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Combining 3-D GPR and ERT surface data for aquifer characterization at a restored river section

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The hydrological, ecological and biochemical effects of river restoration at the River Thur in northern Switzerland are being investigated by a multidisciplinary research team. Our particular contribution involves combining 3-D ground-penetrating radar (GPR) and 3-D electrical resistivity tomography (ERT) measurements made on an exposed gravel bar located in an active part of the riverbed. The principal goals are to image aquifer structure and improve our understanding of fluid flow and river water – groundwater interactions. The surface-based geophysical data provide comprehensive volumetric coverage over an area where frequent flooding precludes extensive deployment of permanent borehole installations. The electrical resistivity distribution in the subsurface is closely related to hydrologically important properties such as porosity and amount of fines. On the other hand, models from ERT inversions have inherently low spatial resolution. In particular, deep features and sharp interfaces are poorly resolved. By including structural information provided by GPR images in the ERT inversions, this deficiency can be partially overcome. GPR data were recorded on a dense grid (i.e., 0.5 m line spacing) covering the entire 240 m x 40 m gravel bar. The processed GPR data reveal typical features of braided river systems such as foresets and a paleo-channel that matches the position of a side-channel in an 1811 map. Picked horizons from the migrated GPR image are used to constrain 3-D inversions of the ERT data acquired over roughly the same area. A novel inversion scheme allows us to invert for the electrical resistivity distribution within distinct zones (e.g., 1: vadose zone, 2-3: sub-regions of the gravel aquifer, 4: basal clay aquitard) using different regularization parameters for each zone and no regularization across zone boundaries. The GPR-determined interfaces help to provide a better constrained ERT model, which is otherwise dominated by artificially smooth layer boundaries where strong resistivity contrasts are known to exist. The combined interpretation of the GPR and ERT models enables us to identify lithological features that are likely to control the groundwater flow regimes and to draw primary conclusions about hydraulic conductivity variations. The resulting models are used together with hydrological logging data to improve our knowledge of river water – groundwater dynamics at the restored river section. A conductive tracer experiment and subsequent time-lapse ERT measurements and associated inversions will be used to assess the validity of this characterization approach.