Time-lapse imaging of river-water intrusion into a contaminated aquifer using time-lapse electrical resistivity tomography

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Cold-war era waste disposal practices resulted in a persistent uranium plume in the groundwater beneath the Hanford 300 Area. Uranium transport in the Hanford 300 area is driven by both the chemical and physical effects of stage fluctuations in the adjacent Columbia River and resulting river water, ground water interactions. Because river water is less conductive than groundwater at this site, it serves as a natural tracer that can be monitored using time-lapse electrical resistivity tomography (ERT). In order to characterize river water intrusion into the 300 Area during spring high stage, we monitored bulk-conductivity variations beneath three 2D surface ERT lines placed at successive distances from the river, approximately parallel to the shore line. These lines overlay former waste disposal sites including processing ponds and sanitary leach trenches. Over the duration of the experiment we acquired approximately three surveys per day, or nearly 400 data sets from each line of electrodes..

Time-lapse inversion of these data revealed two dominant influences on the transient bulk conductivity response; 1) the intrusion of less conductive river water and 2) the rise and fall of the water table. The inversion results were dominated by water table effects when standard regularization constraints were implemented, which encourage a smooth conductivity transition across the water table boundary, obscuring changes caused by river water intrusion. To address this, we inverted the data using a time-varying regularization operator whereby smoothing constraints are relaxed across the water table, allowing a sharp water table boundary in the inverse solutions. Using this approach, transient changes in bulk conductivity revealed a primary region of preferred river water influx thought to be a paleochannel serving as a former secondary flow channel of the Columbia River.

Time-lapse inversion of the entire data set produced a bulk-conductivity time-series for each element in the inversion mesh, providing an extensive amount of information that is difficult to reduce from visual inspection alone. To distill the salient information in the ERT time-series, we investigated a number of time series analysis techniques including continuous wavelet transform (CWT) and principal component analysis (PCA). When applied to the models calculated with standard regularization constraints, the CWT calculated the wavelet coherency shared between an individual model element's conductivity time-series and river stage elevation. PCA separated the time signals into a series of linear components, with the first corresponding to the most highly correlated noise. Both time-series analysis techniques were less useful for identifying regions of resistive water influx than applying time-varying regularization to the inversion process.

Utilizing the river water as a natural tracer allowed us to identify pathways of fresh water influx. This has improved our knowledge and understanding of field scale flow into and out of the 300 area, flow that drives the migration of uranium and other contaminants. It is also information that, in the future, can be incorporated into flow and transport models.

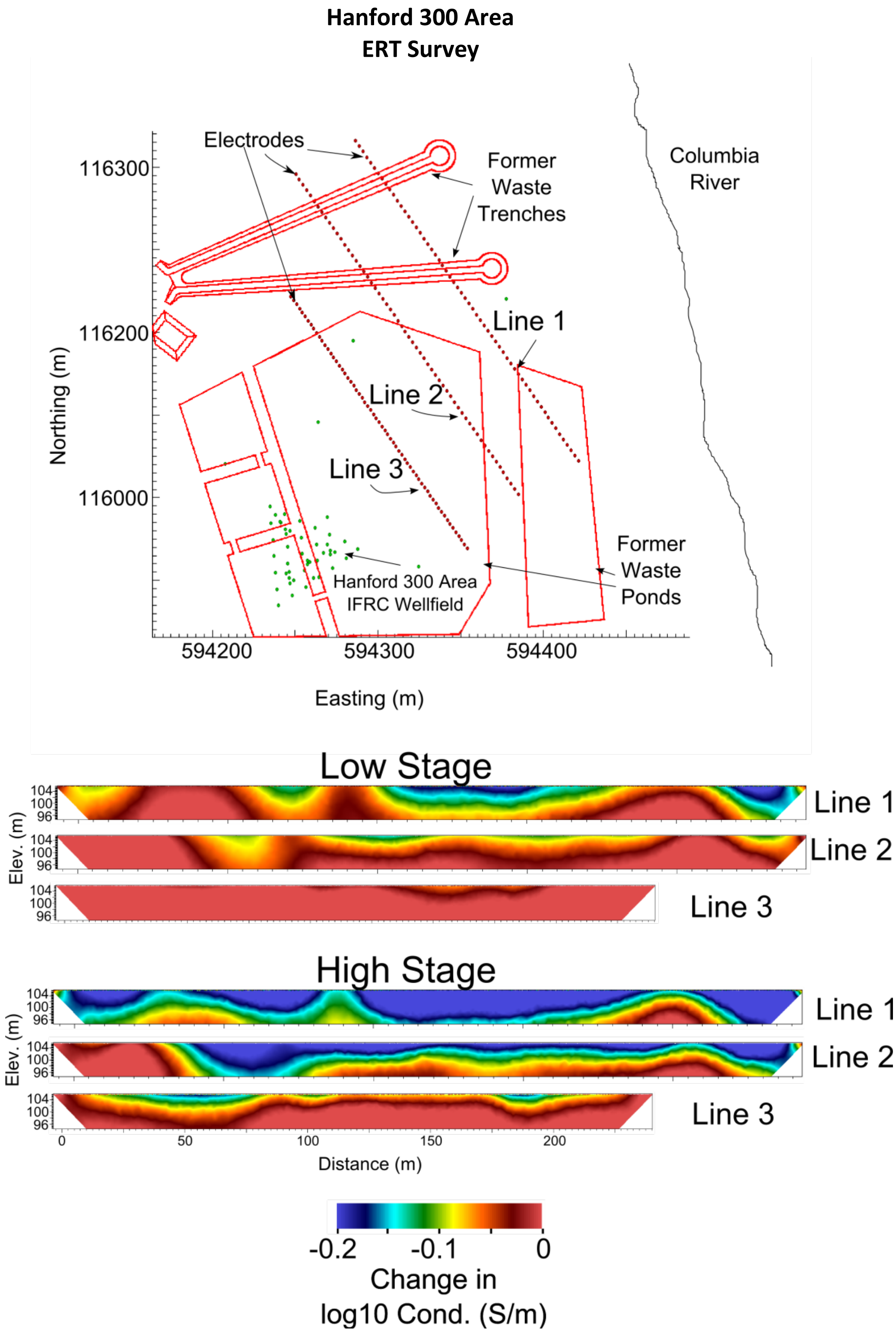

Figure 1. Hanford 300 Area ERT survey. Upper panel shows a map of the area under investigation. The middle panel shows the results from inverse modeling of data acquired at low river stage (and low water table elevation). The lower panel is the modeled result at high river stage. Note the larger regions of higher resistivity on all three lines indicating the influx of resistive fresh water. Both results are from inverse modeling that employed the time varying regularization operator.