Geophysical Research Abstracts,
Vol. 11, EGU2009-2303, 2009
EGU General Assembly 2009

Joint Inversion Improves Zonation for Aquifer Characterization

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A multidisciplinary research team is currently investigating the hydrological, ecological and biochemical effects of river restoration using field-based studies at the Thur River in northern Switzerland. We describe the results of a hydrogeophysical pilot study of a producing gravel aquifer in the vicinity of an unrestored section of the river. Our objectives are to estimate the spatial variability of hydrogeological and geophysical properties of the river sediments and to derive a three-dimensional zoned representation of the subsurface. The 7 m thick gravel aquifer is being examined through four 11.4 cm fully-slotted PVC-cased boreholes located at the corners of a 5 x 5 m square approximately 10 m from the river. Seismic, radar and electrical resistivity data were acquired between all boreholes. These data were jointly inverted in three dimensions using a non-linear Occam's-type inversion that uses stochastic regularization operators and either least-squares (L2) or robust (L1) model and data norms. Coupling of the inversions was achieved by employing cross-gradient constraints that enforce structural similarity between the three models. The resulting velocity and resistivity models were combined in a zonation algorithm that models Gaussian mixtures and performs maximum likelihood classification to produce zones of similar petrophysical characteristics. This zoned representation of the subsurface was tested by inverting for three uniform parameters (seismic and radar velocities and resistivity) within each zone and by comparing the resulting data misfit with those of the joint inversions. We find that joint inversion makes velocity and resistivity models significantly more consistent and reduces inversion artifacts. The improvements compared with individual inversions are even more pronounced when the resulting models are used in an appropriate zonation algorithm to identify lithological units. Hydrological monitoring and testing will be used to assess to what extent the identified lithological zones control groundwater flow and transport.