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Understanding Radionuclide Migration from the D1225 Shaft, Dounreay, Caithness, UK

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A vertical shaft was sunk at Dounreay in the 1950s to build a tunnel for the discharge of radioactive effluent from the various nuclear facilities then under construction. The Shaft has an average diameter of 4.6 m and a total height of 65.4 m, with the lower 52 m being unlined and in direct contact with micaceous flagstones of the Devonian Dounreay Shore Formation. In 1959, the Shaft was licensed as a disposal facility for radioactive wastes and was routinely used for the disposal of unconditioned intermediate level waste (ILW) until 1970. All material consignments to the Shaft ceased in 1977 following an explosion in the head-space above the waste column. In 1998, it was decided to retrieve the waste for treatment and surface storage. The first phase of decommissioning is hydraulic isolation, creating a containment barrier between the waste in the Shaft and the groundwater that flows through the surrounding rock. This has involved drilling approximately 400 boreholes and injecting very fine cement grout under pressure in a 10 m wide band of rock around the Shaft. This process was completed in Spring 2008.

Despite the operation of a hydraulic containment scheme around the Shaft, some radioactivity from the wastes disposed to the Shaft is known to have leaked into the surrounding rocks. Detailed logging, together with mineralogical and radiochemical analysis of drillcore from the dense network of boreholes around the Shaft has revealed four distinct bedding-parallel zones of contamination. The most extensive zones of contamination are associated with hydraulically transmissive layers and while most of the contamination is located around the Shaft itself, it is clear that a small amount of contamination has travelled approximately 100 m from the Shaft. The data show that Sr-90 dominates the bulk beta/gamma contamination signal, whereas other radionuclides such as Cs-137 and Pu-248/249 are found only to be weakly mobile in the geosphere, leading to very low activities and distinct clustering around the Shaft. These differences may be explained by different sorption mechanisms and different mineralogical sorption substrates in the Caithnesss flagstones. The data also suggest that all uranium seen in the geosphere is natural in origin and any component from the Shaft is sufficiently small that it cannot be distinguished from the natural signature. At the smaller scale, contamination adjacent to fracture surfaces is present within a zone of enhanced porosity created by the dissolution of carbonate cements from the Caithness flagstones during long-term rock-water interactions.

This communication describes quantitative modelling of radionuclide migration using Quintessa's QPAC computer code, aimed at increasing confidence in potential controls on the predicted distribution of radioactive contamination around the Shaft. The results of the modelling show that realistic chemical models for radionuclide retardation (ion exchange, surface complexation), with some simplifying assumptions regarding rock physicochemical properties, groundwater flow, and chemistry, can provide valuable insights into the migration of contaminants. In particular, the following features of the measured contamination distribution around the Shaft can be reproduced: the spatial extent and general activity levels of the dominant rock contaminant, Sr-90; the sparsity and low rock contamination levels of Cs, U, and Pu; and the desorption of Sr from ion exchange sites due to competition from major cations from seasonally-variable marine aerosols and road salt application.