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Hydrogeophysical investigations of three-dimensional lithology and river-groundwater interactions in restored and unrestored river corridors

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The hyporheic zone is a key interface for many biochemical and hydrological processes in a watershed. We report on hydrogeophysical studies that have been carried out at the River Thur and its immediate vicinity in Switzerland, where a large multi-disciplinary research team (RECORD) seeks to increase the mechanistic understanding of coupled hydrological and ecological processes in near-river corridors. Hydrogeophysics in naturally dynamic systems is challenging, but a key advantage is that natural forcing by river flood events can help to investigate hydrogeological transport properties. Our work focuses on two study areas. The first is underlain by a gravel aquifer in direct contact with an unrestored section of the river where 18 boreholes and 180 electrodes have been installed. An autonomous electrical resistance tomography (ERT) system continuously track temporal changes in the electrical resistivity structure associated with changing hydrological state variables (temperature, pressure, salinity) during flood events. The ERT data are first corrected for water-table variations and temperature to construct a data set that is only sensitive to temporal variations in the electrical conductivity of the pore water (i.e., salinity). This corrected data set correlates well with point-measurement time-series of temperature-corrected electrical conductivity data of the groundwater and it will be used in future 3D time-lapse inversions. A sub-region between four boreholes is also being extensively studied via 3D joint inversions of three different geophysical data types (ERT, and seismic and georadar traveltimes) that allow us to resolve three different lithological zones of the gravel aquifer. The second site is a gravel bar located in a restored section of the river where surface-based geophysics has been carried out. At this site, a high-resolution 3D ERT and ground-penetrating radar (GPR) model shows the major lithological units of the river sediments and overall changes in the electrical formation factor. The construction of the ERT model is considerably improved by using the GPR model to define a prior model of regions where zone boundaries are expected to be strong and where regularization can be decoupled in the ERT inversion. Several months of self-potential monitoring data have also been acquired at this site to track changes in the piezometric head. It has been found that changes as small as a few cm can be reliably detected. Future work at this site will include tracer experiments, as well as hydrological modeling of the gravel bar constrained by our geophysical models and monitoring data.