Groundwater Flow and Solute Transport Modeling in the SFR Nuclear Waste Repository

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Abstract

The Swedish Nuclear Fuel and Waste Management Company (SKB) operates the underground repository for low- and intermediate-level nuclear waste (SFR) located in Förstmark, Sweden. An extension of the SFR is planned to accommodate mainly waste arising from the decommissioning of Swedish nuclear power plants (Figure1). The long-term safety assessment for the SFR repository takes into account the future hydrogeological conditions in the near-field of the existing facility (SFR 1) and the SFR planned extension (SFR 3). Two COMSOL Multiphysics® models represent the detailed geometry of the SFR 1 and SFR 3 repositories, with 10,748,580 and 11,548,320 tetrahedral quadratic finite elements, respectively (Figure 2), as well as the heterogeneity of the rock surrounding the repository (Figure 3).

The main objective of this study is to estimate groundwater fluxes in the repository under saturated and steady-state conditions, and for different future shoreline positions. These flow values are then used as input to a separate model for radionuclide transport. A second objective is to deepen the system understanding of the SFR from a hydrogeological perspective, focusing on the effects of barrier degradation, closure alternatives, permafrost, and the uncertainty related to the rock permeability fields on the groundwater flow through the repository. Knowledge gained allows for the evaluation of proposed engineering solutions with increased confidence.

The models of the repository were successfully implemented in COMSOL Multiphysics® and represent an important contribution to the development and assessment of different engineering solutions for nuclear waste disposal in SFR. The results of the model of groundwater flow in the repository (Figure 4) can be used to optimize the design of the barriers from a hydrogeological perspective.

Figures used in the abstract

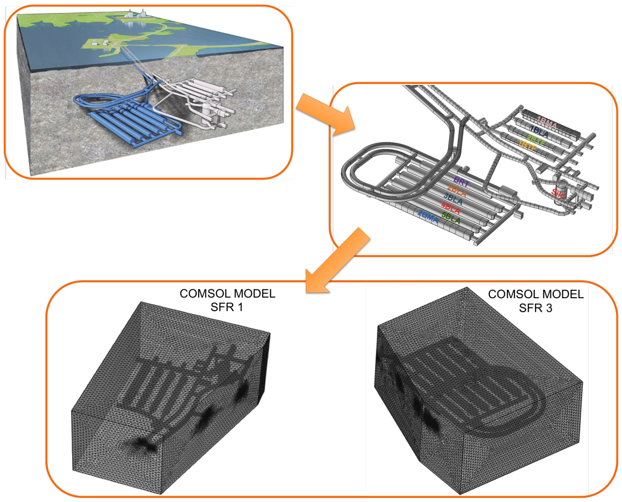

Figure 1: Schematic view of the SFR repository in the Försmark area (top): SFR 1 (in gray) and SFR 3 (in blue). Geometry of the repository included in the models (middle) and finite element meshes of the SFR 1 and SFR 3 COMSOL models (bottom).

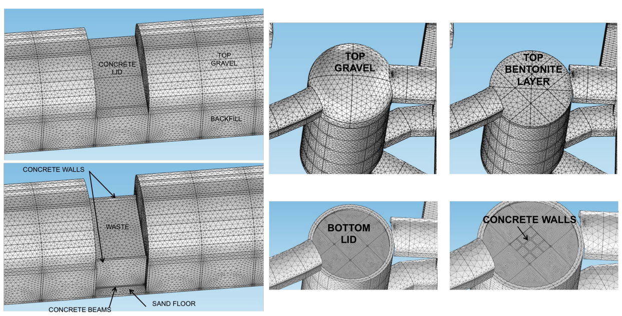

Figure 2: Detailed finite element mesh of two vaults in the SFR 1 repository: 1BMA (left) and Silo (right).

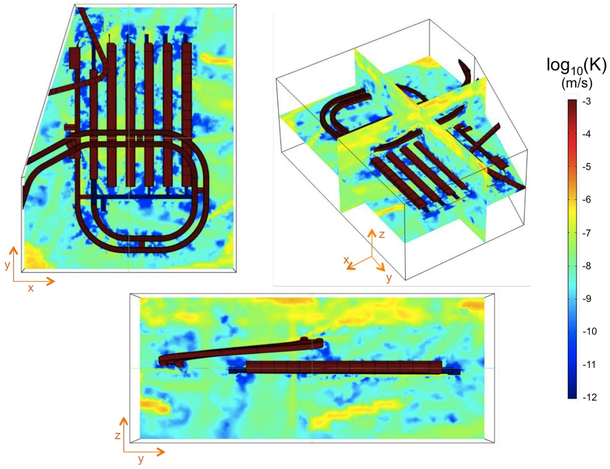

Figure 3: Detail of the hydraulic conductivity of the fractured rock and the SFR 3 repository.

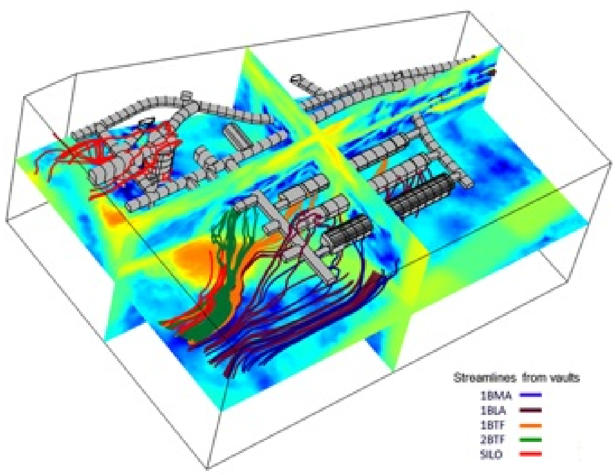

Figure 4: Groundwater streamlines leaving individual vaults (color tubes) of SFR 1 for the degraded plugs case with the repository well removed from the shoreline position, and hydraulic conductivity field of the rock in three orthogonal planes. The streamline thickness is proportional to the magnitude of the flow.