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Successes and challenges of geoelectrical monitoring at Sellafield, UK – a retrospective

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A challenging field experiment applying 4D cross-borehole Electrical Resistivity Tomography (ERT) to the monitoring of simulated subsurface leakage has been undertaken at a legacy nuclear waste silo at the Sellafield Site, UK. The experiment constitutes the first application of geoelectrical monitoring in support of high-hazard decommissioning work at a UK nuclear licensed site. Images of resistivity changes occurring since a baseline date prior to the simulated leaks have revealed likely preferential pathways of silo liquor simulant flow in the vadose zone and upper groundwater system. The geophysical evidence was found to be compatible with historic contamination detected in permeable facies in sediment cores retrieved from the ERT boreholes. Our results suggest that laterally discontinuous till units forming localized hydraulic barriers can substantially affect flow patterns and contaminant transport in the shallow subsurface at Sellafield. We conclude that only geophysical imaging of the kind presented here has the potential to provide the detailed spatial and temporal information at the (sub-)metre scale needed to reduce the uncertainty in models of subsurface processes at nuclear sites.

Amongst the many achievements of this work since 2009 has been the full acceptance of geoelectrical monitoring by the UK nuclear industry and the recognition of its value as a tool for environmental site assurance within the safety case for decommissioning. Our work has directly led to the endorsement of 'Technology Readiness Level 6' by Sellafield Ltd for future use on the UK nuclear estate.

Further advances arose from a detailed consideration of the effects of the long monitoring periods required to support nuclear decommissioning (25 years and more). Geoelectrical arrays that, once installed in permanently grouted boreholes, cannot be retrieved or replaced due to the immense cost and logistical effort associated with drilling at Sellafield.

Results of a study of advanced alternative electrode materials suggest that, besides aqueous metallic corrosion, the formation of surface scales is the principal mechanism responsible for the deterioration of stainless steel sensor performance over time. Novel sensors with noble metal coatings displayed outstanding properties and easily surpassed the performance of stainless steels. Stability of these electrodes in all aspects was found to be remarkable and their susceptibility to ERT noise was only marginally greater than that of stainless steels. These observations are regarded as a milestone achievement for ERT methodology, as they open a new perspective on sensor longevity, providing a real design alternative where contact resistance growth is a threat to the long-term viability and cost-effectiveness of geoelectrical monitoring.