Uranium, Groundwater, Supercomputing, and Chaos

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The American West has abundant natural beauty, but faces a host of environmental challenges including wildfires, energy development, water resources, abandoned mines, and—the topic of this presentation—uranium mining. Since the time of the Cold War, uranium has had a significant environmental impact on the American West. One particular uranium remediation site in Rifle, Colorado is of particular interest because it has played host to an integrated suite of hydrology, geochemistry, and microbiological studies since the early 2000s. The tailings were removed from this former uranium mill site adjacent to the Colorado River in the 1990s, but significant residual uranium remains in the alluvial aquifer beneath the Rifle floodplain, mostly in the form of mobile U(VI). The general research goal has been to test various approaches to stimulate microbially-mediated reduction of mobile U(VI) to immobile U(IV), for example, by injection of acetate into the floodplain aquifer. This process, including the linked geochemical and microbiological processes, has been modeled using the reactive transport code eSTOMP, the massively parallel version of STOMP (Subsurface Transport Over Multiple Phases), which runs on the Cascade supercomputer at Pacific Northwest National Laboratory (PNNL). Like essentially all groundwater remediation, the Rifle site suffers from the fact that reactive transport in porous media is transport-limited. That is, in the absence of turbulent flow, mixing reagents and removing reaction products is no trivial task. To address this fundamental limitation, we apply chaotic advection, which is has been shown to optimize plume spreading in laminar flows. This presentation will report preliminary numerical simulations in which the hydraulic boundary conditions in the eSTOMP model are manipulated to simulate chaotic advection resulting from engineered injection and extraction of water through a manifold of wells surrounding the plume of injected acetate.