situation and possible initial measures.*

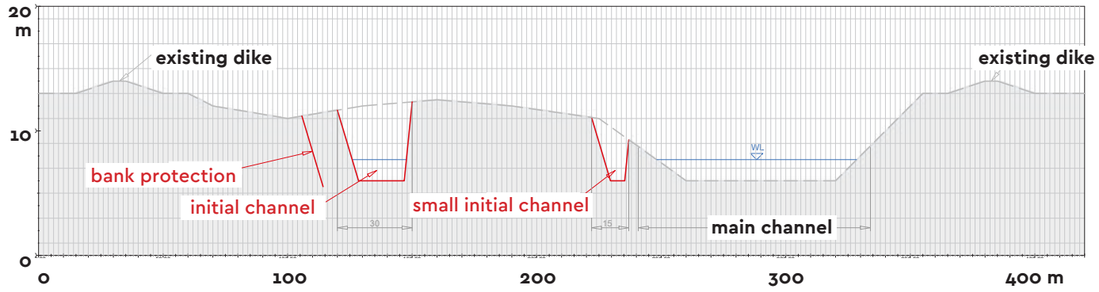


Figure 19: *Initial measures in section 1.*

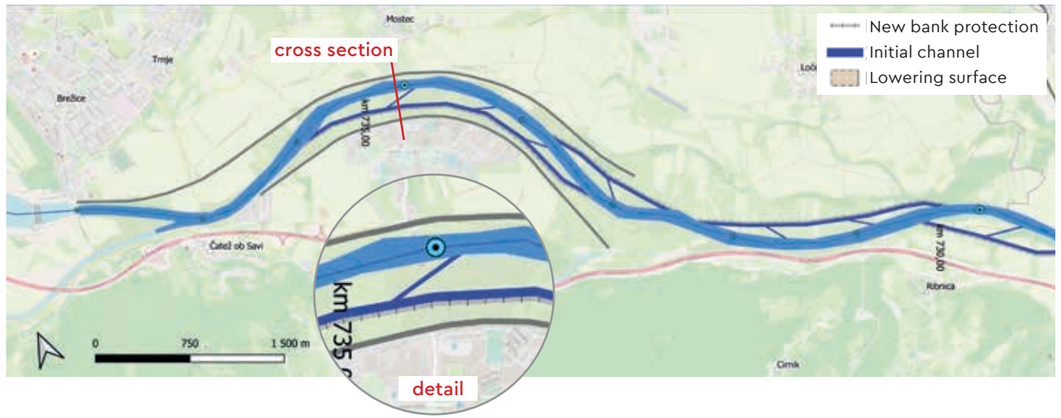
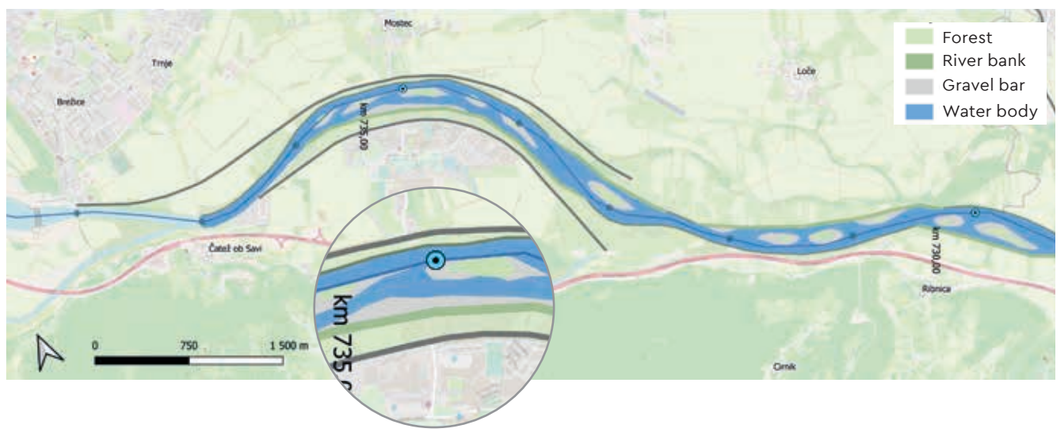


Figure 20: *Target state in section 1.*



FIGURES BY: REVITAL

SECTION 2·
UPSTREAM THE CITY OF ZAGREB

RKM 730 - RKM 715

Current situation:

This section is approximately 15 km long, the average river width is around 90 meters. The river is canalised and only on a short reach of the river a dike is close to the river (area around Samoborski Otok and Medsave). Some gravel banks, that are visible by average water level, still exist. On both sides of the river grassland and different sorts of forest dominate the area. Small areas are also used by agriculture (Fig. 21).

Transformation:

From the monotonous canal to the braided river with gravel banks and islands.

After the implementation of the described measures the average target river width will be around 270 m, including gravel bars, water body, soft and hardwood and grassland.

Initial measures:

- Building initial channels: see Fig. 22 and 23
  - Main initial channel 30 m wide
  - Small initial channel 15 m wide
- Restoring soft banks with flat embankments
- Reinforce and reset bank protection (where needed) to protect existing dikes (see Fig. 23 and 24)

Benefits:

- More discharge capacity
- Additional flood retention area above Zagreb
- Riverbed stabilisation
- Huge potential for bed load input
- Natural dynamic processes lead to a good ecological status of the river Sava
- New gravel banks
- Hardwood forests reconnected to ground water

Figure 21: *Current situation of section 2 with aerial photo.*

Figure 22: *Cross section at rkm 719 of section 2 with current situation and possible initial measures.*

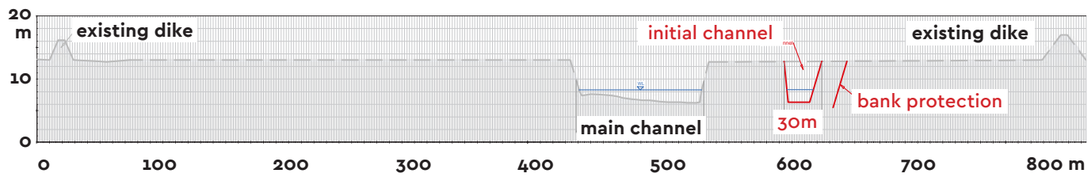


Figure 23: *Initial measures in section 2.*

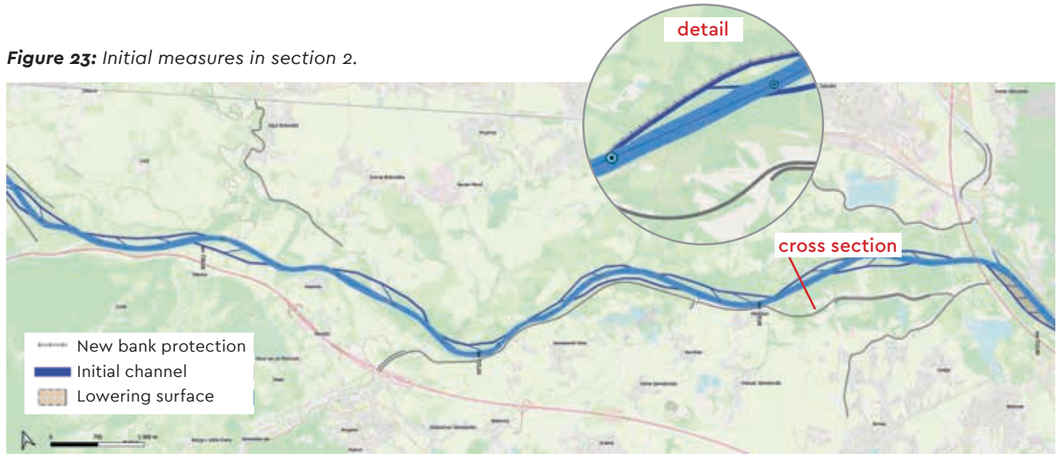
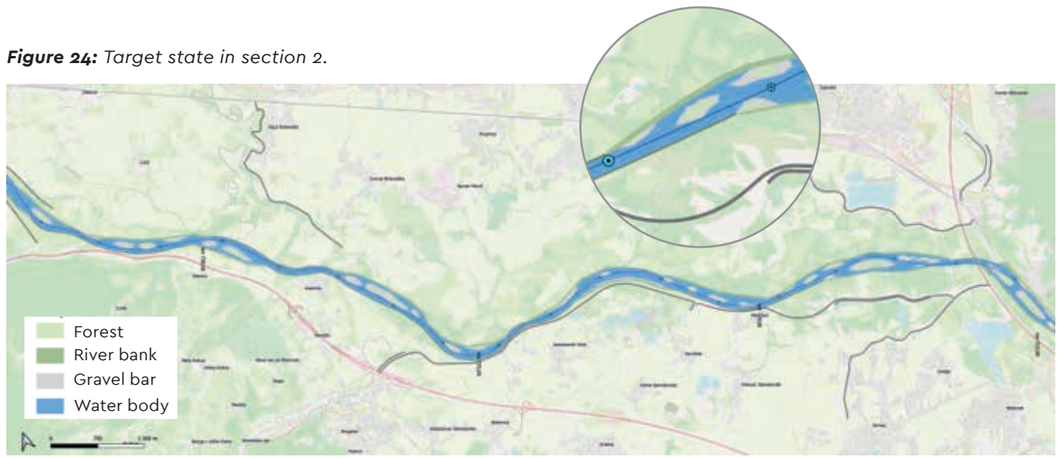


Figure 24: *Target state in section 2.*



FIGURES BY: REVITAL

SECTION 3· THROUGH THE CITY OF ZAGREB

RKM 715 - RKM 695

Current situation:

The section through the city of Zagreb is about 20 km long. The river width varies from 95 m up to 110 m. The whole stretch is canalised and bounded by dikes. The steep embankments are mostly covered by trees, the heigth difference between the foreland and the water body is up to 3 meters. Within the dikes there is mostly grassland but also some trees. Due to riverbed incision, the river cannot be perceived from the outside (Fig. 25).

Transformation:

From the monotonous canal to the river with alternating gravel banks.

After the implementation of the described measures the average target river width will vary between 200 m and 300 m, including gravel bars, water body, softwood and grassland.

Initial measures:

- Building initial channels: see Fig. 26 and 27
  - Main initial channel 25 m wide
  - Small initial channel 15 m wide
- Restoring soft banks with flat embankments
- Reinforce and reset bank protection to protect existing dikes
- Lowering foreland (see Fig. 27 and 28)

Benefits:

- More discharge capacity
- Additional flood retention area for Zagreb
- Reconnecting derivation channel Sava-Odra
- Riverbed stabilisation
- Natural dynamic processes lead to a good ecological status of the river Sava
- New gravel banks
- New recreational sites

Figure 25: *Current situation of section 3 with aerial photo.*

Figure 26: *Cross section at rkm 706 of section 3 with current situation and possible initial measures.*

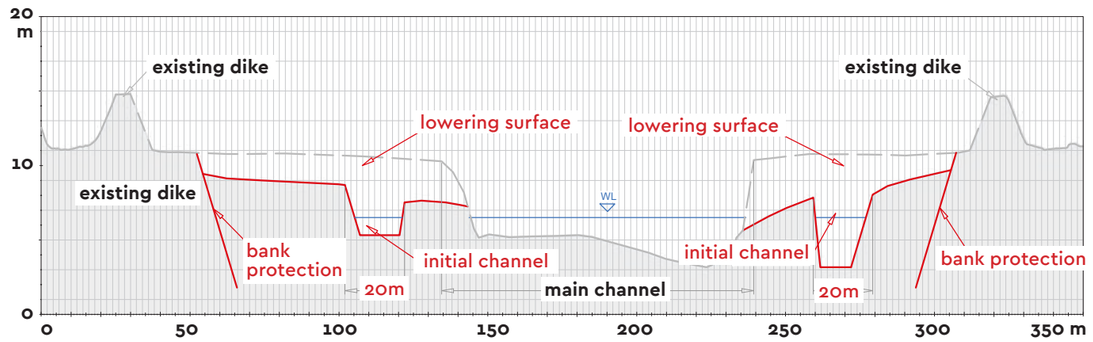


Figure 27: *Initial measures in section 3.*

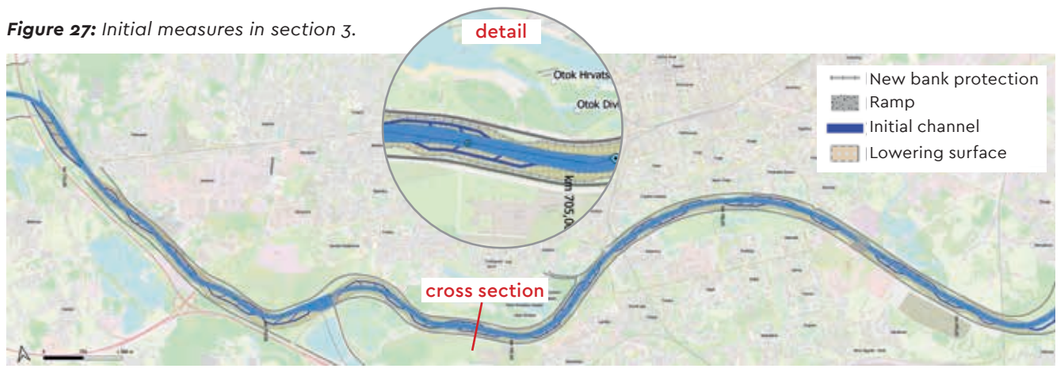


Figure 28: *Target state in section 3.*

FIGURES BY: REVITAL

SECTION 4· DOWNSTREAM THE CITY OF ZAGREB

RKM 695 - RKM 687

Current situation:

The section downstream the city of Zagreb is about 8 km long. The river width varies from 100 m up to 112 m. The whole stretch is canalised and is bounded by dikes on both sides. Huge areas of grassland cover the area between river and dikes. In the lower section the river Sava is accompanied by soft- and hardwood forests. However, they are not well connected to the water body (Fig. 29).

Transformation:

From the monotonous canal to the river with alternating gravel banks.

After the implementation of the described measures the average target river width will vary between 350 m and 500 m, including gravel bars, water body, softwood, hardwood forests and wet grassland.

Initial measures:

- Building initial channels: see Fig. 30 and 31
  - Main initial channel 40 m wide
  - Small initial channel 15 m wide
- Restoring soft banks with flat embankments
- Reinforce and reset bank protection to protect existing dikes (see Fig. 30 and 31).

Benefits:

- More discharge capacity
- Riverbed stabilisation
- Natural dynamic processes lead to a good ecological status of the river Sava
- New gravel banks
- Hardwood forests reconnected to ground water
- New recreational sites

Figure 29: *Current situation of section 4 with aerial photo.*

Figure 30: *Cross section at rkm 695 of section 4 with current situation and possible initial measures.*

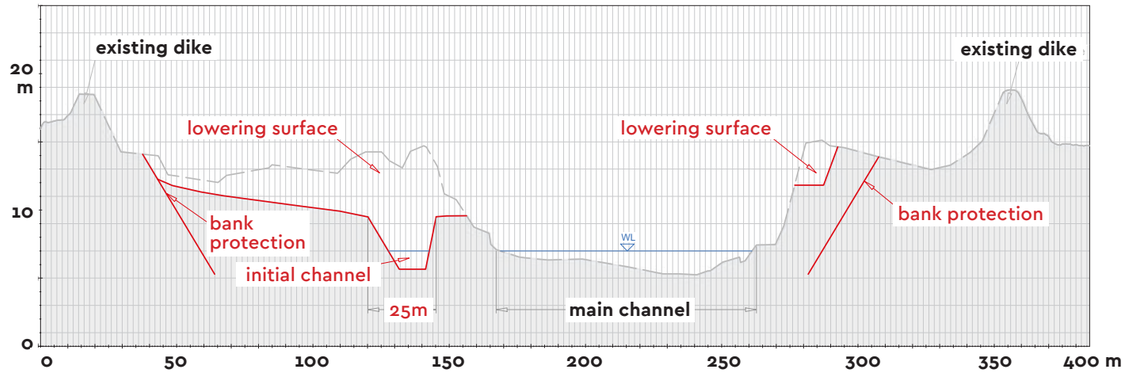


Figure 31: *Initial measures in section 4.*

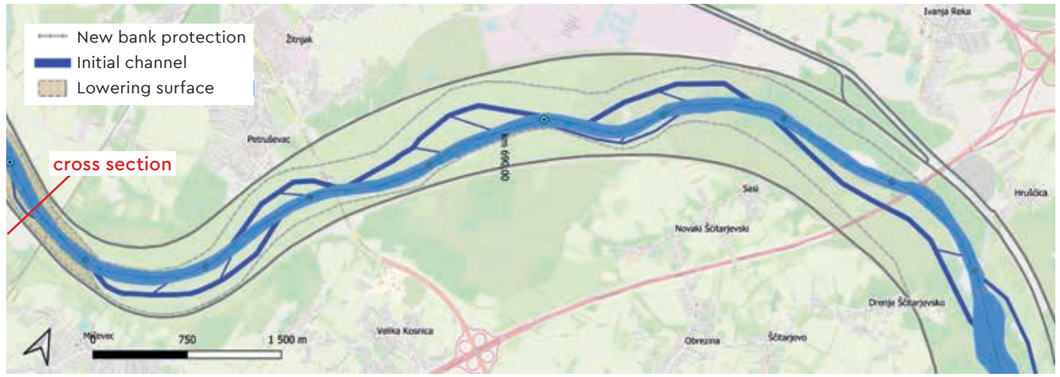
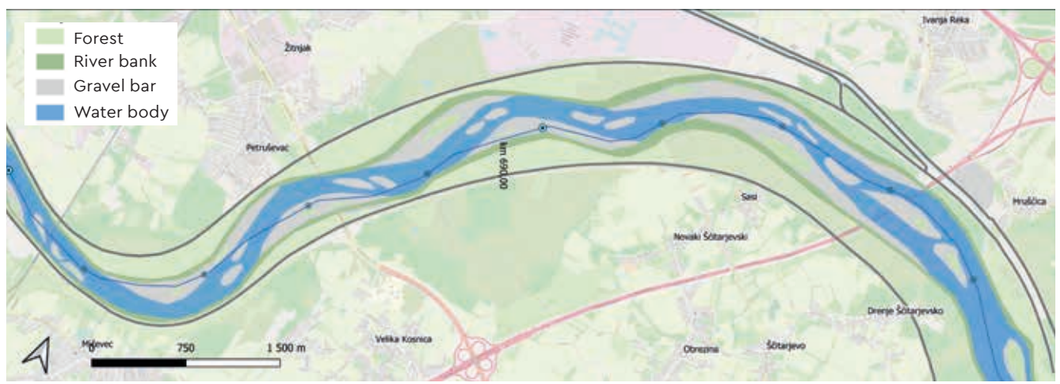


Figure 32: *Target state in section 4.*



FIGURES BY: REVITAL

SECTION 5· FROM THE BRIDGE AT RKM 687 DOWN TO RUGVICA

RKM 687 - RKM 672

Current situation:

This section is approximately 15 km long. It corresponds almost to the natural state, as large areas of softwood and hardwood forests cover the floodplain area. In addition also some areas of grassland and small sectioned agriculture occur (Fig. 33).

Transformation:

After the implementation of the described measures the average target river width will vary between 350 m and 500 m, including gravel bars, water body, softwood, hardwood forests and wet grassland, connected to floodplain dynamics.

Initial measures:

- Building initial channels (see Fig. 34 and 35):
  - Main initial channel 30-40 m wide
  - Side channel 15 m wide

Benefits:

- More discharge capacity
- Riverbed stabilisation
- Natural dynamic processes lead to a good ecological status of the river Sava
- New gravel banks
- Hardwood forests reconnected to ground water
- New recreational sites

Figure 33: *Current situation of section 5 with aerial photo.*

Figure 34: *Cross section at rkm 681 of section 5 with current situation and possible initial measures.*

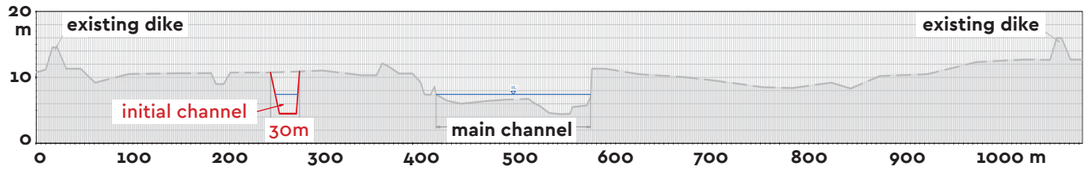


Figure 35: *Initial measures in section 5.*

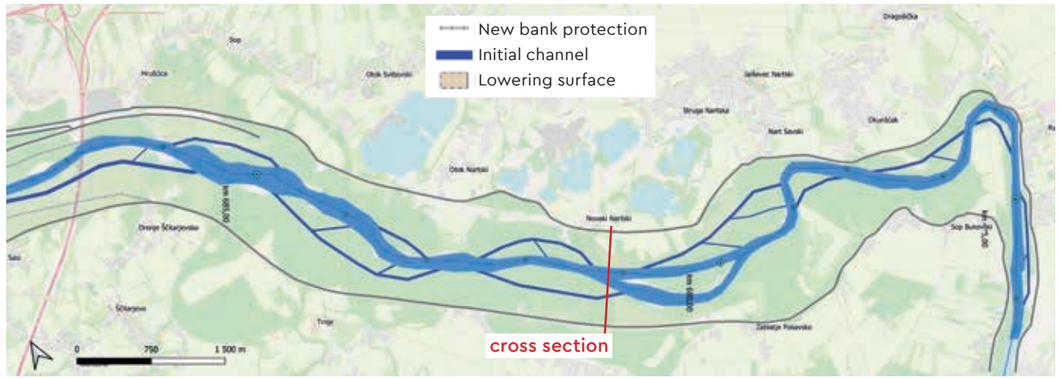
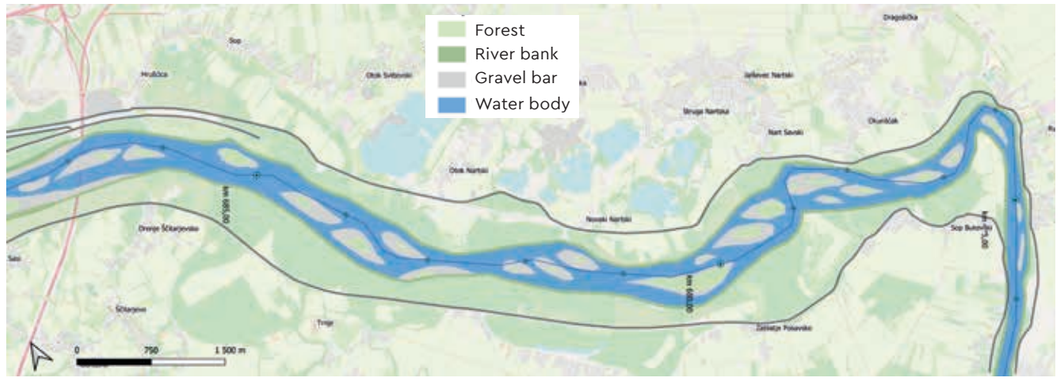


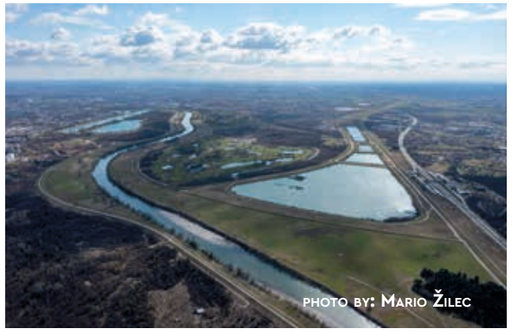
Figure 36: *Target state in section 5.*



FIGURES BY: REVITAL

RAMP 1·
AT DERIVATION OF CHANNEL SAVA-ODRA

RKM 709



Current situation:

The derivation channel Sava-Odra, an important flood protection measure for the city of Zagreb, located at rkm 709, is not working properly due to incision of the Sava river bed.

Measures:

- Reset dikes to prevent material from being deposited in the derivation channel
- Building an open brank weir, 280-300 meter long, parallel to the flow direction (Fig. 35)
- Building a new 130-meter-long fish passable ramp to stabilize riverbed, support the open brank weir and make sure, that flood protection system works.

Benefits:

- Riverbed stabilisation
- Derivation channel Sava-Odra will be reconnected, thus flood protection works again
- Fish migration will be possible
- Gravel is transported in the river, not in the derivation channel

Figure 33: *Current situation around derivation channel Sava-Odra with aerial photo.*

Figure 34:
Flat fish passable ramp - best practice (Salzach at Freilassing, Austria/Germany).

Figure 35: *Proposed measures around the derivation channel Sava-Odra.*

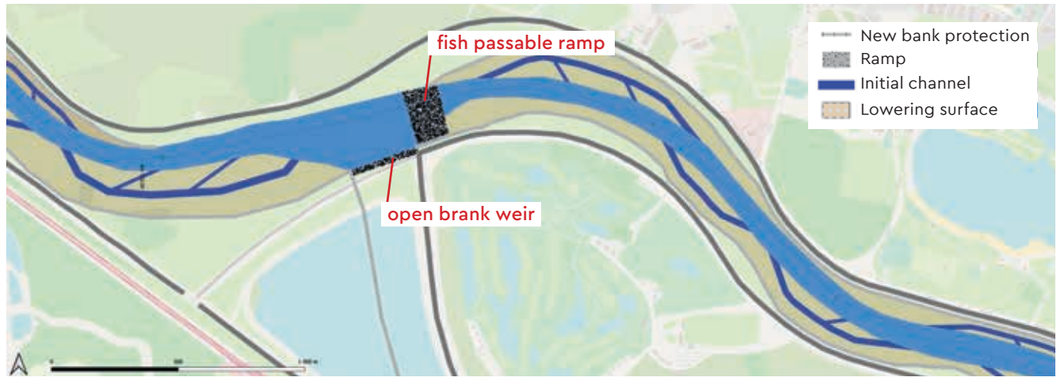


Figure 36: *Target state around derivation channel Sava-Odra.*

FIGURES BY: REVITAL

RAMP 2:
AT HEP – TOPLINARSTVO

RKM 697

Current situation:

At rkm 697, next to the existing HEP Toplinarstvo, a ramp keeps the water level constant and the riverbed stable. Next to the ramp huge rocks are located to be put back onto the ramp to stabilize it (Fig. 38).

Measures:

- Rebuild a 270-300-meter-long fish passable ramp for riverbed stabilisation (Fig. 39)
- Integrate the ramp into measures which have to be implemented up and downstream the ramp.

Benefits:

- Riverbed stabilisation
- Fish migration will be possible again

Figure 37: *Current situation around derivation HEP Toplinarstvo with aerial photo.*

Figure 38: *Rocks and stones prepared to secure the ramp.*

Figure 39: *Proposed initial measures at Sava around HEP Toplinarstvo.*

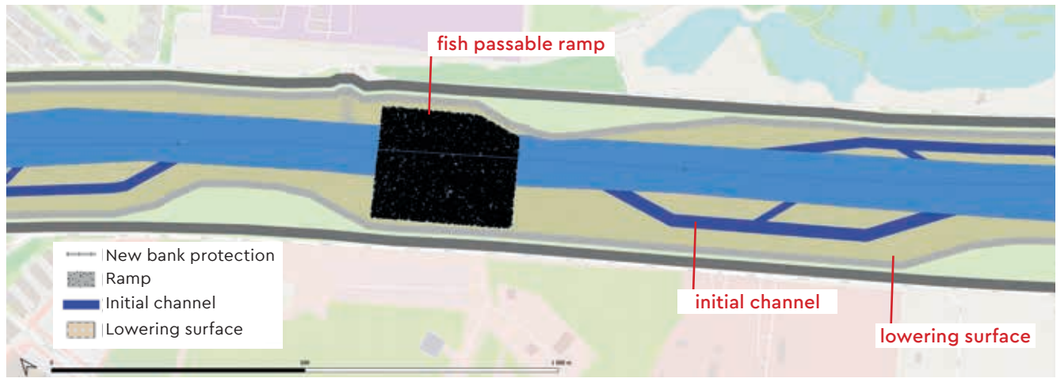


Figure 39: *Target state of Sava around HEP Toplinarstvo.*

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COST AND BENEFITS

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COSTS

Estimated costs:

(in total for the five river sections and two selective intervention areas)

Measures	Estimated quantity	Estimated costs [Mio. €]
Initial channels	~ 50 km	80
Open brank weir, ramps	~ 9 ha	10
Bank protection	~ 80 km	70
Lowering foreland	~ 331 ha	50
Subtotal 1		**210**
Accompanying measures	~ 25% of subtotal 1	50
Unexpected	~10% of subtotal 1	20
Subtotal 2		**280**
planning services, building supervision	~ 10% from sub-total	30
Total		**310**

Priorities for implementation:

The order of implementation depends largely on the type of funding:

- If nature conservation has priority and co-financing might come from the LIFE Nature Fund of the European Union, sections 2 and 5 should be given priority.
- If the emphasis is on recreational use, stopping river bed deepening and improving the ecological condition of water bodies (e.g. hydromorphology), implementation should start with section 4.

BENEFITS

	Description	Section 1 DOWN-STREAM BREŽICE	Section 2 UPSTREAM THE CITY OF ZAGREB	Section 3 THROUGH THE CITY OF ZAGREB	Section 4 DOWN-STREAM THE CITY OF ZAGREB	Section 5 FROM BRIDGE RKM 687 DOWN TO RUGVICA	Ramp 1 AT DERIVATION OF CHANNEL SAVA-ODRA	Ramp 2 AT HEP – TOPLI-NARSTVOA
River maintenance - less effort	Riverbed stabilisation leads to less need for maintenance.	✓	✓	✓	✓	✓	✓	✓
	Natural bed load input instead of technical gravel input or ramps.	✓	✓	✓	✓	✓		
	Gravel remains in the river, is not transported into derivation channel.						✓	
Flood protection improved	Increased discharge capacity improves flood safety.	✓	✓	✓	✓	✓		
	Additional flood retention area for Zagreb.	✓	✓	✓				
	Flood relief through reconnected derivation channel, thus flood protection works again.						✓	
Good ecological status of river	Natural dynamic processes are improved and preserved, river habitats can develop in a natural or near-natural way and the side arm system is adequately endowed and flowed through.	✓	✓	✓	✓	✓		
	Fish migration is possible again.	✓	✓	✓	✓	✓	✓	✓
Riparian habitats improved	More typical riparian habitats, especially gravel banks, pioneer vegetation and softwood will be initiated.	✓	✓	✓	✓	✓		
	Hardwood forests get reconnecting to ground water.		✓		✓	✓		
Protected areas - goals supported	Objectives of protection, in particular species and habitats of dynamically shaped river, riparian forests and meadow habitats are supported.	✓	✓			✓		
Agriculture - better ground water conditions	Higher or stable groundwater level favor agricultural production.	✓	✓		✓	✓	✓	✓
Beauty of landscape	A near-natural river makes the landscape appear more beautiful for both, locals and tourists.	✓	✓	✓	✓	✓		
Recreation and a health lifestyle	New recreational sites bring people closer to their river again.	✓		✓	✓			
Tourism	Potential for biking and canoeing promotes regional economy.	✓	✓	✓	✓	✓		
Fishery	River restoration creates better places and conditions for fishermen.	✓	✓	✓	✓	✓		
Jobs	The implementation of the initial measures creates jobs for decades.	✓	✓	✓	✓	✓	✓	✓
Regional welfare	Sava will be a sustainable natural resource for regional welfare.	✓	✓	✓	✓	✓	✓	✓

FURTHER INFORMATION

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EuroNatur Stiftung | Westendstr. 3 | 78315 Radolfzell | Germany

PUBLICATIONS & LITERATURE

Sava White Book:

Schwarz, U. (2016): Sava White Book. The River Sava: Threats and Restoration Potential. Radolfzell/Wien: EuroNatur/Riverwatch.

LINKS

www.euronatur.org
www.zeleni-prsten.hr
www.ptice.hr

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in alphabetic order

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CROATIAN SOCIETY FOR THE BIRD AND NATURE PROTECTION

ZELENI PRSTEN Zagrebačke županije

REVITAL

View on Sava - to the west from Medvednica (Meglenik probably) today and before river regulation.
(The photo was provided by the Tošo Dabac Archive at the Museum of Contemporary Art Zagreb. The owner of the photo is the City of Zagreb)

SAVA PARKS NETWORK

AAGE V. JENSEN CHARITY FOUNDATION

EURONATUR FOUNDATION