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A novel multi-parameter approach to assess the effects of river restoration measures on the sediment matrix

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Clogging of riverbeds, also referred to colmation, has been frequently reported in residual flow river reaches. In such river reaches, colmation occurs mostly due to regulated (minimum) flow conditions without significant flood events that drive morphodynamics. Consequently, incoming fine sediments continuously deposit, infiltrate, and accumulate in the gravel matrix of the riverbed. The negative effect of such clogged layers on river ecology is well-known, especially with respect to the hyporheic interstitial leading to reduced porosity and hydraulic conductivity. These limitations results in a reduced supply of dissolved oxygen for aquatic species living in the hyporheic interstitial. However, no standardized quantitative measuring technique exists to determine the vertical location and the degree of colmation. Most available measuring methods involve a variety of mapping methods or single-parameter approaches. While mapping methods enable only qualitative assessments, single-parameter approaches are insufficient to describe the complexity of colmation.

The objective of this study is to test a novel multi-parameter approach in a residual flow river reach to assess the effect of river restoration measures on colmation. The multi-parameter approach includes four key parameters to describe colmation: i) the grain size distribution of the riverbed using freeze core sampling and sieving, ii) the hydraulic conductivity using a newly developed double packer system, iii) the porosity identified with a photogrammetric approach, and iv) the interstitial dissolved oxygen content (DOC) using optodes. This novel approach enables a quantitative description of colmation and an identification of clogged layers in stratified riverbeds as the hydraulic conductivity and the DOC are measured in vertical profiles. The entire measuring concept is applied before and after the implementation of river restoration measures to detect the intervention's effects on colmation.

The first analyses of the measurement show clearly the effects of dredging with an artificial alteration of the riverbed on the sediment matrix. The vertical profiles of hydraulic conductivity and dissolved oxygen show typically high values in the permeable upper sediment layer and significant reductions in deeper sediment layers. The thickness range of the permeable upper layer is between 5 and 15 cm before the intervention and increased up to 30 and 50 cm after the interventions. The analyses of a coarsened grain size distribution and porosity support the

observation of this declogging effect, although a direct correlation is challenging because both parameters are not detected in the form of vertical profiles, but rather as a bulk information for every measurement point.

These very first results provide the conclusion that the measured vertical profiles of hydraulic conductivity and DOC are promising data to assess the location and degree of colmation and their modification as a result of river restoration action. Yet, grain size and porosity analyses provide only little evidence because those represent bulk information only. In summary, the multi-parameter approach represents an innovative and quantitative approach to objectively assess the degree and vertical location of clogged layers in gravel riverbed, which is a major advantage over existing methods for assessing colmation.