Three-dimensional parallel inversion of two massive surface resistivity datasets to characterize vadose zone contamination beneath waste infiltration galleries at the Hanford Site

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Past-practice waste disposal operations at the Hanford Site allowed waste to be discharged to retention basins, trenches, or cribs where the waste percolated into the vadose zone. Vadose zone contamination included high volumes of liquid waste comprising radionuclides, metals, organics, and inorganics originating from various sources. Remediation of the vadose zone is a significant challenge at the Hanford Site where the vadose zone can be hundreds of feet thick. One of the most significant challenges inhibiting deep vadose zone cleanup and closure is the ability to map the distribution of vadose zone contamination. Due to the high ionic strength of most waste types discharged, contaminated regions of the vadose zone exhibit elevated bulk conductivities within a relatively low-conductivity host material, making them excellent imaging targets for electrical resistivity tomography (ERT).

In this paper, we demonstrate the utility of parallel ERT inversion for imaging vadose zone contamination at the Hanford Site. Large scale ERT surveys were conducted over two former subsurface waste disposal facilities; the BC-Cribs and Trenches Area, and the B-Complex which includes the B, BX and BY Tank Farms, BX-Trenches, BY-Cribs, B-Tile Field. The BC-Cribs survey covered an area of approximate 0.3 km^2 using 7421 electrodes producing 124,650 measurements. The B-Complex survey covered an area of 0.6 km^2 using 4848 electrodes to produce 301,916 measurements. We inverted each of these data sets in 3D using parallel distributed-memory computing systems (software and hardware) to accommodate the large number of mesh elements and memory required for optimal inversion. For the B-Complex inversion, infrastructure (i.e. buried waste retention tanks) was explicitly modeled into the mesh. This allowed customized regularization constraints whereby smoothing across the soil-tank boundary was relaxed to allow a sharp conductivity contrast. Smoothing constraints were similarly relaxed across the water table boundary. In addition, tank conductivities were estimated by the inversion, and surface topography was modeled into the mesh using LiDAR data. These constraints, coupled with the capability to invert large data sets on adequately refined meshes, provided highly resolved 3D images of contaminant distribution that are being used to help guide subsurface sampling efforts and remediation decisions.

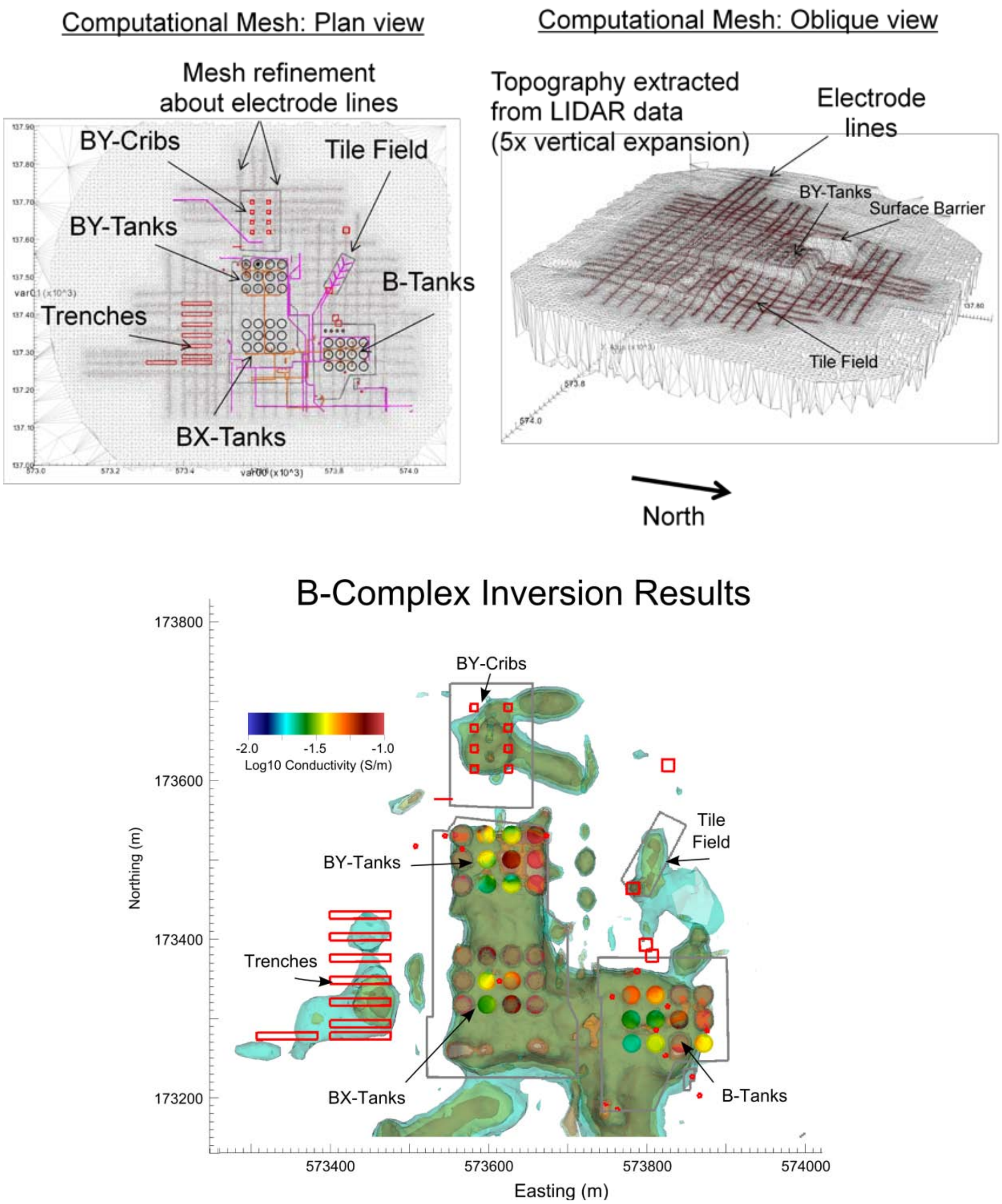

Figure 1. Computational mesh and 3D parallel inversion results of surface ERT data collected over the Hanford Site B-Complex. (top) Plan and oblique views of forward and inverse computational mesh. (Bottom) Plan view of inversion results shown as bulk conductivity iso-surfaces delineating vadose zone contamination resulting from past waste discharge practices. (Note areas beneath tank farms are highly influenced by metallic infrastructure such as pipes and wells). This data set contained 4848 electrodes and 301,916 measurements. The inversion mesh contained approximately 1.1 million elements. Inverse computations were conducted on 2430 processors of the high-performance computing cluster housed at Pacific Northwest National Laboratory.