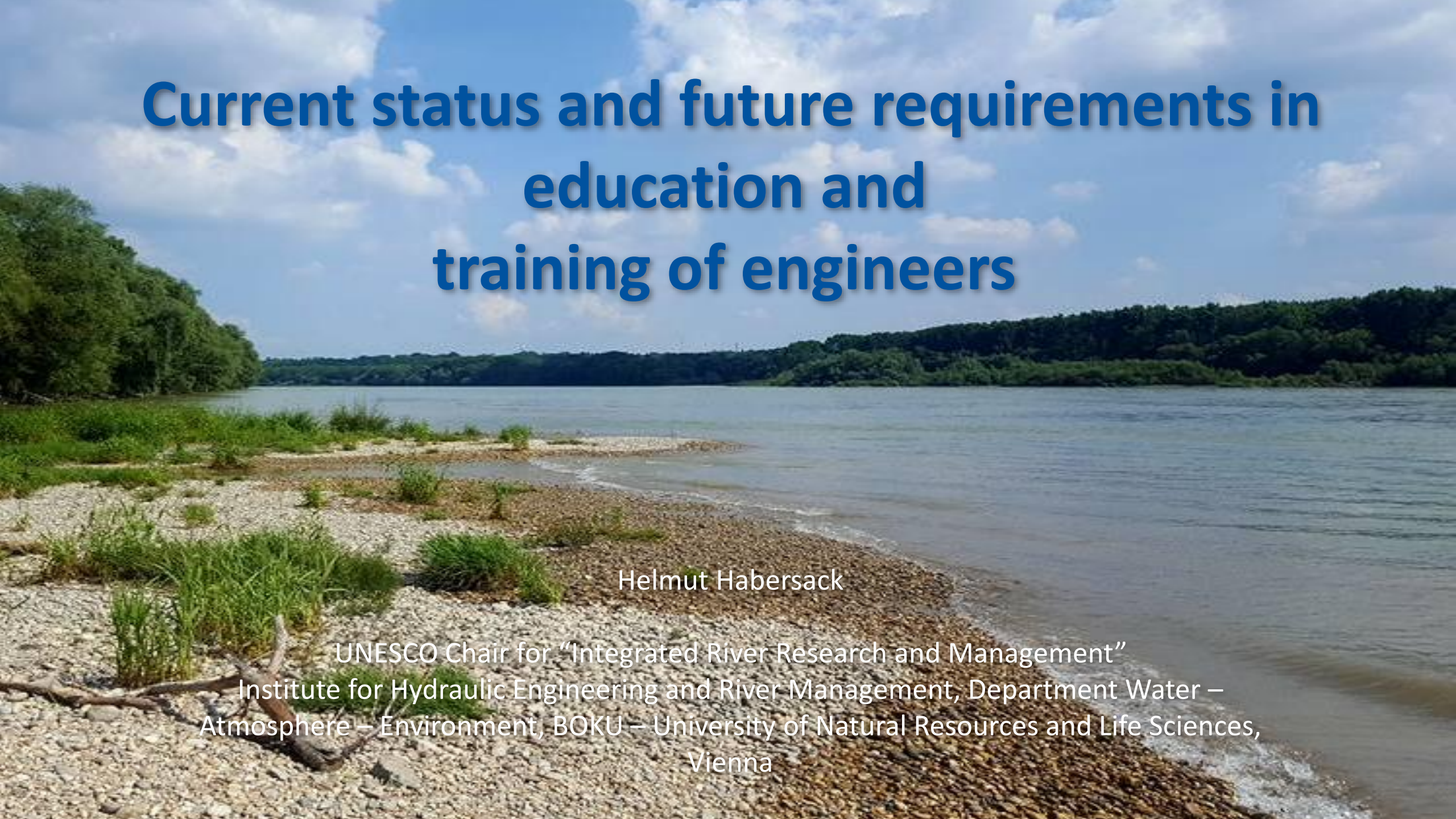
Current status and future requirements in education and training of engineers



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Contents

- Introduction and actual problems
- Current status in education and training
- Future requirements
- Conclusions

Introduction

Large rivers in the context of multiple uses / pressures

Irrigation

Nile

Sediments

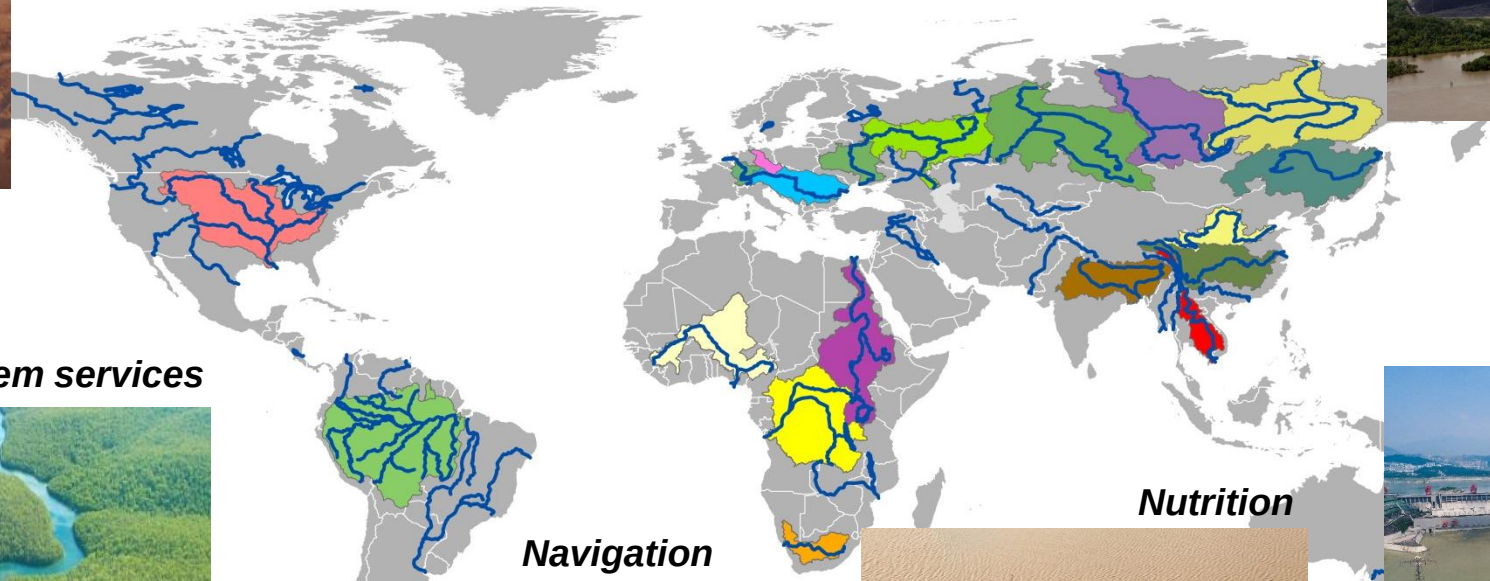
Danube

Industrial use

Mississippi

Water supply

Colorado River



Ecosystem services

Amazon

Navigation

Rhine

Nutrition

Niger River

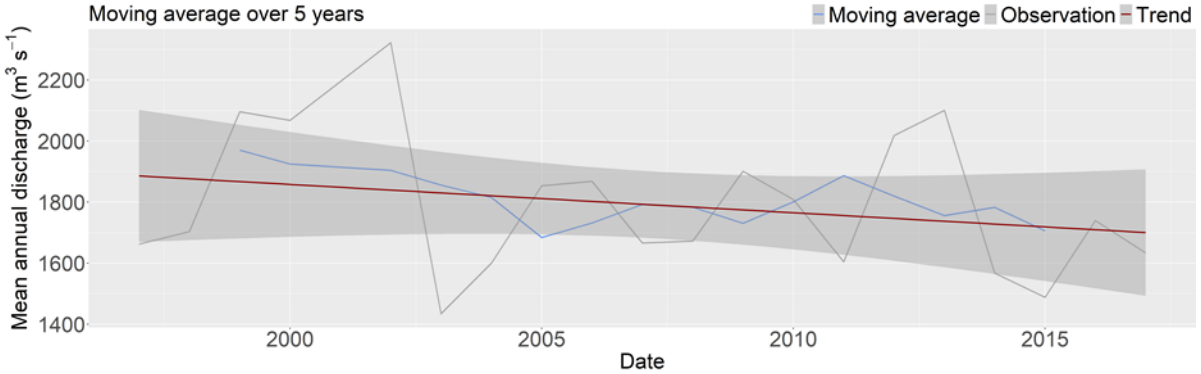
Hydropower

Jangtse

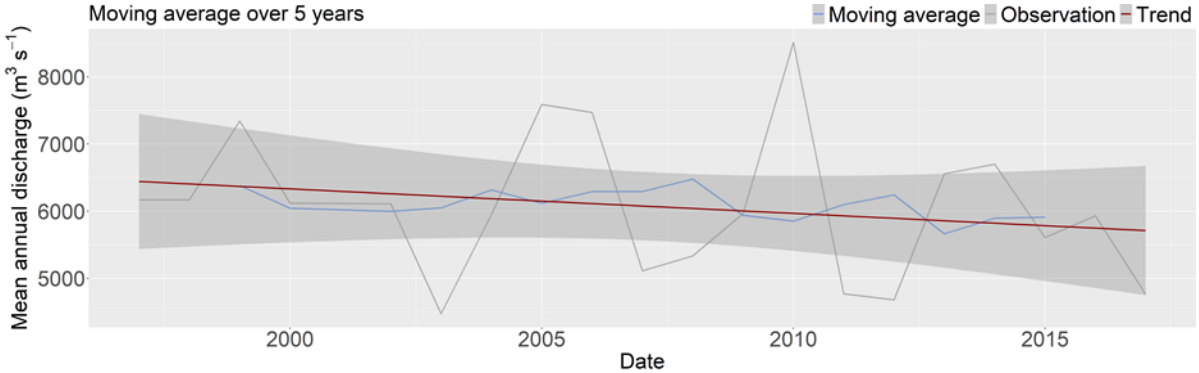
Hydrology & Hydraulics

Mean annual discharge

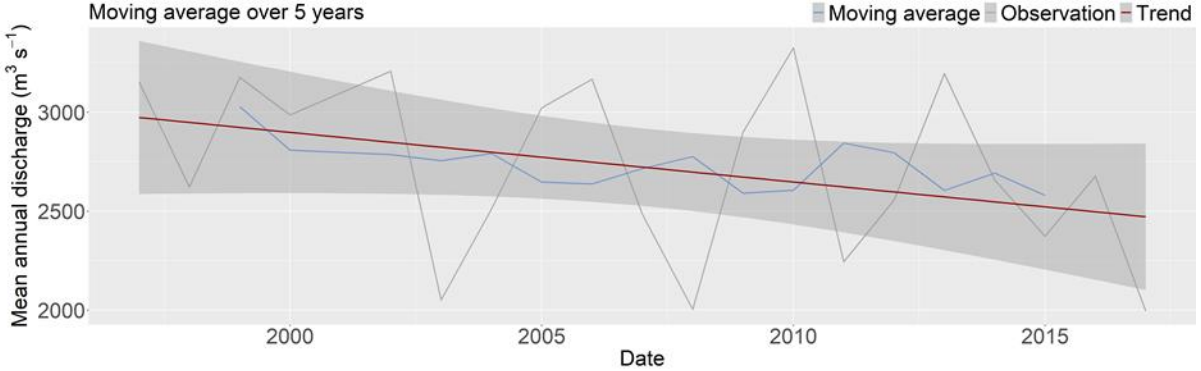
- **Temporal change of mean annual discharge (1997 – 2017)**
  - A decreasing mean annual discharge in the period between 1997 and 2017 (between **-10%** (Upper Danube) and **-17%** (Middle Danube) was found, which was not significant from the statistical point of view.



Temporal change in annual discharge (1997-2019) based on yearly data at **Upper Danube**. Data: ICPDR (2020b), modified and processed.



Temporal change in annual discharge (1997-2019) based on yearly data at **Lower Danube**. Data: ICPDR (2020b), modified and processed.

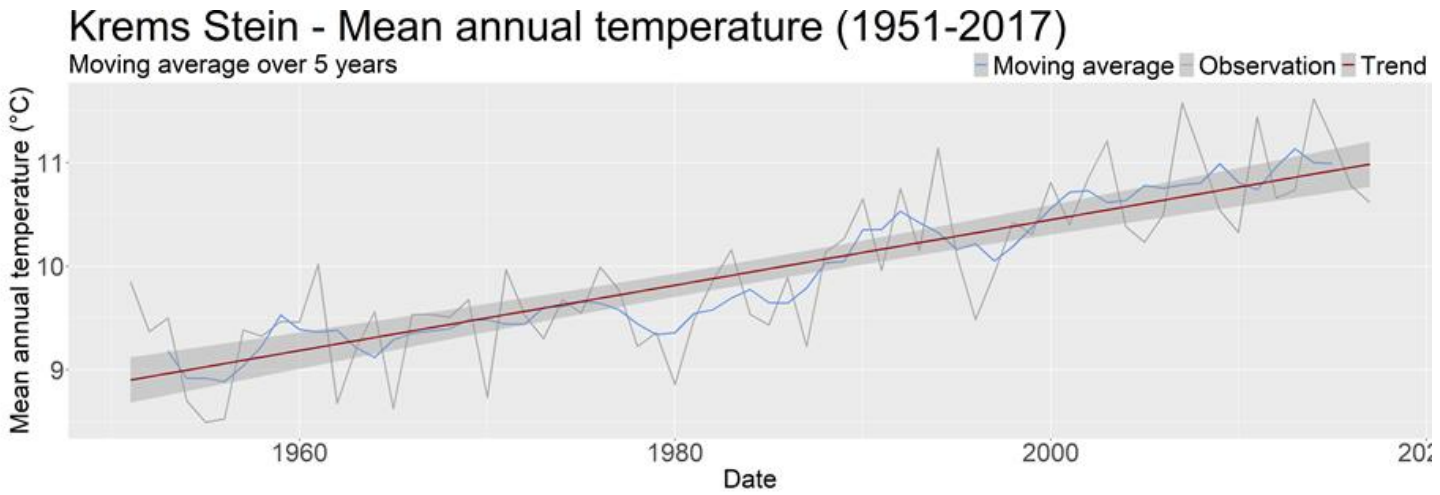


Temporal change in annual discharge (1997-2019) based on yearly data at **Middle Danube**. Data: ICPDR (2020b), modified and processed.

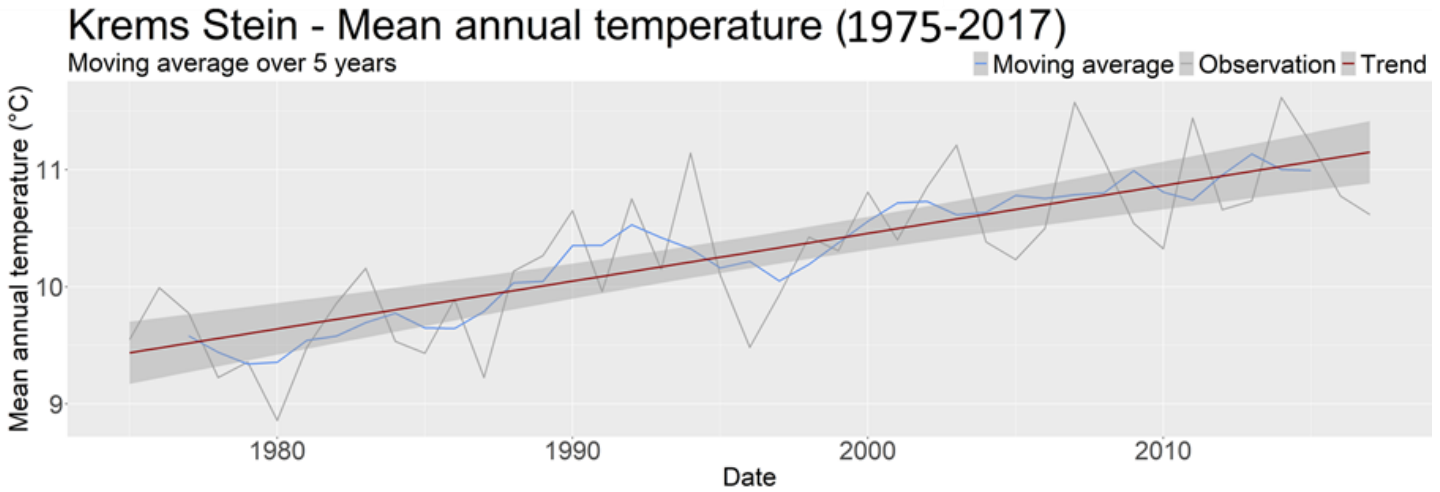
Hydrology & Hydraulics

Mean annual water temperature

- **Temporal distribution of mean annual water temperature:**
  - Long term investigation of changes in water temperature was applied in the Upper Danube at station Krems / Stein (rkm 2,003) indicating a highly significant rise between 1951 and 2017 of **0.031 °C per year** ($p < 0.0001$).
  - An even higher and also highly significant trend of **0.040 °C per year** ($p < 0.0001$) was found, when the investigated period was reduced to 1975 and 2017 (Figure 39), as applied in ICPDR (2021b).



Temporal development of the mean annual water temperature in °C (data from 1951-2017) at Krems / Stein (rkm 2,003) in the Upper Danube. Data: ehyd (2021), modified.

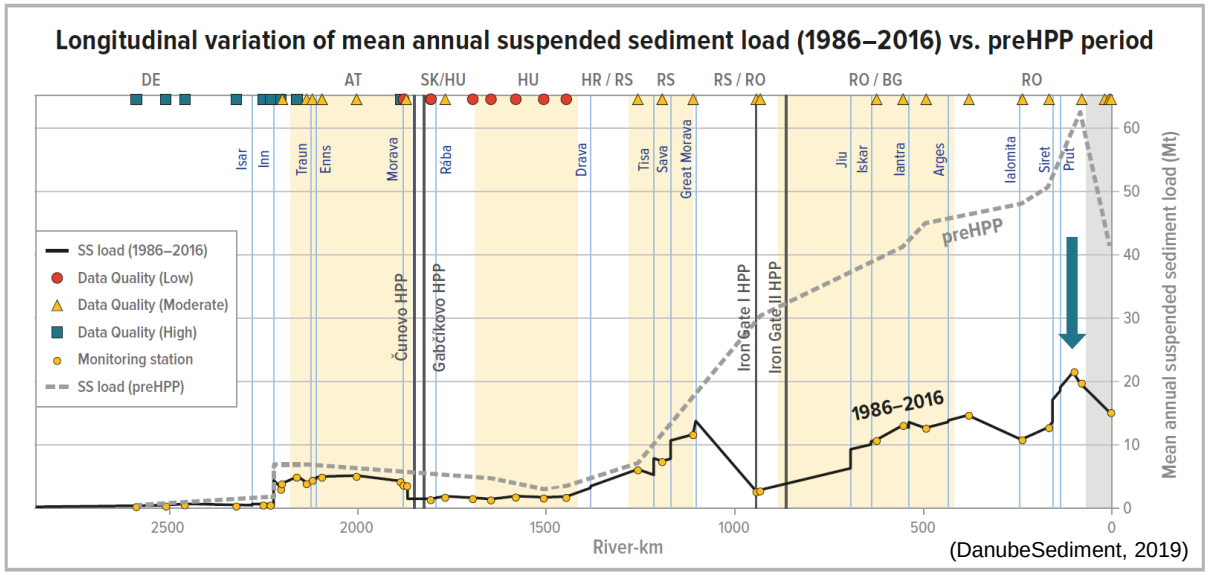


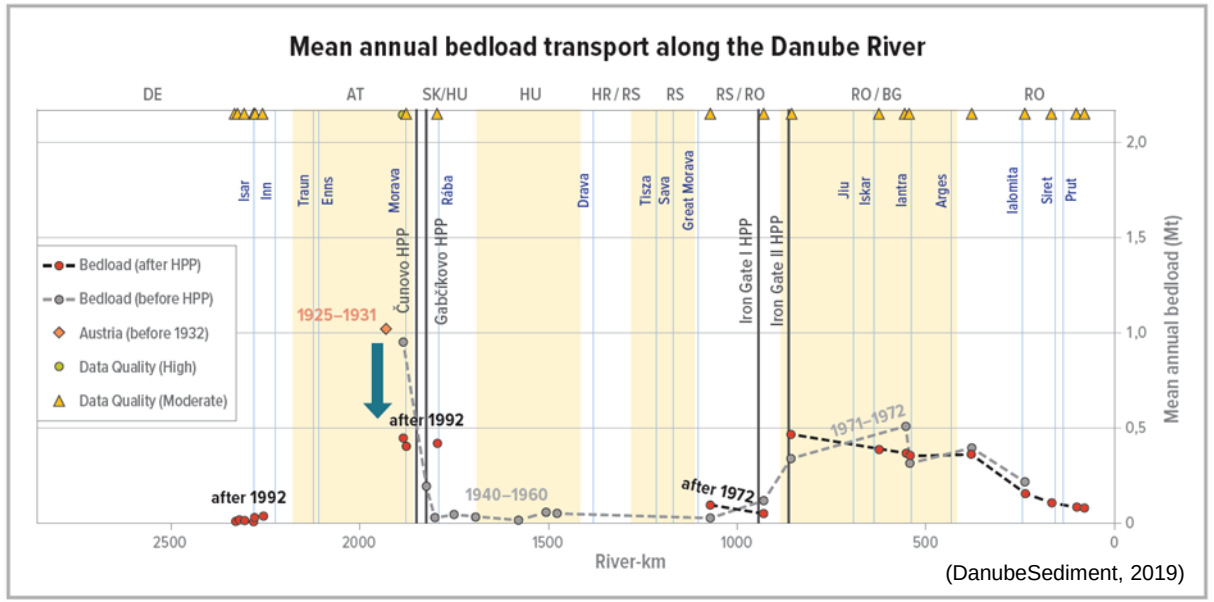
Temporal development of the mean annual water temperature in °C (data from 1975-2017) at Krems / Stein (rkm 2003) in the Upper Danube. Data: ehyd (2021), modified.

Sediment Transport & Morphodynamics

Sediment transport

- The **total suspended sediment input** to the **Danube Delta** and the Black Sea **decreased by more than 60%**, from former amounts of approximately 60 Mt yr^{-1} and 40 Mt yr^{-1} to approximately 20 Mt yr^{-1} and 15 Mt yr^{-1} nowadays.
- **Bedload transport** decreased by **55%** for the time after the construction of the last hydropower plant in the **Austrian Danube River**.
- The **interruption of river continuity** also prevents the transport of bedload, which leads to a lack of those sediments that shape the river.
- **Bedload transport** contributes up to 10% of the total sediment transport at the Upper Reach of the Danube River and up to 5% at the lower part, with higher ratios downstream of Gabčíkovo and Iron Gate Dams.

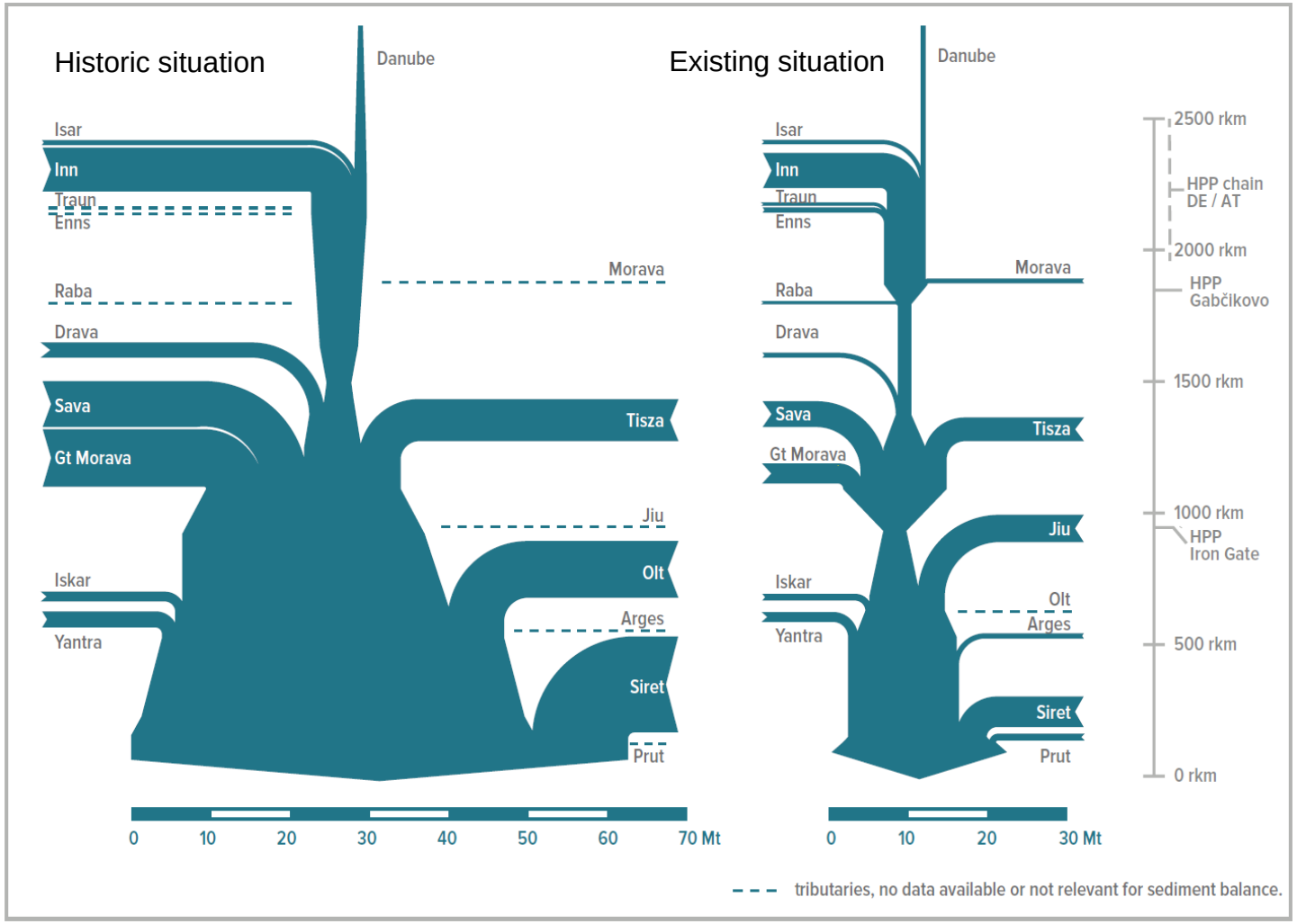




Sediment Transport & Morphodynamics

Sediment budget

- For **tributaries** with enough data available to cover both periods, the **reduction of suspended sediment** load ranges **from 20% to 70 %**.
- The chain of hydropower plants on the Upper Danube and especially the large reservoirs of Gabčíkovo and Iron Gate I impact the suspended sediment balance, as **a large amount** of the **sediments is trapped in these reservoirs.**
- For the three largest hydropower plants at the Danube, **trap efficiencies of 21%, 60% and 60-80%** were calculated based on suspended sediment measurements up- and downstream of the impoundments

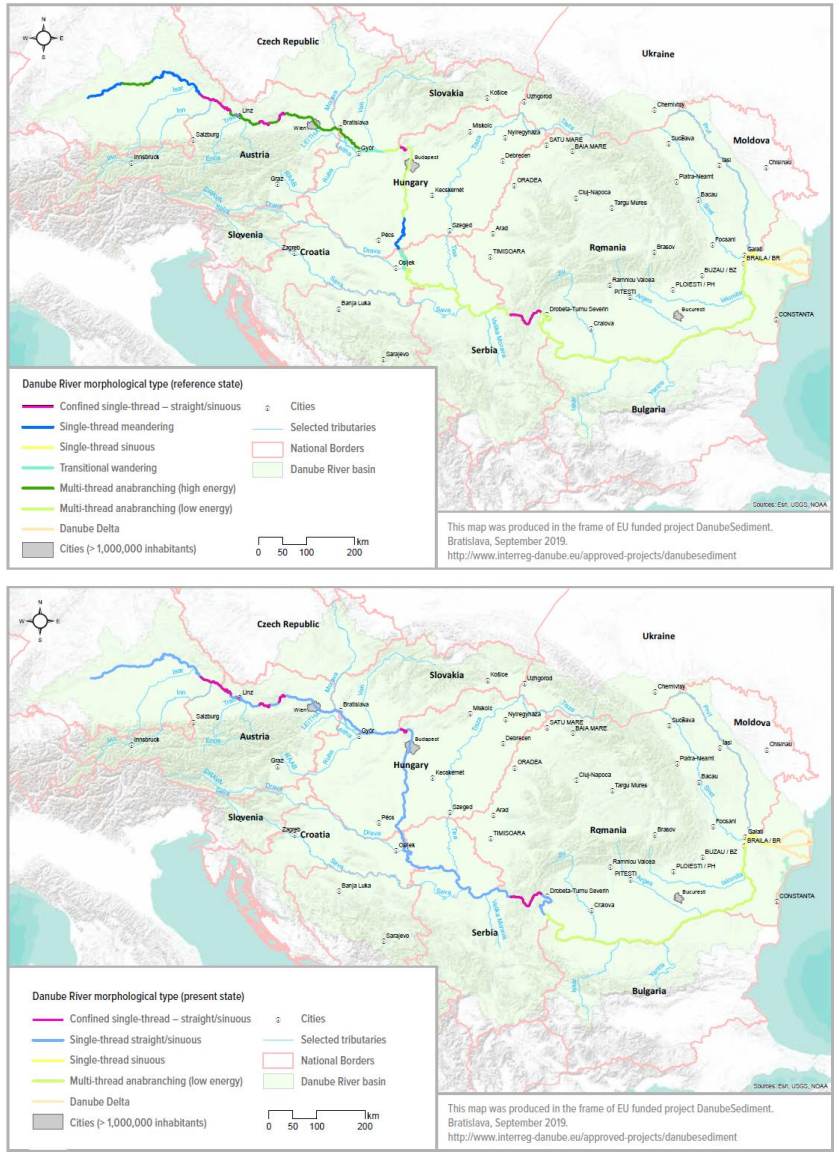


(DanubeSediment, 2019)

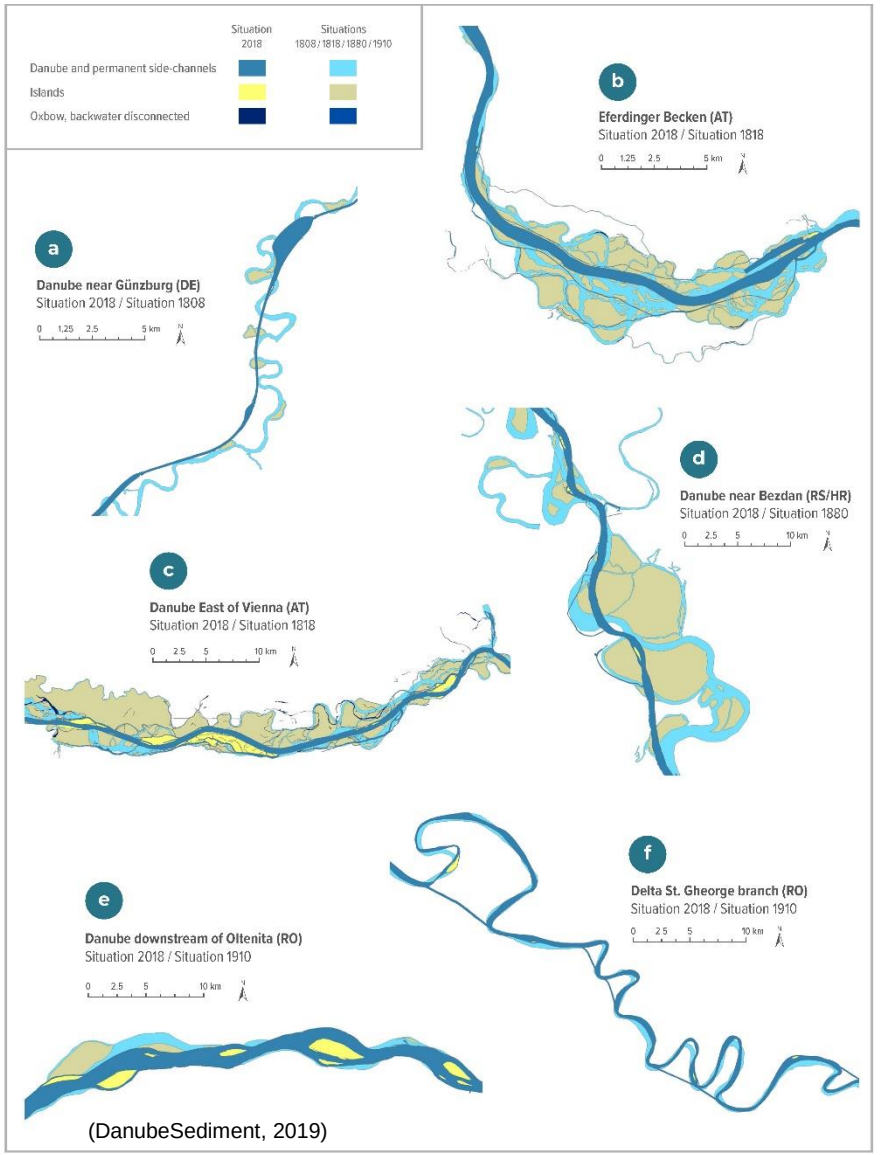
Sediment Transport & Morphodynamics

Channel patterns, forms

- In the **Upper and Middle Danube**, larger sections of the former complex and dynamic river system have **changed to a single-thread sinuous river type making up 58% of the river length** nowadays.
- The **multithread anabranching (high energy)** river type, in the past found along 14% of the river length in the Upper Danube, **no longer exists**.



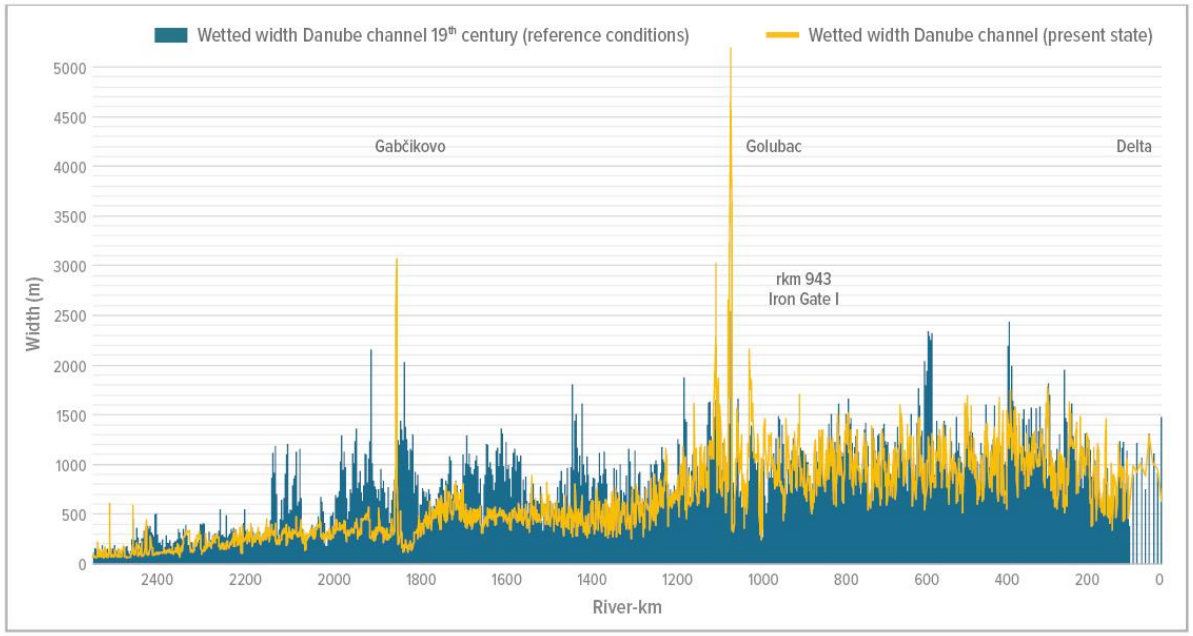
(DanubeSediment, 2019)



(DanubeSediment, 2019)

Sediment Transport & Morphodynamics

Metamorphosis



(DanubeSediment, 2019)

Section	Change in length	Change in whole width	Change in active width
Upper Danube	-11,4%	-39%	-22%
Middle Danube	-3,6%	-12%	-1%
Lower Danube	-0,4%	-4%	1%

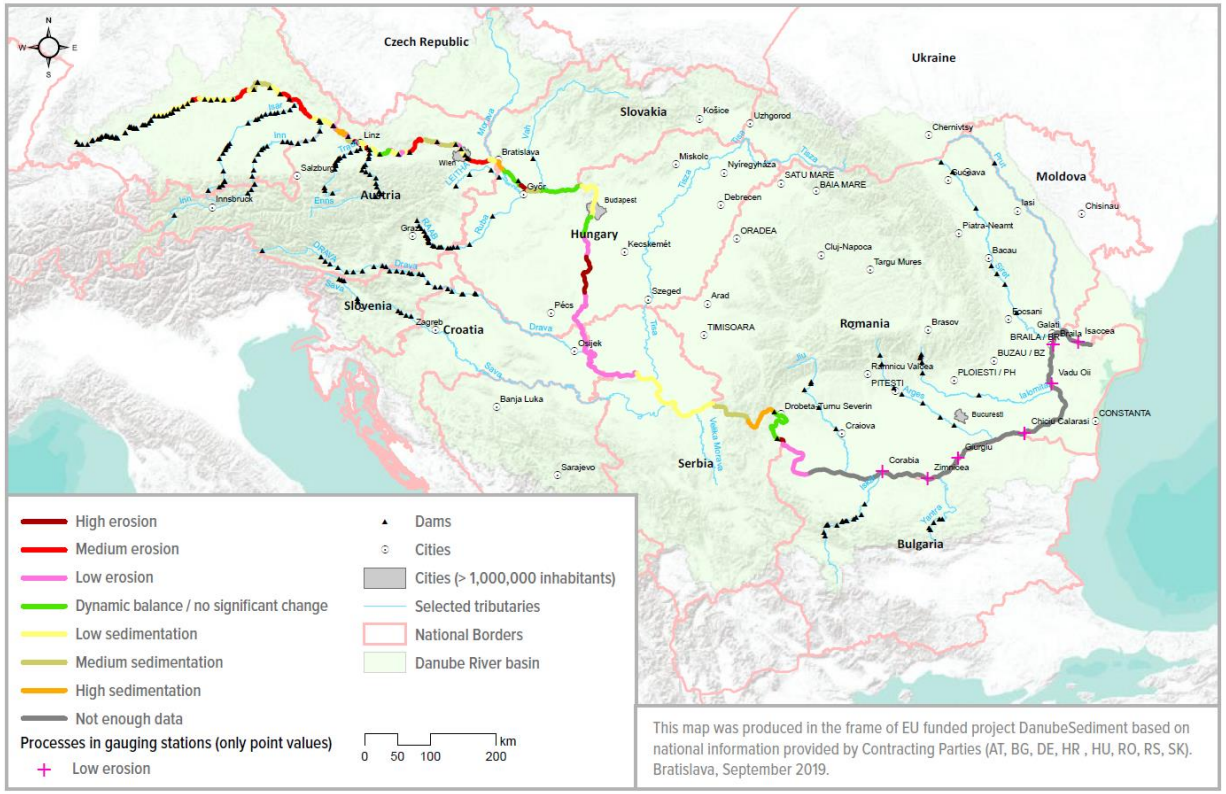
- In the **Upper and Middle Danube**, the formerly complex river morphology was transformed to a **uniform channel over large stretches**.
- The river length was shortened by 11% and the Middle Danube by 4%.
- The average width of the river was reduced by 39% in the Upper and by 12% in the Middle Danube.
- In the Lower Danube River, the length was marginally reduced by around 1% and the average width by 4%.

Interreg
Danube Transnational Programme
DanubeSediment

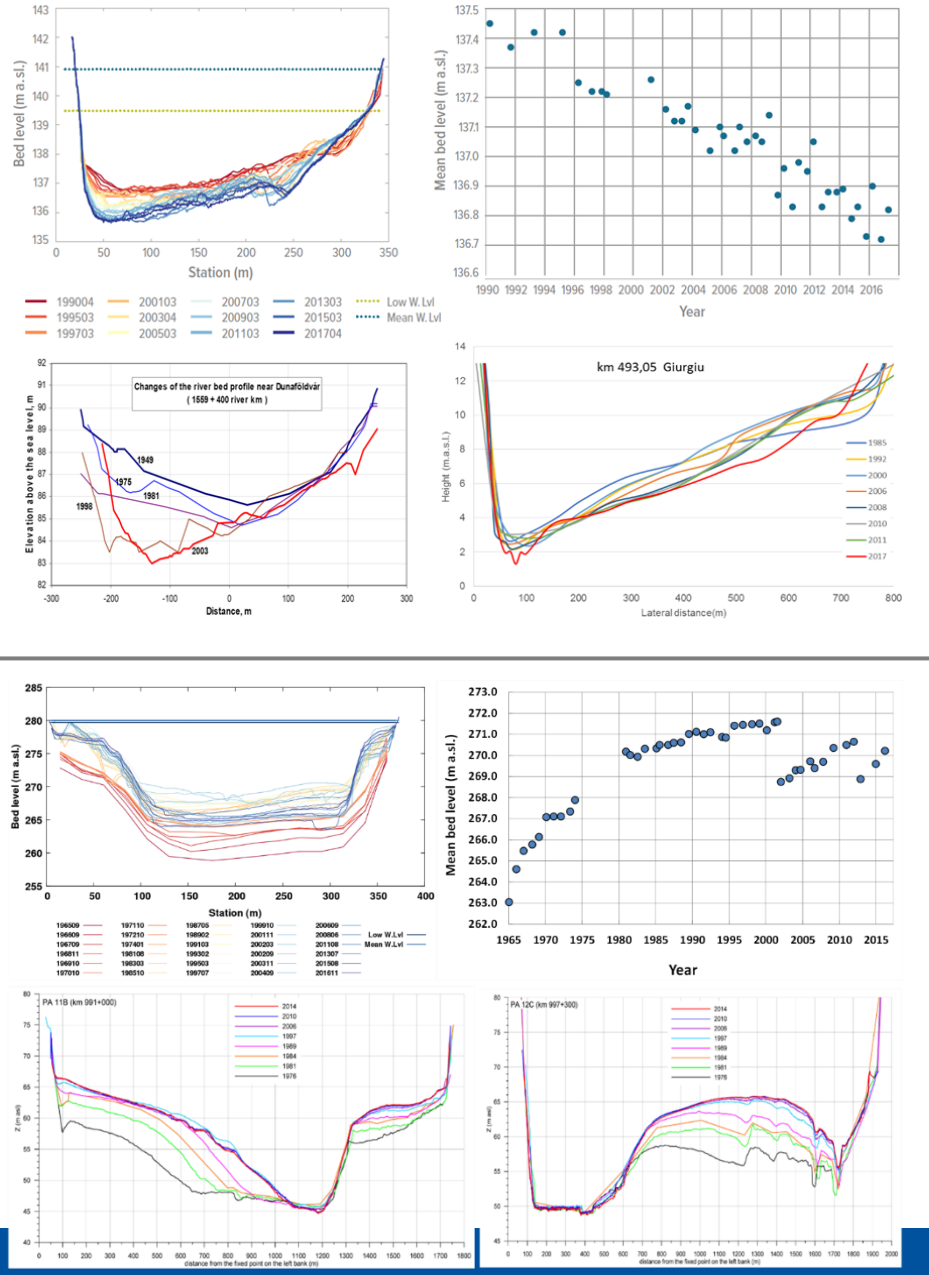
Sediment Transport & Morphodynamics

Riverbed level changes, including trends

- Free-flowing sections are prone to erosion, while impounded sections are subject to sedimentation.
- Erosion: 56 % (29 %), Sedimentation: 34 %, Equilibrium: 10 %



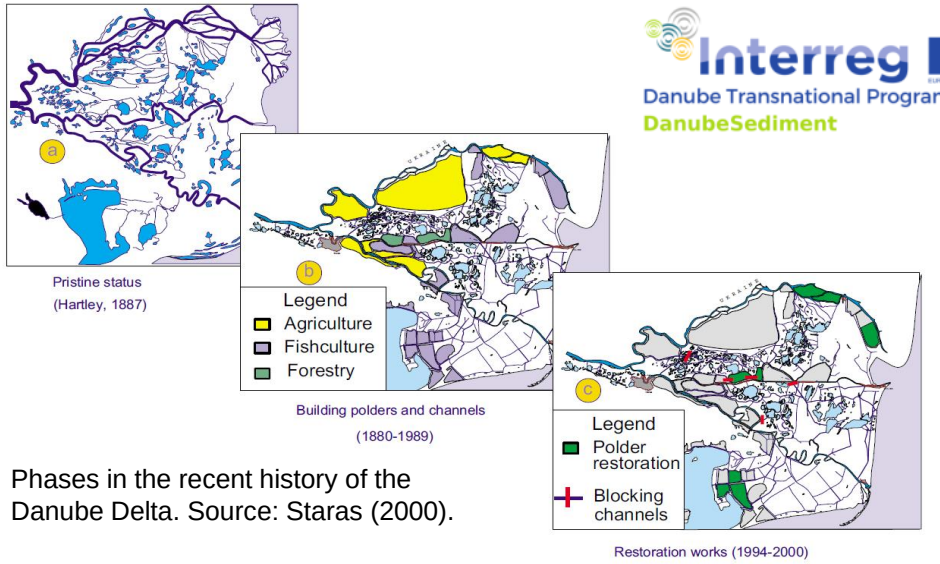
(DanubeSediment, 2019)



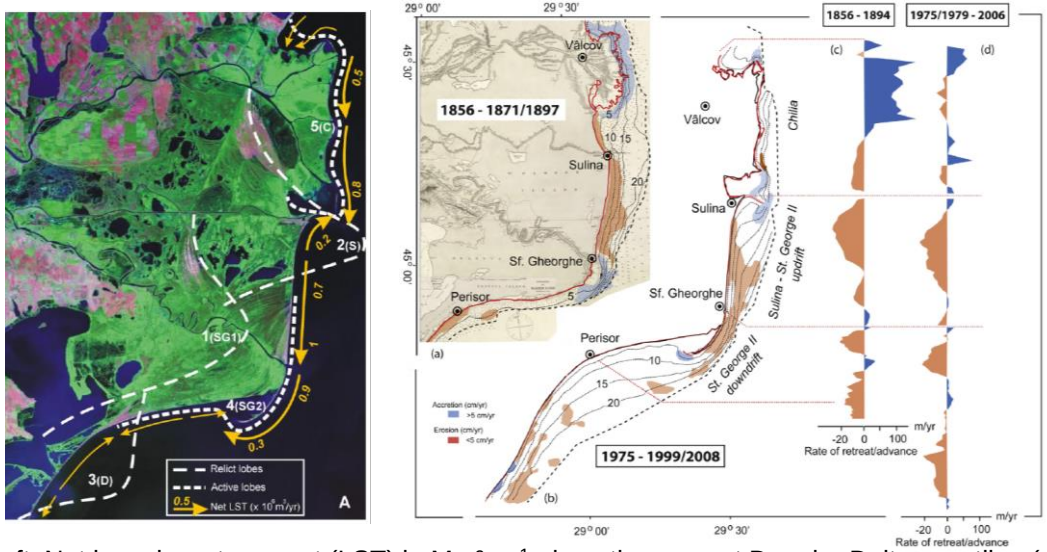
Sediment Transport & Morphodynamics

Coastal erosion

- The **natural pattern of coastal morphodynamics** in the Danube Delta (accretion at active lobs and mild erosion / stability in non-active nearshore regions), has **mainly disappeared due to the anthropogenic influence**.
- Shoreline advance in the Danube Delta is at the present limited to the mouth of the largest branches and the impacts of coastal engineering works in combination with the reduced sediment supply from the Danube River have led to **accelerated erosion in the past 50 years,** with values **up to 24 m yr^{-1}.**
- Overall, at the present around **55%** of the Danube Delta shoreline are subject to **erosion, 15%** are relatively **stable** and **30%** are **advancing**.



Phases in the recent history of the Danube Delta. Source: Staras (2000).

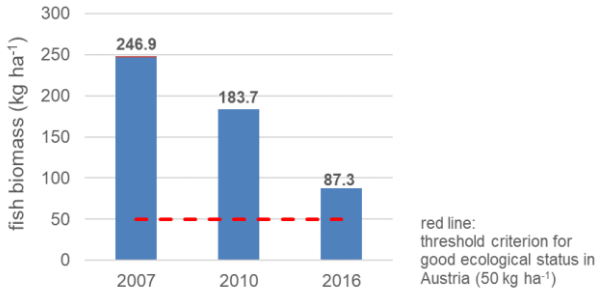


Left: Net longshore transport (LST) in Mm^3 yr^{-1} along the present Danube Delta coastline (orange line). Source: Vespremeanu-Stroe and Preoteasa (2015). Right: Morphodynamics of shoreline and nearshore region Danube Delta coast and lagoon coast. Source: Giosan et al. (2013).

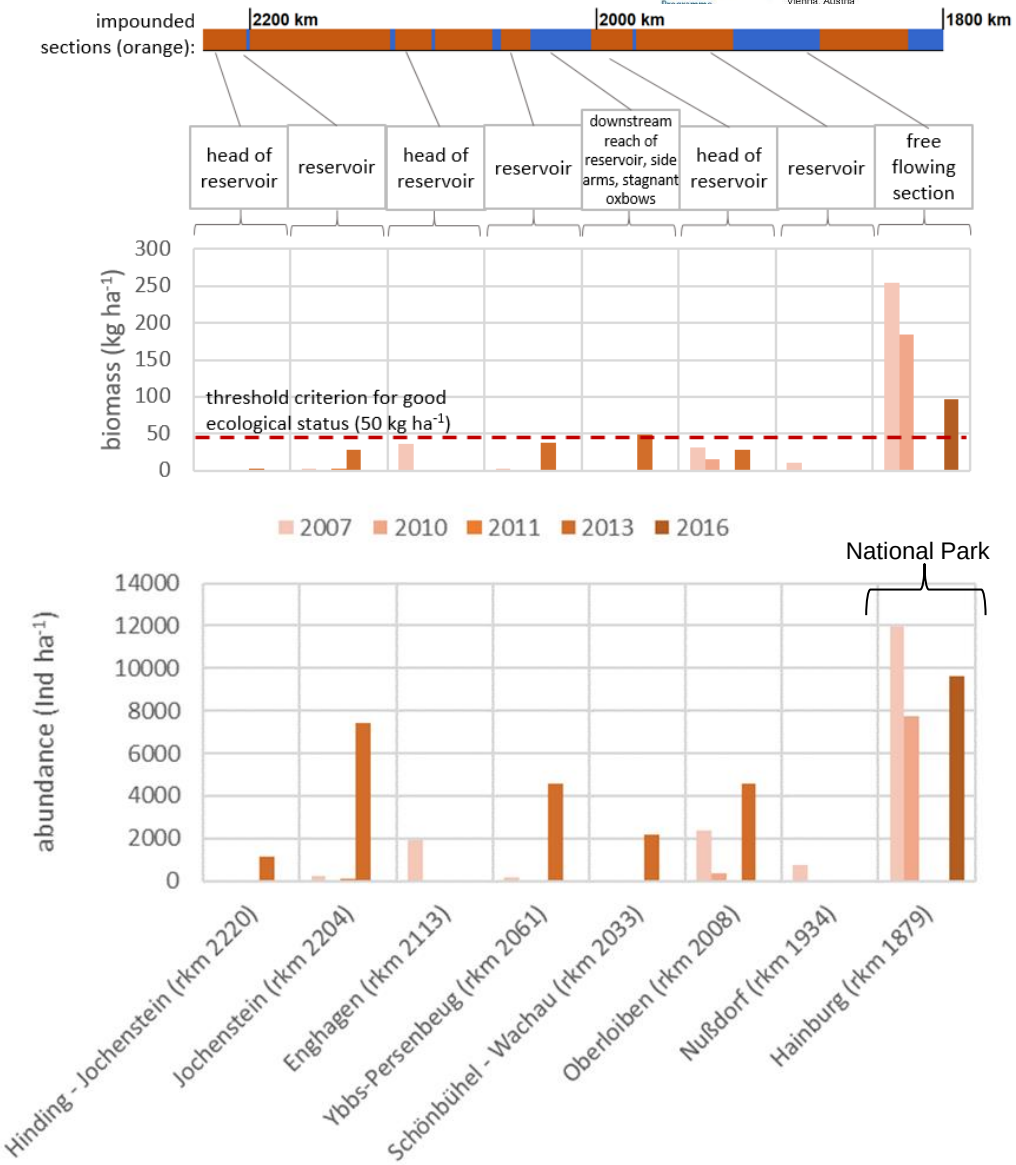
Ecology and Water Quality

Fish biomass and abundance

- As a result of various human interventions (e.g. dam construction), the **fish biomass and abundance** are decreasing.
- High quality and comparable, **systematic data on fish fauna is lacking, despite the efforts of transnational measurement campaigns** and surveys by national authorities to comply with the Water Framework Directive.



Temporal development of fish biomass in the Danube River at Hainburg (AT). Data: UBA (2021).



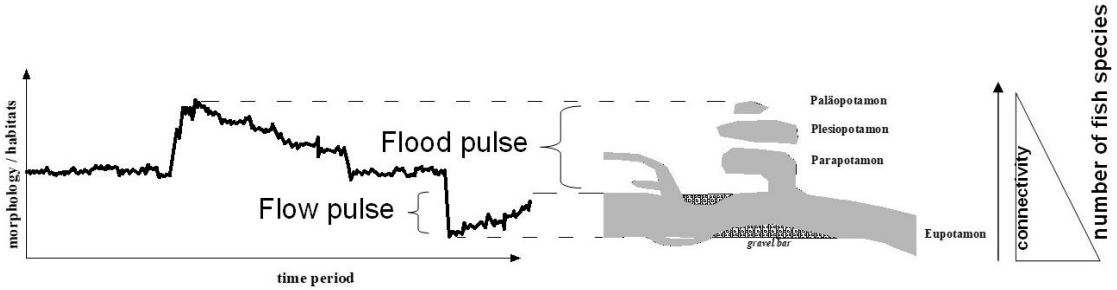
Temporal development of fish biomass and abundance in Austria and hydromorphological parameters of measuring points along the course of the Danube River. Source: UBA (2021), modified.

Ecology and Water Quality

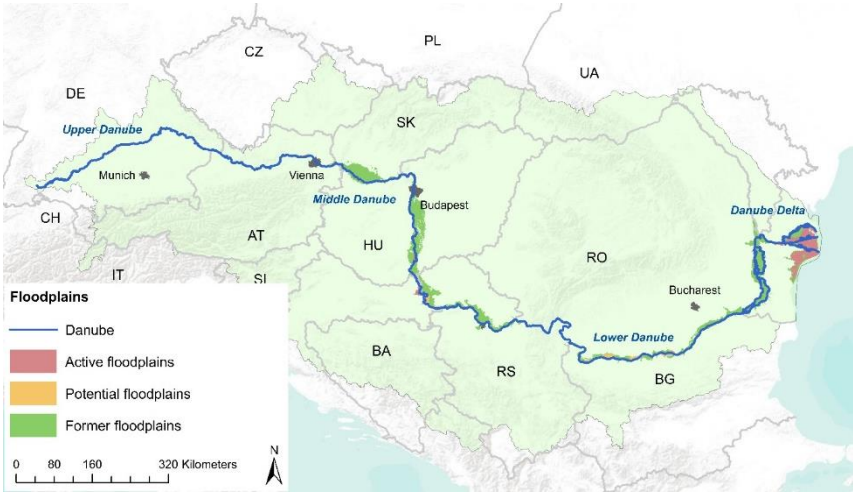
Wetland / Floodplain disconnectivity

- Approximately **70% of the floodplains** along the Danube River have been already lost and were disconnected from the main channel due to past river regulation measures (e.g. dams, dikes).

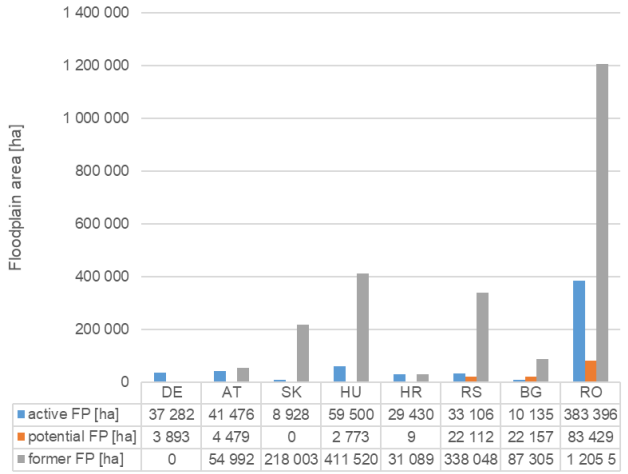
- Multiple ecological and socioeconomical benefits from floodplains, e.g. connected floodplains go along with a higher number of fish species (cf. Hauer, 2013)



Application of the flow pulse and flood pulse concept to different habitat types at the Upper Danube. Source: Hauer (2013).



Floodplains at the mainstream Danube River; active floodplains = red; potential floodplains = yellow; former floodplains = green. Data: Danube Floodplain (in prep.).

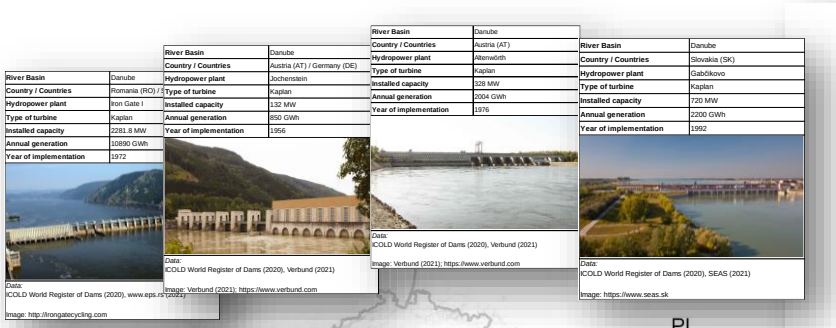


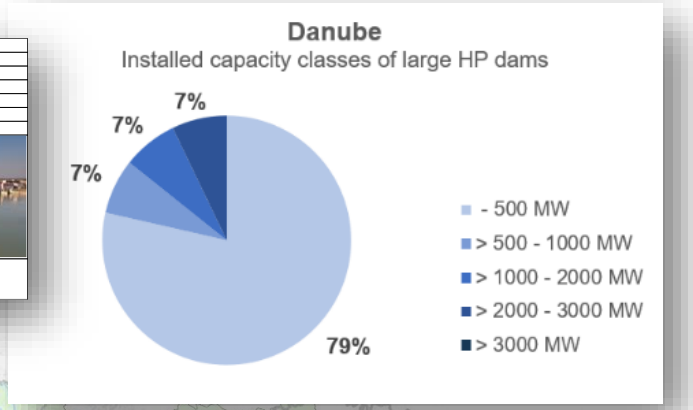
	DE	AT	SK	HU	HR	RS	BG	RO
active FP [ha]	37 282	41 476	8 928	59 500	29 430	33 106	10 135	383 396
potential FP [ha]	3 893	4 479	0	2 773	9	22 112	22 157	83 429
former FP [ha]	0	54 992	218 003	411 520	31 089	338 048	87 305	1 205 5

Area analysis of active, potential and former floodplains along Danube River. Data: Danube Floodplain (in prep.).

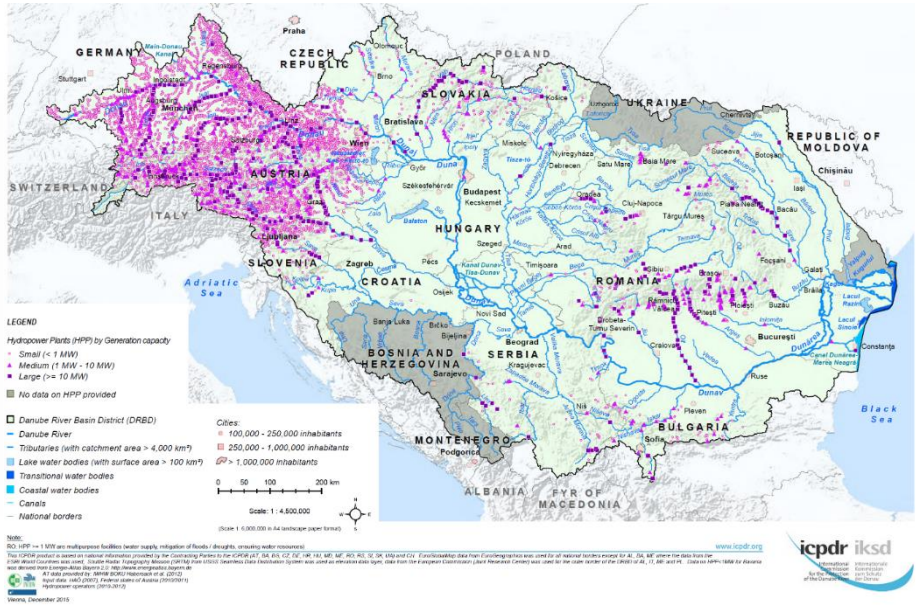
River Management & Socioeconomics

Hydropower: Current status





Data: several data bases (ICOLD, 2021, websites of dam operators), modified



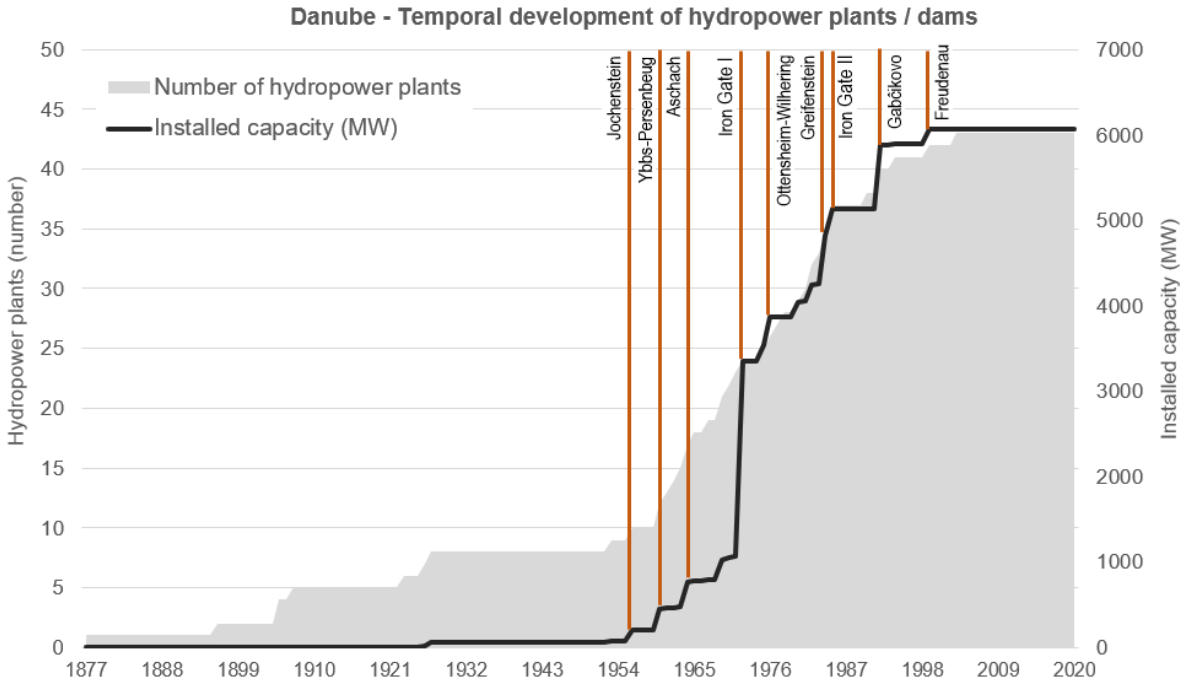
Source: ICPDR (2015a)

Country		Installed hydropower capacity in 2010	Electricity production from hydropower in 2010	Share of hydropower generation
		in MW	in GWh yr^{-1}	in % of total electricity generation
Austria	AT	12,469 (2008)	37,958 (2008)	56.8
Bosnia and Herzegovina	BA	90 (201)	1,667	18
Bulgaria	BG	3,108	5,523	11.9
Croatia	HR	339	1,495	31.8
Czech Republic	CZ	2,203	2,790	3.2
Germany	DE	4,050 (2009)	19,059 (2009)	3.3
Hungary	HU	57.7 (2012)	213 (2013)	0.7 (2013)
Moldova	MD	none	n/a (79.1 including pumped storage)	none (6% if pumped storage is included)
Montenegro	ME	n/a	n/a	n/a
Romania	RO	6,453	19,857.2	33.2
Serbia	RS	2,859 (2009)	10,636 (2009)	24.2
Slovak Republic	SK	2,515 (2012)	5,125 (2013)	18.4 (2013)
Slovenia	SI	1,188 (2011)	4,198	29.6
Ukraine	UA	36.2	0.16	n/a

Source: ICPDR (2015a), modified

River Management & Socioeconomics

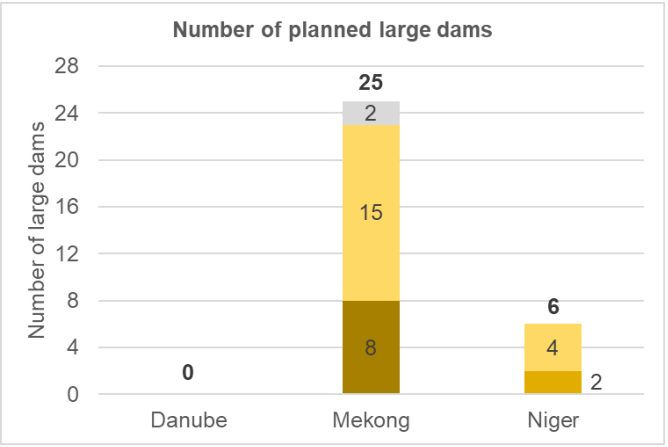
Hydropower: Temporal development

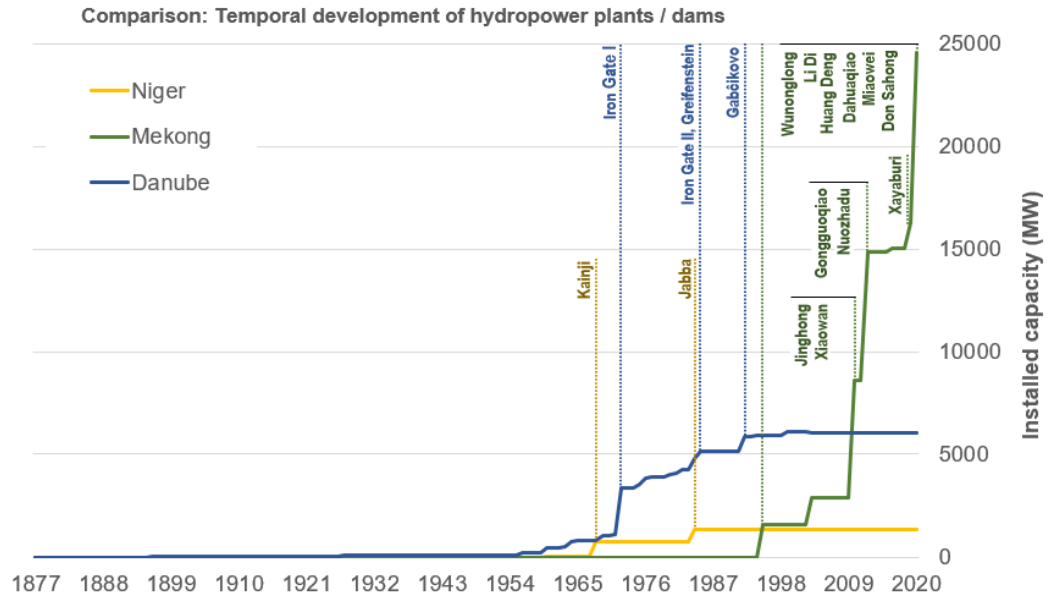


Data: several data bases (ICOLD, 2021, websites of dam operators), modified

- Danube HP development is **shaped by intense development activities in the past**
- **Current HP activities** are mainly addressing **efficiency improvements** and **expansions** of existing facilities (e.g. turbine replacement Ybbs-Persenbeug)

Excursion:
Comparison with other Large Rivers

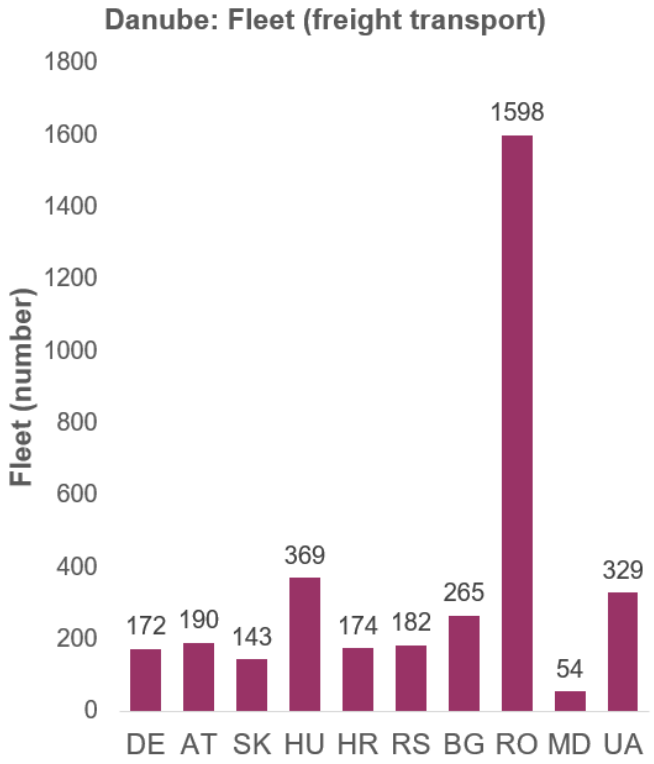


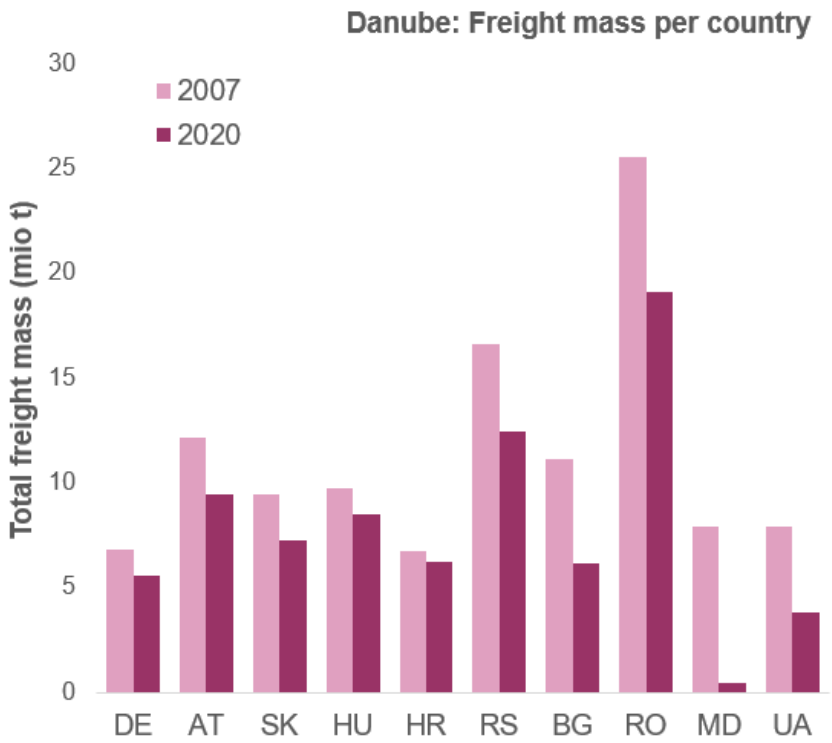


Sources: ICOLD, reports, websites of dam operators

River Management & Socioeconomics

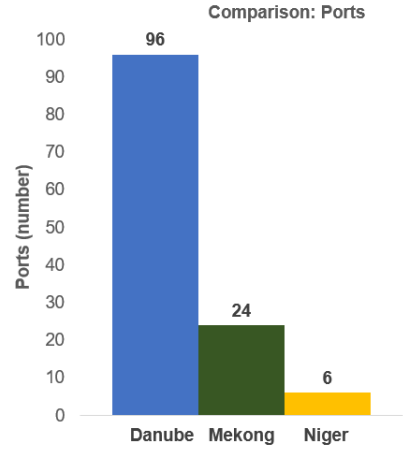
Navigation

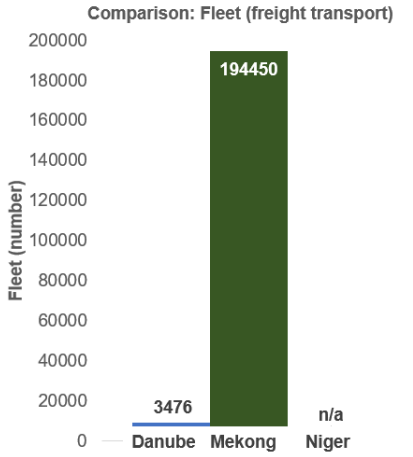


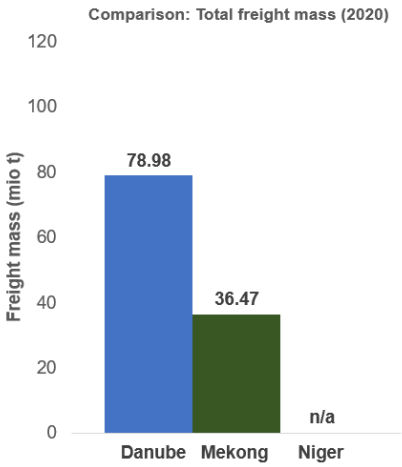


Data: Danube Commission (2018), viadonau (2008, 2018)

Excursion:
Comparison with other Large Rivers







Current status in education and training of engineers

- **Long tradition in hydraulic engineering** → strong practical experience given
- **Solid knowledge given** → available engineering measures
- **Lots of empirical formulas available, derived from small scale flume experiments** → deviation from natural processes
- **Frequently subject based education and training (focus on single themes)** → integration is not always given
- **Not always access to modern lab equipment, numerical modelling, field monitoring methods**

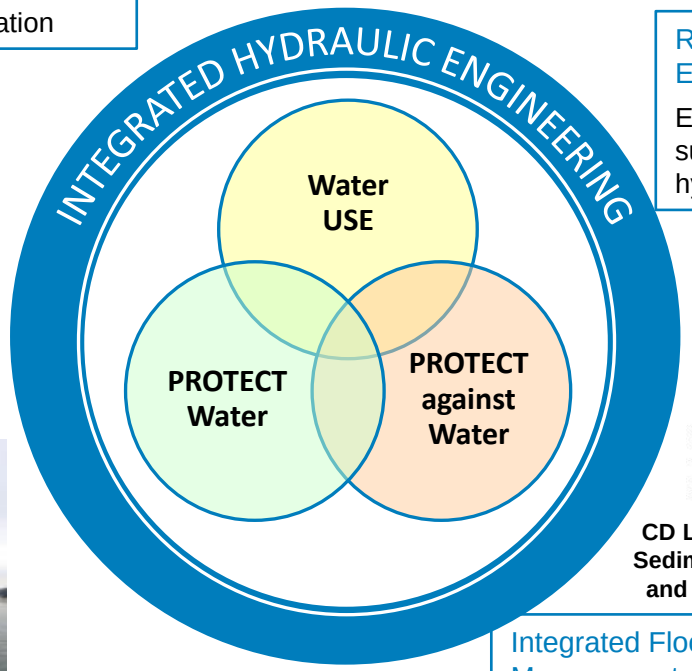
Research THEMES

Transport

Infrastructure in the area of inland navigation

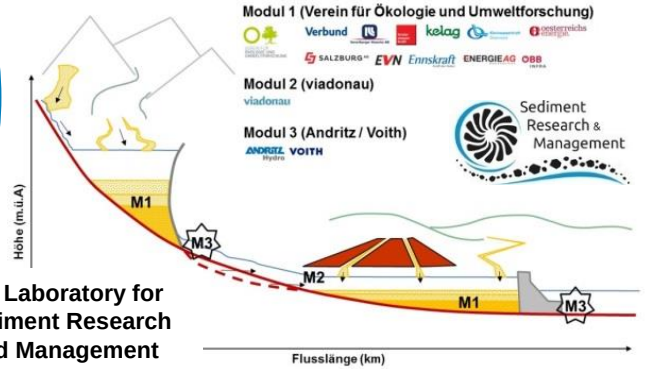
Renewable Energy

Especially sustainable hydropower



River engineering

With a focus on sediment regime and river morphology



CD Laboratory for Sediment Research and Management

River research

Basic research concerning transport of water and sediments (incl. plastics), for ecology and anthropogenic use of river management (measures)

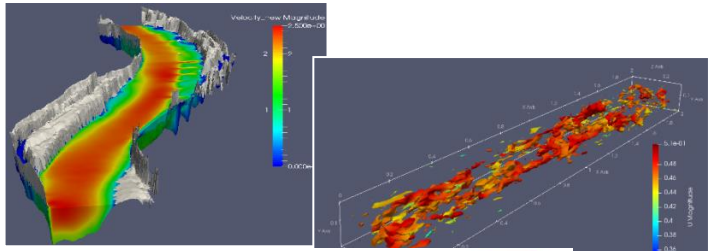
Ecohydraulics

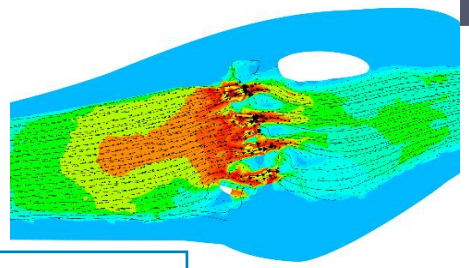
and ecosystem services

Integrated Floodrisk Management

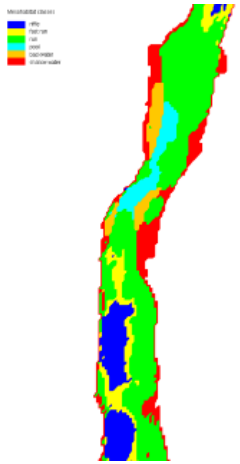
From awareness, floodplain management to dams and mobile flood protection

Research METHODS





Numerical modelling of hydrodynamics, sediment transport, morphodynamics and habitat

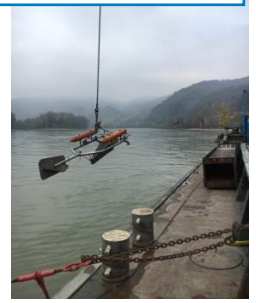


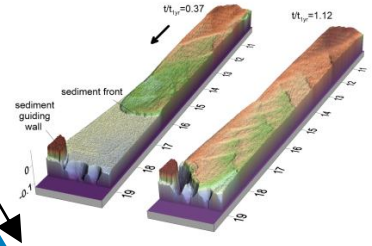
Theory

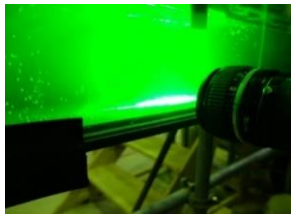
Numerical modelling

In situ measurements, monitoring

Field monitoring



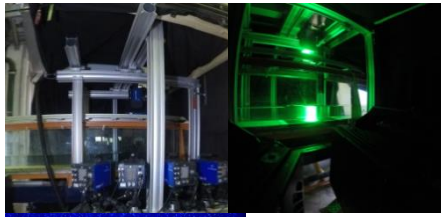


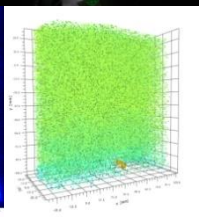


New Hydraulic Engineering Laboratory

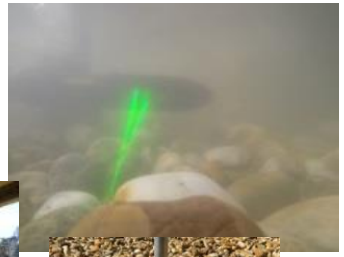
Hybrid Modelling

Physical modelling





Empirical research

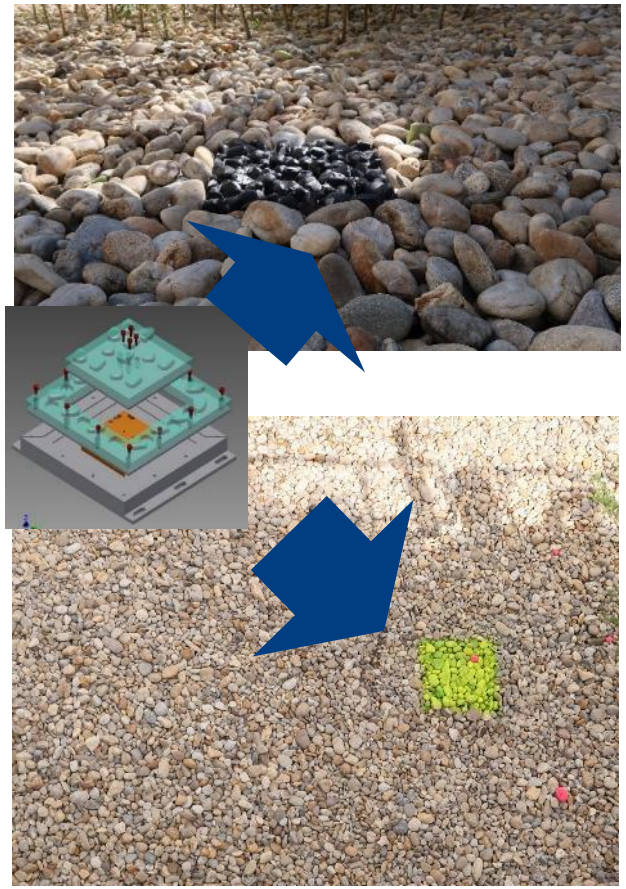


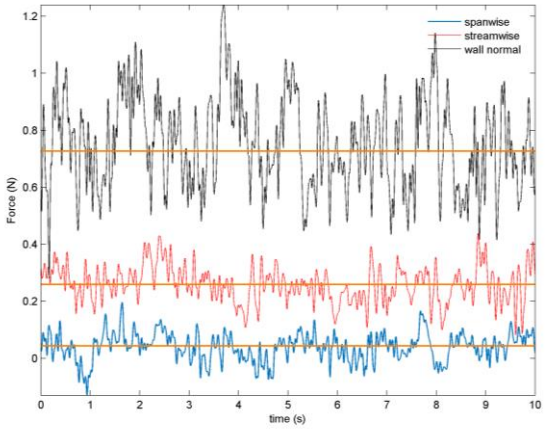
Physical modelling
From small to 1:1 scale; hybrid modelling, research channel, new BOKU Hydraulic Engineering Laboratory

Education and training THEMES

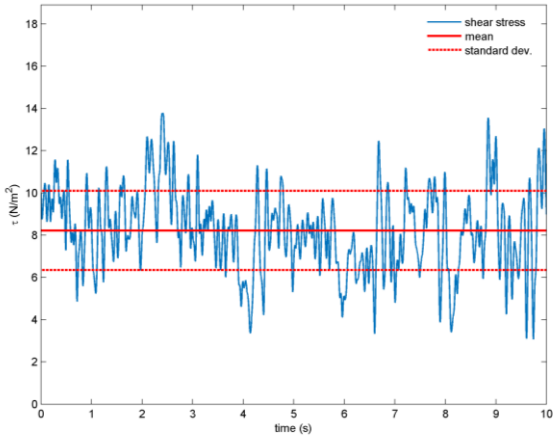
- **River research**: fundamental research including water and sediments (also plastic), interacting with the ecosystem
- **Hydraulic and river engineering**: with an emphasis on sediment management, river morphology and river restoration
- **Sustainable hydropower:** renewable energy and new technologies
- **Integrated flood risk management:** from dams to mobile flood protection
- **Sustainable waterway infrastructure for inland navigation:** from fixed groynes to flexible waterway infrastructure
- **Fundamental and applied hydraulic research, ecohydraulics:** river research and management

Monitoring → Shear stress

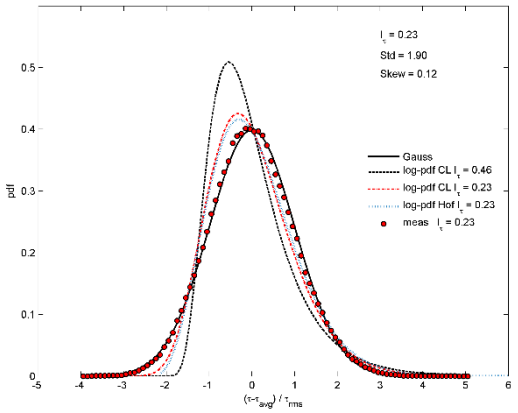


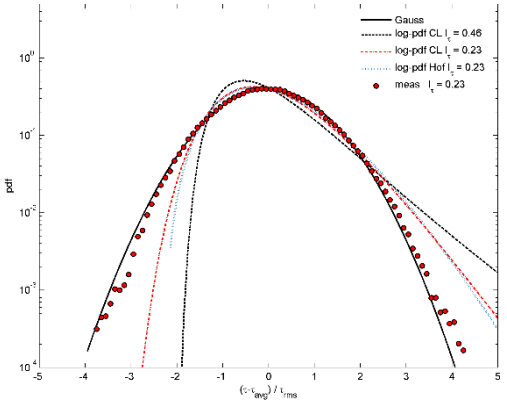


➢ Forces 3D



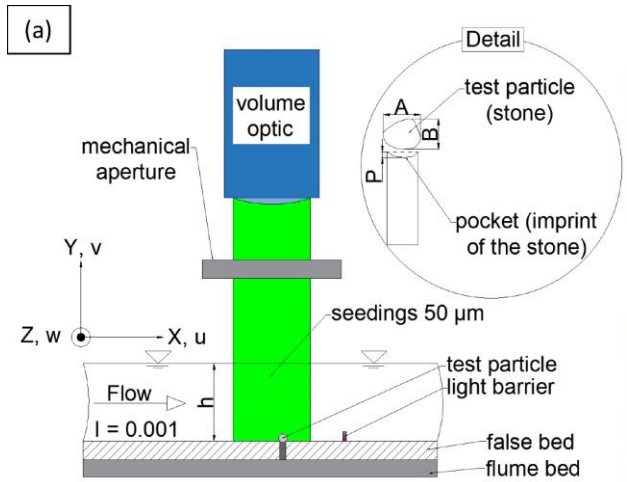
➢ Shear stress, mean value and standard deviation

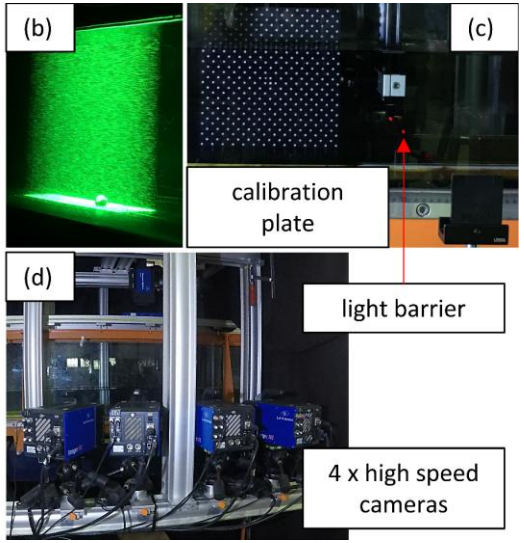


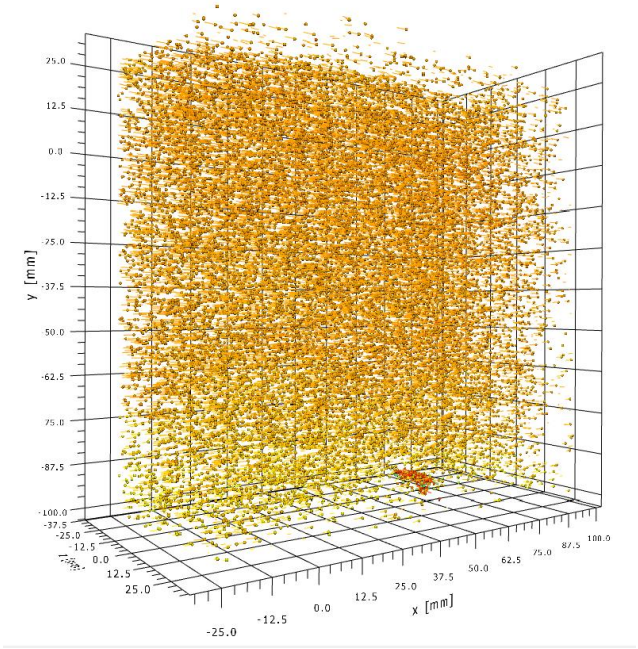


Gmeiner et al., 2019

Physical model – sediment transport



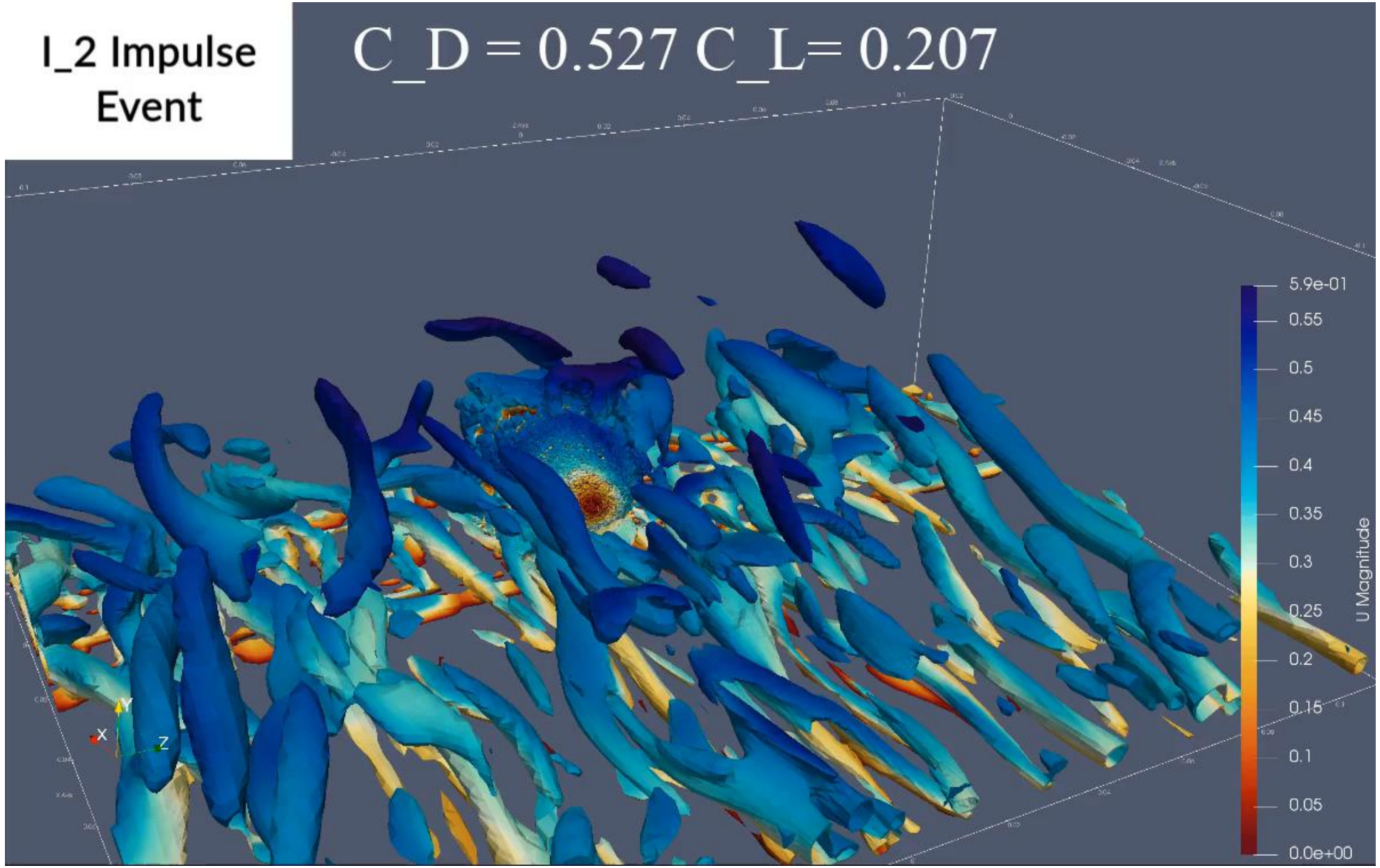




Tomographic Particle Tracking Velocimetry (Tomo-PTV) and the "**Shake the Box**"

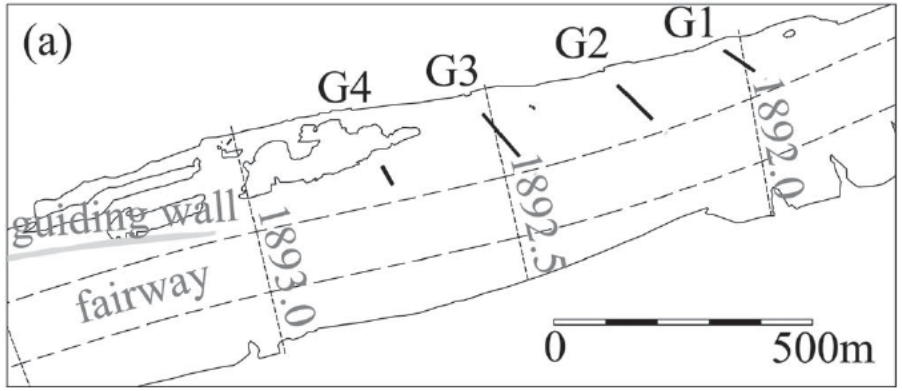
Sindelar et al., 2022, Schobesberger et al., 2021

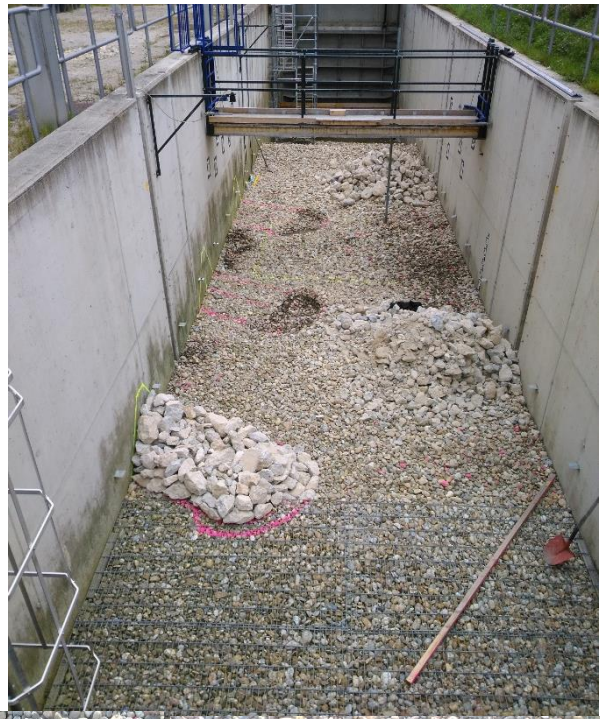
Numerical modeling

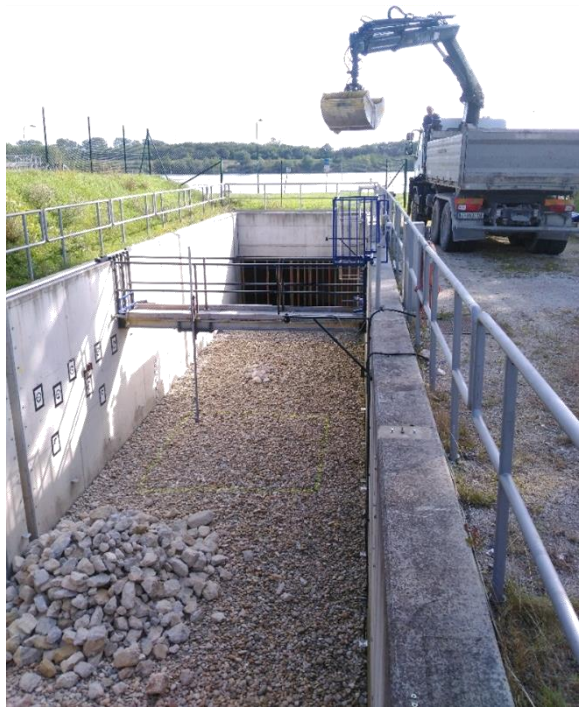


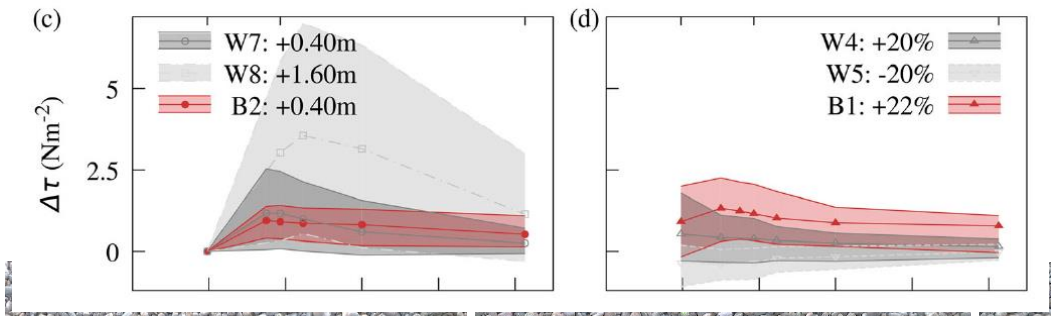
Yücesan et al, 2021

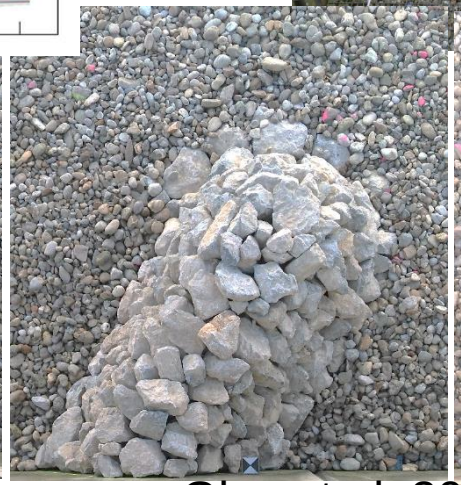
1:1 scale and numerical groyne modeling

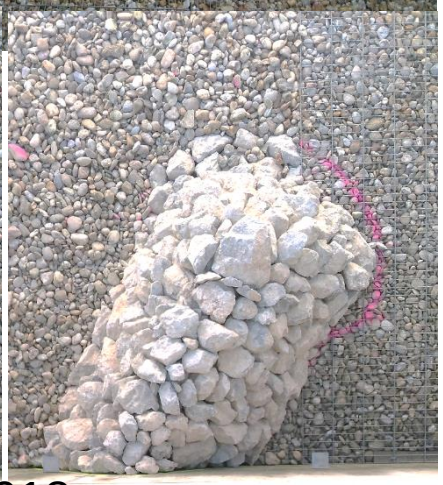












Glas et al, 2018

Conclusions

- Significant changes occur at the Danube and other rivers
- Diverging interests are given, modern engineering tries to find integrated solutions
- New approaches are needed and should be used in education concerning monitoring, physical and numerical modelling
- Research and teaching infrastructure must be updated
- Skills in engineering, natural sciences and socioeconomics are important
- Maybe a Danube wide initiative to improve the education and training of engineers might be important → eventually use the Danube Strategy Flagship Project DREAM (Danube River Research and Management) and DANUBE4all Horizon Europe Mission Project (start 1.1.2023)

Thanks for your attention!

University of Natural Resources and Life Sciences

Department of Water, Atmosphere and Environment
Institute of Hydraulic Engineering and River Research
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