# High-Resolution Monitoring for Thermal Remediation Optimization

Anne M. Chrest (anne.m.chrest@nasa.gov) (NASA, Kennedy Space Center, FL, USA)
***Christopher A. Hook*** (chris.hook@tetratech.com), Robert F. Davis, Christopher J. Pike, Mark P. Speranza (Tetra Tech, Pittsburgh, PA, USA)

**Background/Objectives.** National Aeronautics Space Administration (NASA), Kennedy Space Center (KSC), has developed a unique discrete sampling method to evaluate remedial performance of thermal technologies. Electrical resistance heating (ERH) was implemented to address a trichloroethene (TCE) source area, with concentrations indicative of dense non-aqueous phase liquid (DNAPL), at the former Components Cleaning Facility (CCF) site. The conceptual site model, based upon high-resolution site characterization using direct push technology (DPT), identified TCE mass present within a fine-grained semi-confining unit acting as a back-diffusion layer with approximately 76 percent of the overall source mass within the lower permeability unit and 23 percent of the remaining TCE mass within 10 feet in overlying permeable layers. Conventional use of ERH performance monitoring via stainless steel monitoring wells was not preferred because high-density chemical data were instrumental in building the conceptual site model and supporting subsequent remedial decisions. Instead, groundwater sampling were collected using a modified direct push sampling technique capable of sampling groundwater at temperatures up to 270 degrees Fahrenheit within an artesian environment.

**Approach/Activities.** ERH treatment began in spring 2016 and within less than 2 months the entire treatment volume reached azeotropic conditions. Temperature data from 84 sensors provided a 5-foot vertical resolution from 5 to 60 feet below land surface at seven locations. The high-resolution temperature data provided a compelling tool to spatially optimize energy application to vertically nested electrodes. However, temperature data does not directly correspond to chemical data and remedial performance. Therefore, approaches for obtaining high-resolution chemical data beyond that provided by a monitoring well system were developed to support a multiple lines of evidence basis for evaluating and optimizing remedial performance. Traditional DPT sampling methods could not be conducted due to multiple hazards such as artesian conditions from temperature and pressure gradients and potential steam flashing within drill tooling. The project team utilized a modified discrete sampling interface, by which a closed sample extraction system collected discrete samples with a vertical resolution as dense as 1-foot between samples. By using a discrete sampling approach supported by an on-site mobile laboratory, an adaptive performance monitoring program was developed resulting in near-real time data reviews and optimizations coordinated with project stakeholders.

**Results/Lessons Learned.** The project successfully met the performance objectives of treating TCE, cis-1,2-dichloroethene, and vinyl chloride to concentrations less than 300, 700, and 100 µg/L, respectively. A baseline maximum TCE concentration of 1,400 mg/L was reduced to an average concentration of 16 µg/L within the treatment volume. Overall, the average TCE concentration reduction was approximately 99.99 percent. The success of this project and the aggressive concentration reductions were predicated on effective integration of optimization tools in a multiple lines of evidence approach supported by a high-resolution temperature and chemical data acquisition.