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Institut für
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Evaluation of vertical connectivity in regulated river reaches using a multiparametric measuring approach

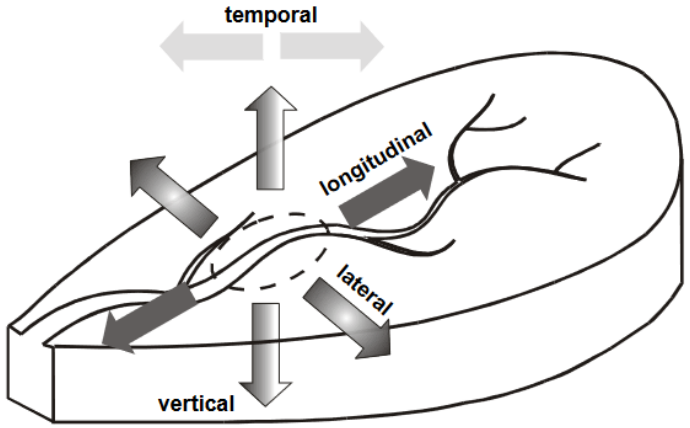
Prof. Dr.-Ing. Markus Noack

Source: Noack 2021

Background and Motivation

Vertical Connectivity and Riverbed Clogging

→ “Four-Dimensional Nature of Lotic Ecosystems” (Ward, 1989)



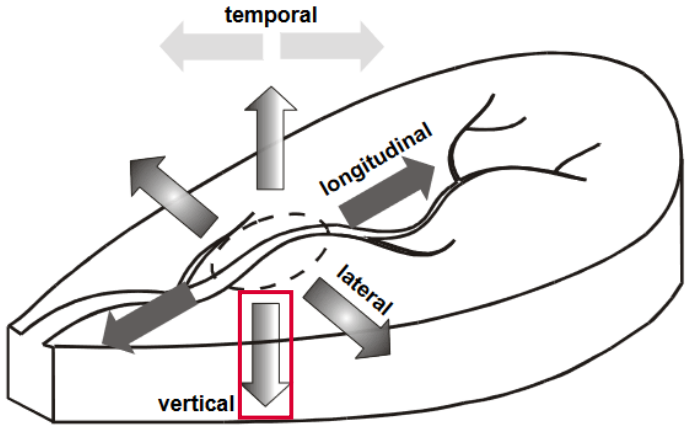
Source: Sieptel & Verdonschot, 2010

- Longitudinal (up- to downstream interactions)
- Lateral (channel-riparian interaction)
- Vertical (channel – aquifer interactions)
- Temporal (impact on natural flow)

Background and Motivation

Vertical Connectivity and Riverbed Clogging

→ “Mapping the world’s free-flowing rivers” (Nature, Vol. 569 → Grill et al. 2019)



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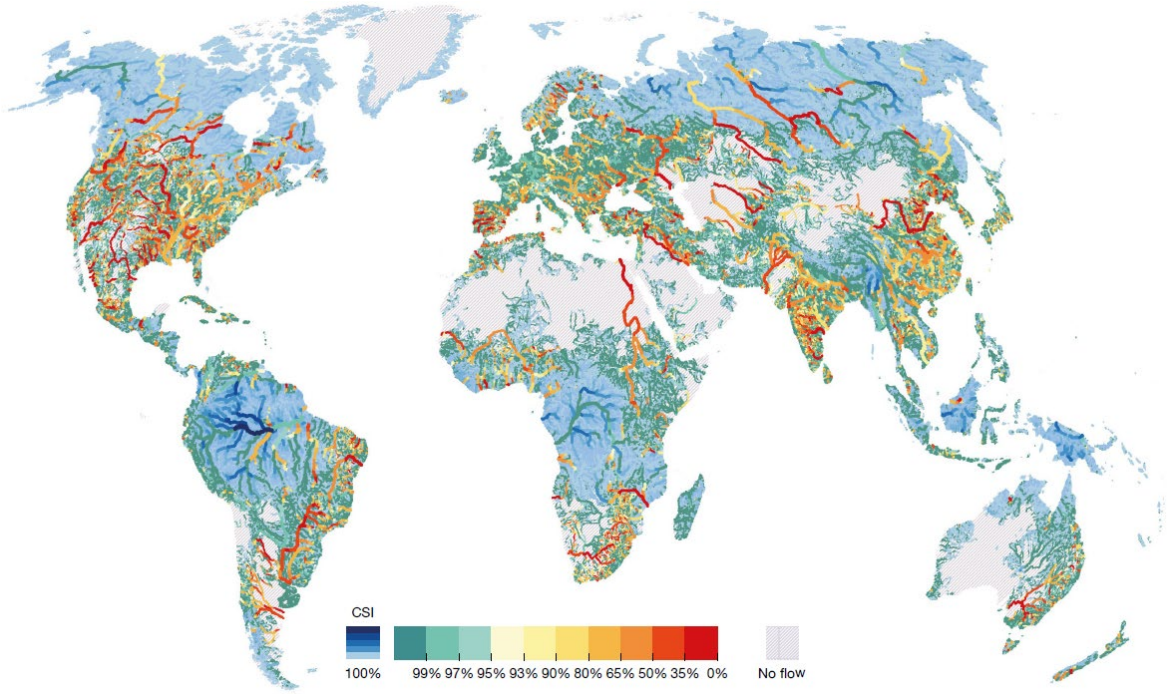


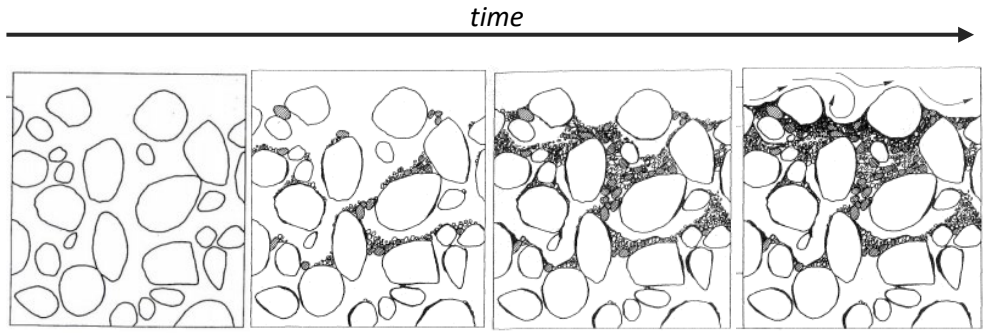
Source: Grill et al. 2019

CSI = Connectivity Status Index
100% = Natural Connectivity

Background and Motivation

Vertical Connectivity and Riverbed Clogging

→ infiltration und accumulation of inorganic and organic fine sediment in the interstitials of graver riverbeds



Infiltration and accumulation of fine sediments (Schälchli 1993)

Riverbed without clogging (Noack, 2021)

Clogged Riverbed (Noack, 2021)

Abiotic Impact: reduction of pore volume, hydraulic conductivity, dissolved oxygen

Biotic Impact: degradation on interstitial habitats (macroinvertebrates, reproduction of gravel spawning fish)

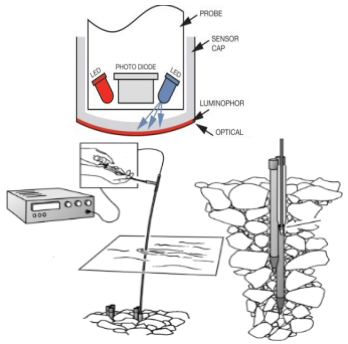
Material and Methods

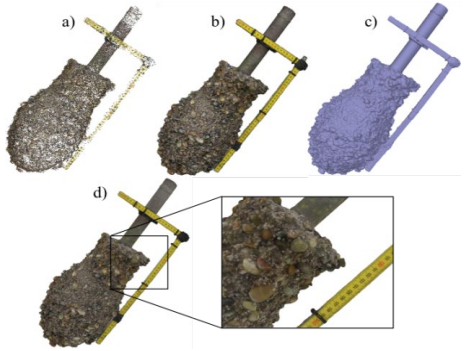
MultiPAC – multiparameter approach for riverbed clogging

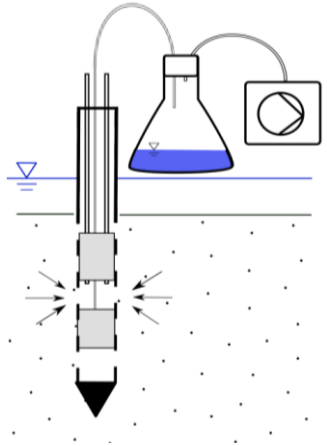
→ quantitative and physical-based approach to assess clogging in the field (PhD of L. Seitz, 2020)

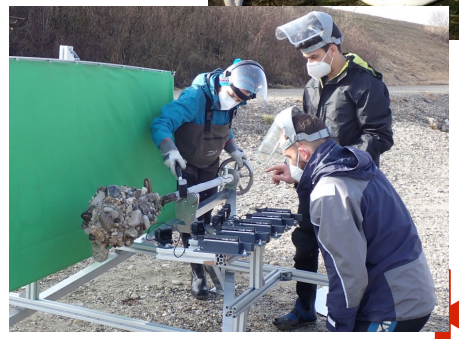
Particle size distribution	Dissolved Oxygen Content (DOC)	Porosity	Hydraulic Conductivity
↓	↓	↓	↓
Freezecores / Freezplates	Optodes	Photogrammetry Structure from Motion	Slurping

Source: Seitz(2020)









Material and Methods

Study Site - River Inn, Germany

→ **Chain of run-of-river plants**

Source: Verbund Innkraftwerke GmbH 2018

Characteristics of River Inn:

Hydropower:
- 21 Hydropower Plants (Austria, Germany)
- Installed Power: 865 MW

Hydrology:
- MQ (summer):Q=966 m³/s
- MQ (winter): Q=512 m³/s
- MHQ: Q=3000m³/s

Morphology:
- glacier-fed river
- high amounts of moveable fine sediments
- “no” bed load transport

Material and Methods

Near-natural Bypass Channels and Artificial Flushings

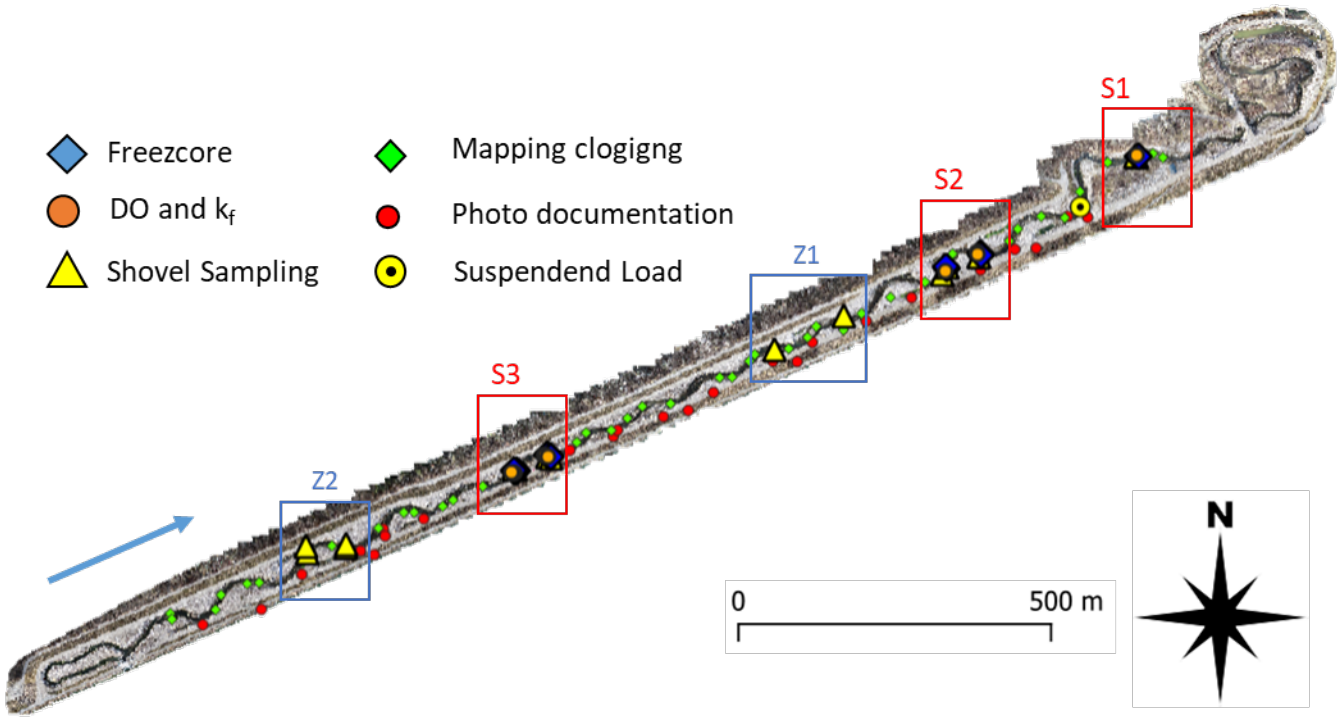
→ **longitudinal** connectivity but also **vertical** connectivity by artificial flushing

Source: Verbund Innkraftwerke GmbH 2018

Exemplary Results – Effect of Artificial Flushing

Hydropower Plant: HPP Ering-Frauenstein, River Inn

→ **near-natural bypass, length = 2600 m, width = 10m, no bank fixation, bankfull discharge Q=12m³/s**

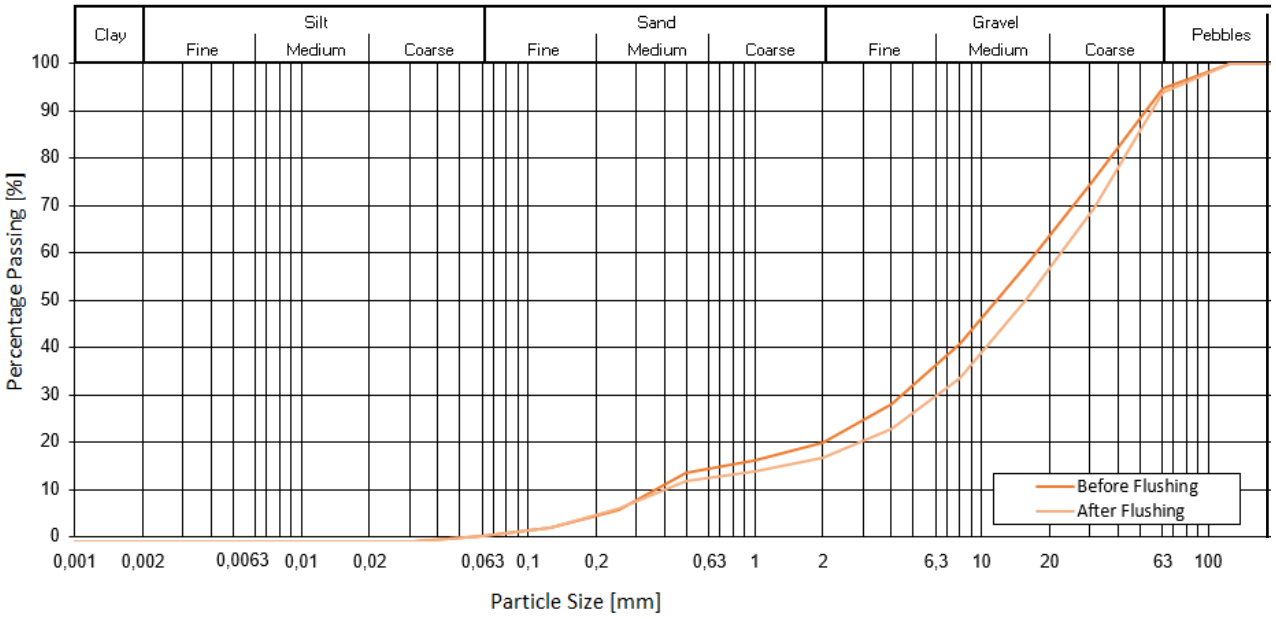


Exemplary Results – Effect of Artificial Flushing

Hydropower Plant: HPP Ering-Frauenstein, River Inn - Sediment Sampling

→ particle size analysis, fine sediment contents, porosity

→ “bulk sampling” → sediment depth (0-50cm)



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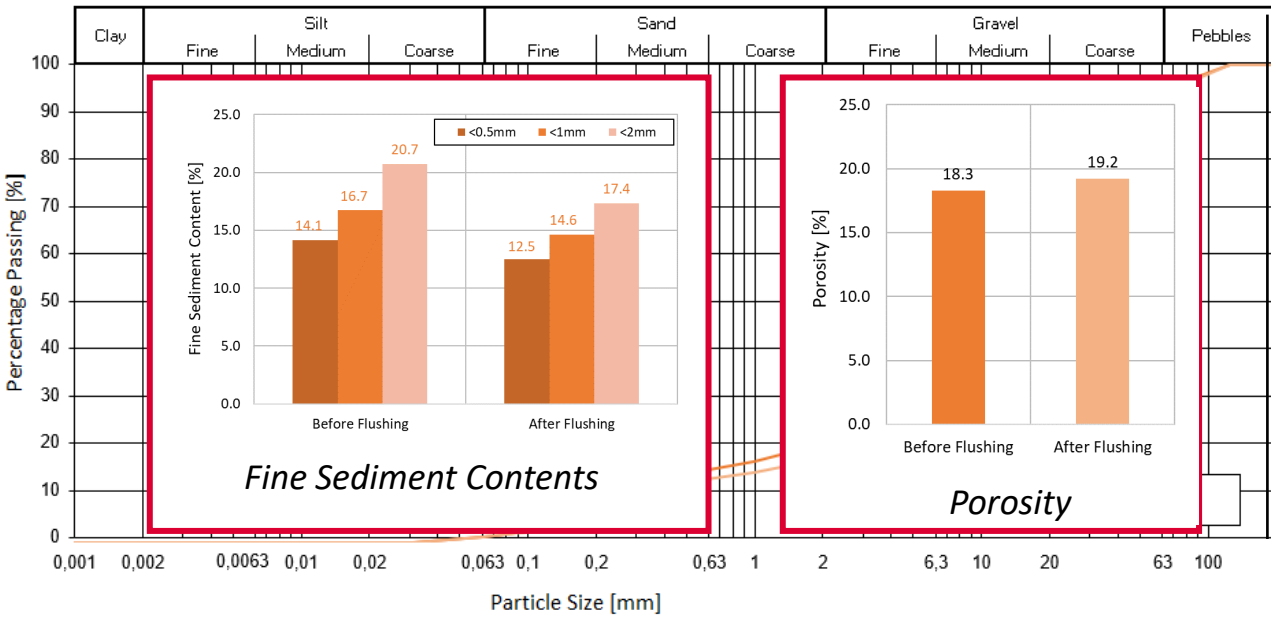
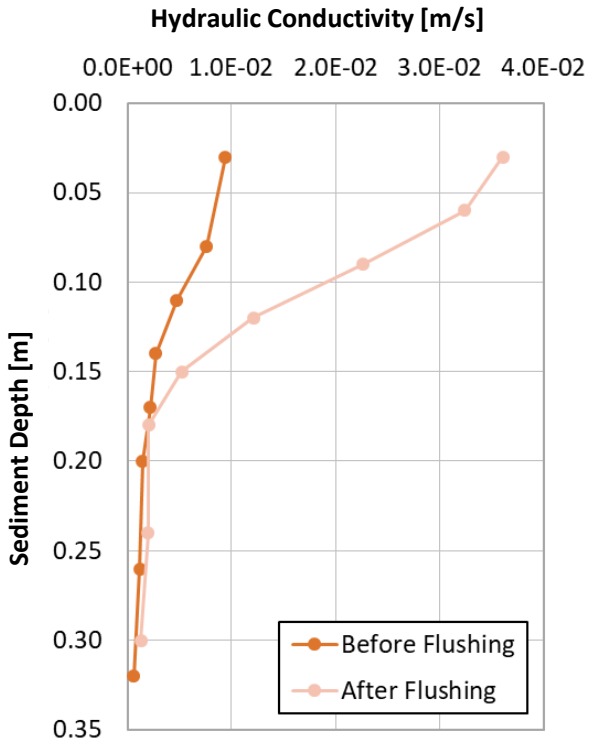


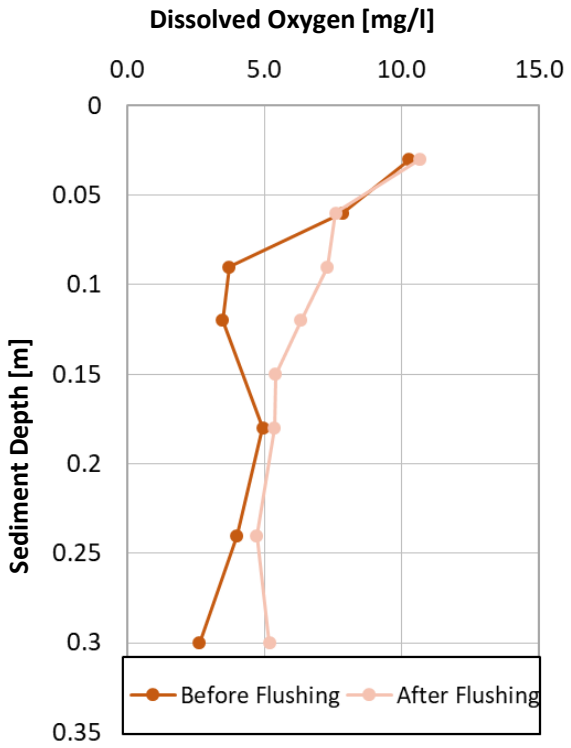
→ all indicators of particle size analysis indicate a coarsening of the riverbed due to the artificial flushing

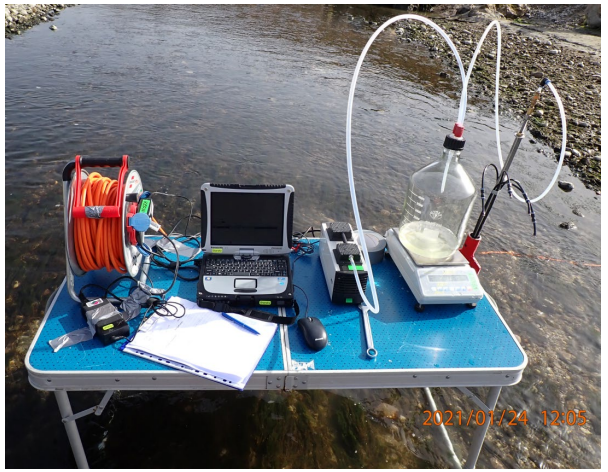
Exemplary Results – Effect of Artificial Flushing

Hydropower Plant: HPP Ering-Frauenstein - Hydraulic Conductivity and Dissolved Oxygen

→ vertical profiles with a spatial resolution of 3.0cm (0-45cm)







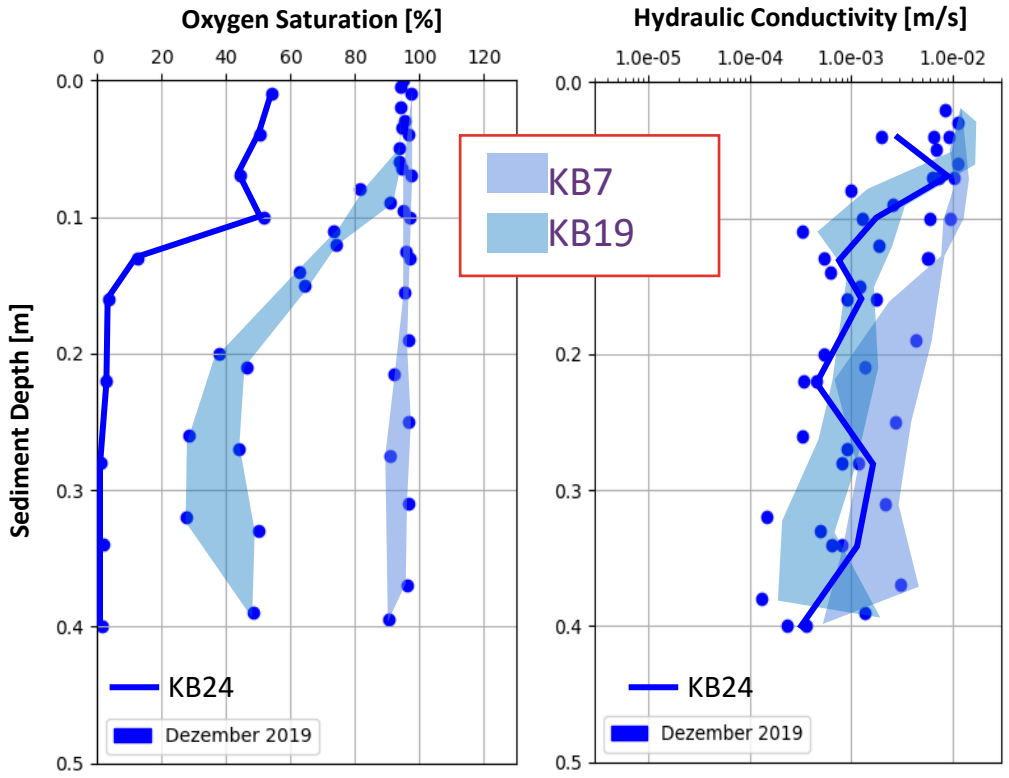
increasing values for approx. the the upper 15 cm of the riverbed

→ identification of the depth impact of artificial flushing in terms of de-clogging

Exemplary Results – Residual River Reach

Hydropower Plant: Töging, River Inn – Dissolved oxygen and hydraulic conductivity

→ vertical profiles of dissolved oxygen contents and hydraulic conductivity in a residual river reach



Gravel Bar: KB7

Gravel Bar: KB24

Gravel Bar: KB19

different gradients over depth for dissolved oxygen but similar gradients for the hydraulic conductivity

→ maybe higher hyporheic respiration processes at gravel bar KB24?

Evaluation of Riverbed Clogging and Vertical Connectivity

How to evaluate these results in terms of clogging or vertical connectivity?

→ Need of Reference Values!

German Federal Environmental Foundation
(Funding: AZ 37315)

<u>Rivertype-specific evaluation concept:</u>

→ Type 5: silicate-based coarse-grained rivers (7 rivers, 3 measuring campaigns from 2021-2022)

- no “organic” impact (inlets of WTP)
- sites of WFD-measurements
- deviation of reference values
- catchment characteristics
- temporal aspects

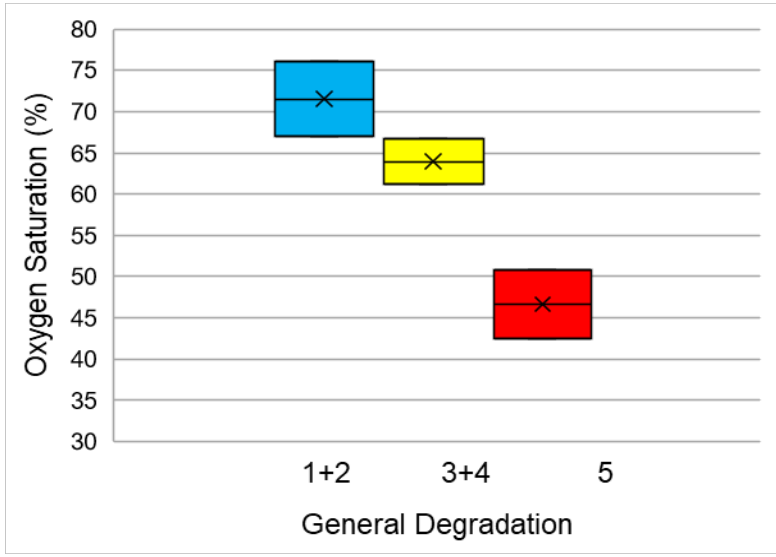
Rivers	Auersbach	Riveris	Prims	Steinalp	Obere Wied	Östelbach	Oberer Gelbach
ecological status	2	2	2	2	3	4	4
general degradation	1	1	1	2	3	4	5
	GD1 + GD2				GD3 + GD4		GD5

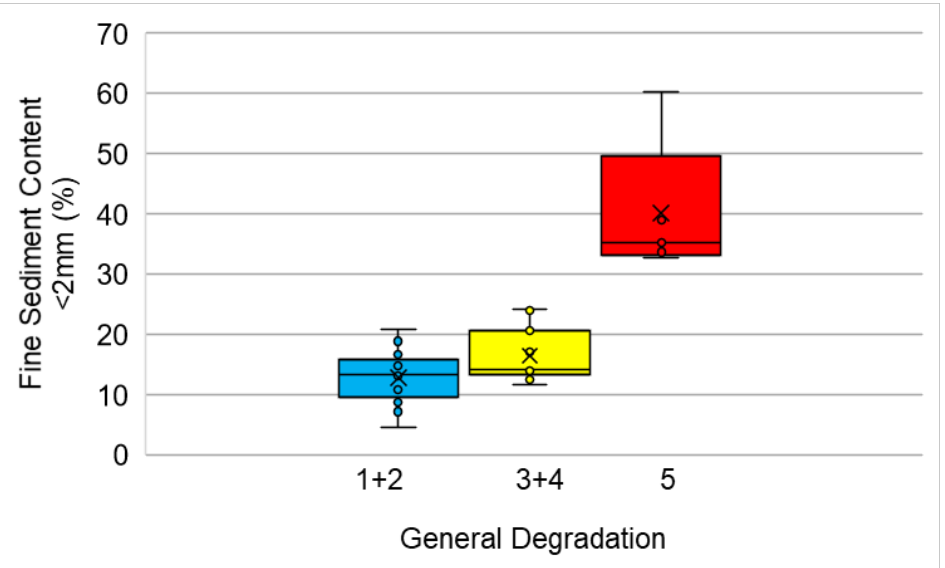
→ (multivariate) statistics to find functional relationships, correlations

Preliminary Results – Reference Values and Correlations

How to evaluate these results in terms of clogging or vertical connectivity?

→ identification of **reference values** and correlations based on three measuring campaigns in seven rivers





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visible/detectable differences between abiotic parameters of MultiPAC and WFD

Preliminary Results – Reference Values and Correlations

How to evaluate these results in terms of clogging or vertical connectivity?

→ identification of reference values and **correlations** based on three measuring campaigns in seven rivers

		Water Framework Directive					
		Ecological Status	General Degradation	Saprobity	Macroinverte-brates	Fish	Morphology
MultiPAC	FSA>0.5mm	0.62	0.65	0.60	0.64	0.37	0.09
	FSA>1.0mm	0.62	0.64	0.58	0.66	0.35	0.09
	FSA>2.0mm	0.64	0.63	0.60	0.69	0.31	0.07
	Porosity	0.07	0.13	0.08	0.10	-0.31	0.87
	Oxygen	-0.45	-0.41	-0.45	-0.44	0.04	0.01
	hydraulic conductivity	-0.02	0.03	0.03	-0.02	-0.16	0.08
	sorting coefficient	0.52	0.42	0.49	0.40	0.16	0.41
	$б_{geo}$	0.20	0.07	0.21	0.08	0.20	0.14

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Summary, Conclusions and Outlook

Key Messages to take home…

- MultiPAC allows for…
  - physically-based and objective multiparametric analysis of the phenomenon clogging using particle size analysis, porosity, dissolved oxygen and hydraulic conductivity
  - dissolved oxygen and hydraulic conductivity are assessed along a vertical profile
    → identification of locations of clogging
  - particle size analysis and porosity result from bulk sampling (freezecores) over a sediment depth of approx. 50cm
    → challenges in comparing to values of vertical profiles

- Current Research DBU
  - What are physically-based reference values of a healthy unclogged riverbed?
    → derive river-type specific reference values for unclogged rivers
    → derive functional relationships between MultiPAC and catchment characteristics, WFD evaluation and meiofauna
    → assessing temporal aspects for a process-based consideration of riverbed clogging

unique database for the development of a multivariate evaluation scheme for riverbed clogging

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