Electrical Resistivity Imaging for Studying Dynamics of Vadose Zone Processes

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Determining the spatial distribution of subsurface hydrologic properties is critical to developing efficient groundwater management strategies. Electrical resistivity imaging (ERI) provides continuous maps of the subsurface electrical conductivity, which can be related to water content, making it particularly useful to groundwater studies. We present an application of ERI to monitoring infiltration in the top 20 m of the subsurface at the Harkins Slough Recharge Pond, located in an agricultural region on the northern California coast.

The purpose of the recharge pond is two-fold: to store diverted storm-flow run-off to meet groundwater delivery demands and to replenish underlying aquifers, which have been overdrawn for several decades, allowing saltwater intrusion. Operators of the pond have rights to divert 2.5e6 m^3 of surface water to the pond each year, but decreasing infiltration rates during diversion reduces the operational efficiency, only allowing infiltration of ~1e6 m^3 each year. It is hypothesized that deposition of fine-sediments from diverted water, run-off from adjacent fields, and/or microbial activity reduce the hydraulic conductivity over time by clogging pore spaces. As part of an effort to better understand the hydrologic processes controlling infiltration to improve operational efficiency of the recharge pond we conducted time-lapse ERI experiments to monitor infiltration processes beneath the pond during the winters of 2008-2009 and 2009-2010.

Each year measurements were made using four 3-m long permanent probes installed in the base of the pond in a T-shape configuration, with 20 m between each probe. The probes allow for monitoring of the conductivity profile to a depth of 2 m; the top meter of each probe monitors bulk conductivity of the pond water. In addition, a number of surface electrodes were laid out in lines between the four probes. In 2008-2009, 20-m lines were used. In 2009-2010, three lines of lengths 10 m, 65 m, and 75 m were deployed. Acquisition geometries designed to target different regions of the subsurface were used to acquire measurements every 1.5 hours. In 2008-2009 ~2000 data sets were acquired; each data set included measurements from probes and surface lines. In 2009-2010 ~1000 data sets were acquired.

Data were processed using an extended Kalman filter (EKF) approach. The EKF was chosen for processing time-series ERI data because it models evolution of the physical system and the observation process, incorporating previous information into data-inversion at each time-step. In this application, the first for surface-based ERI field data, we modify the classical Kalman filter cost functional to incorporate spatial smoothing and impose an update constraint to account for slow state evolution with respect to the sampling interval. Results identified more hydrologic complexity than was originally assumed and indicated that processes in the top 0.5 m of the subsurface control infiltration rates. The results of ERI monitoring demonstrate that integrating geophysics into hydrologic studies can provide increased information about spatial and temporal evolution of vadose zone processes.