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

Elena Abarca[1] (elena.abarca@amphos21.com), Andrés Idiart[1], Orlando Silva[1], Luis Manuel de Vries[1], Jorge Molinero[1], Henrik von Schenck[2], Fredrik Vahlund[2]

[1] Amphos 21 Consulting S.L., [2] Swedish Nuclear Fuel and Waste Management Co.

Introduction

The Swedish Nuclear Fuel and Waste Management Company (SKB) operates the underground repository for low- and intermediate-level nuclear waste (SFR) located in Forsmark, Sweden. An extension of the SFR is planned to accommodate mainly waste arising from the decommissioning of Swedish nuclear power plants (Figure 1). The long-term safety assessment of 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).

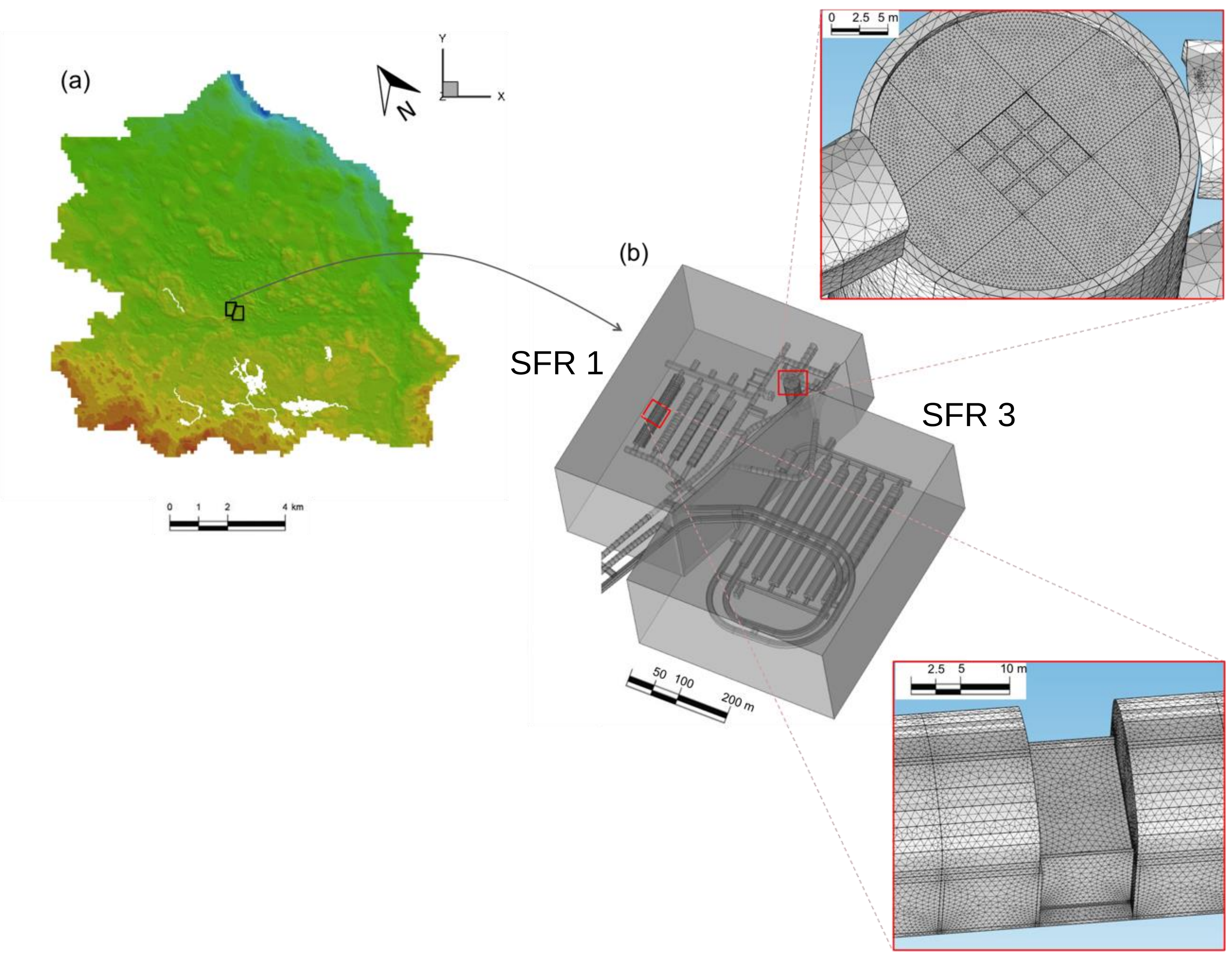

Figure 1. a) Regional scale model domain (km scale) and, in black, location of the repository-scale model domain (b) repository-scale domains (hundred m scale) and details of the structures within the vaults (meter scale).

Objectives

The main objective of the study is to estimate future hydraulic behavior of the repository under saturated and steady-state conditions. 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 advance, etc. and the uncertainty in the rock permeability fields on the flow through the repository.

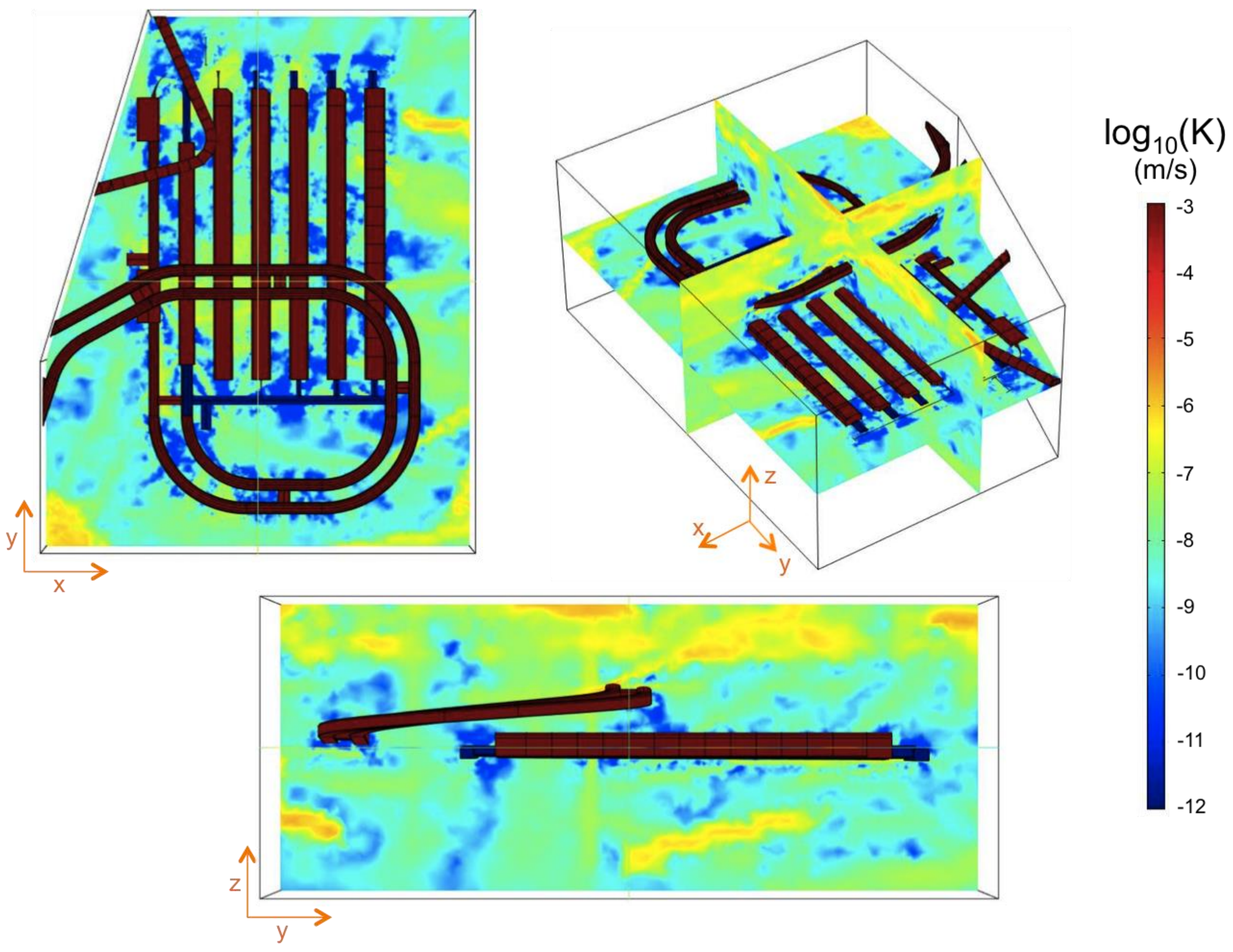

Figure 2. Hydraulic conductivity (m/s) of fractured rock and SFR 3 repository.

Modeling approach and results

Two repository models were implemented using the Subsurface Flow Module, which is tailored for modeling groundwater flow in fractured and porous media (Figure 3). A local mass transport model of the Silo under steady-state conditions was also implemented through the Transport of Diluted Species Interface (Figure 4).

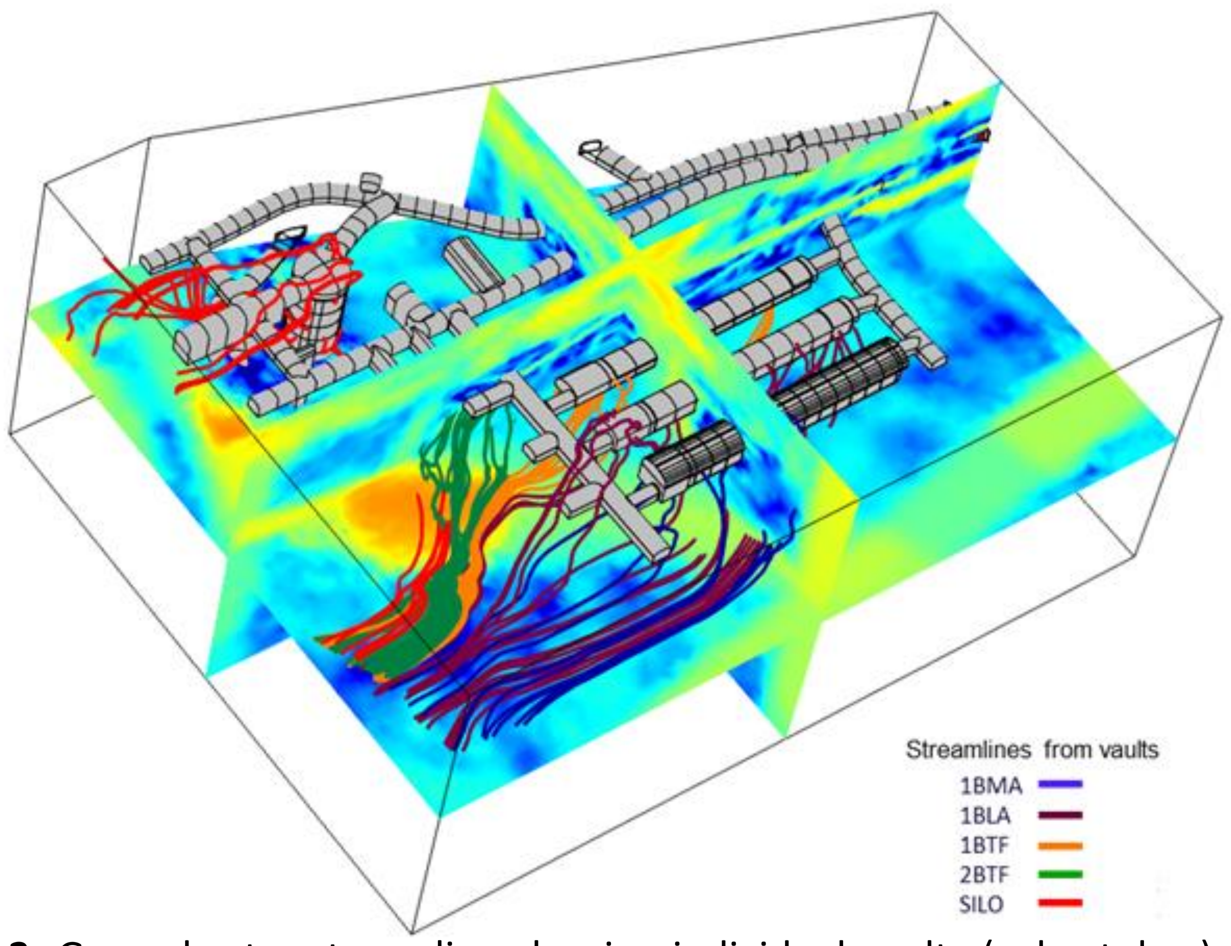

Figure 3. Groundwater streamlines leaving individual vaults (color tubes) of SFR 1 for the degraded plugs case with the repository well removed from the shoreline position, and hydraulic conductivity field of the rock in three orthogonal planes. The streamline thickness is proportional to the magnitude of the flow.

These 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 (see details in Figure 1), as well as the heterogeneity of the rock surrounding the repository (Figure 2). The boundary conditions are imported from a larger regional model performed with an external code.

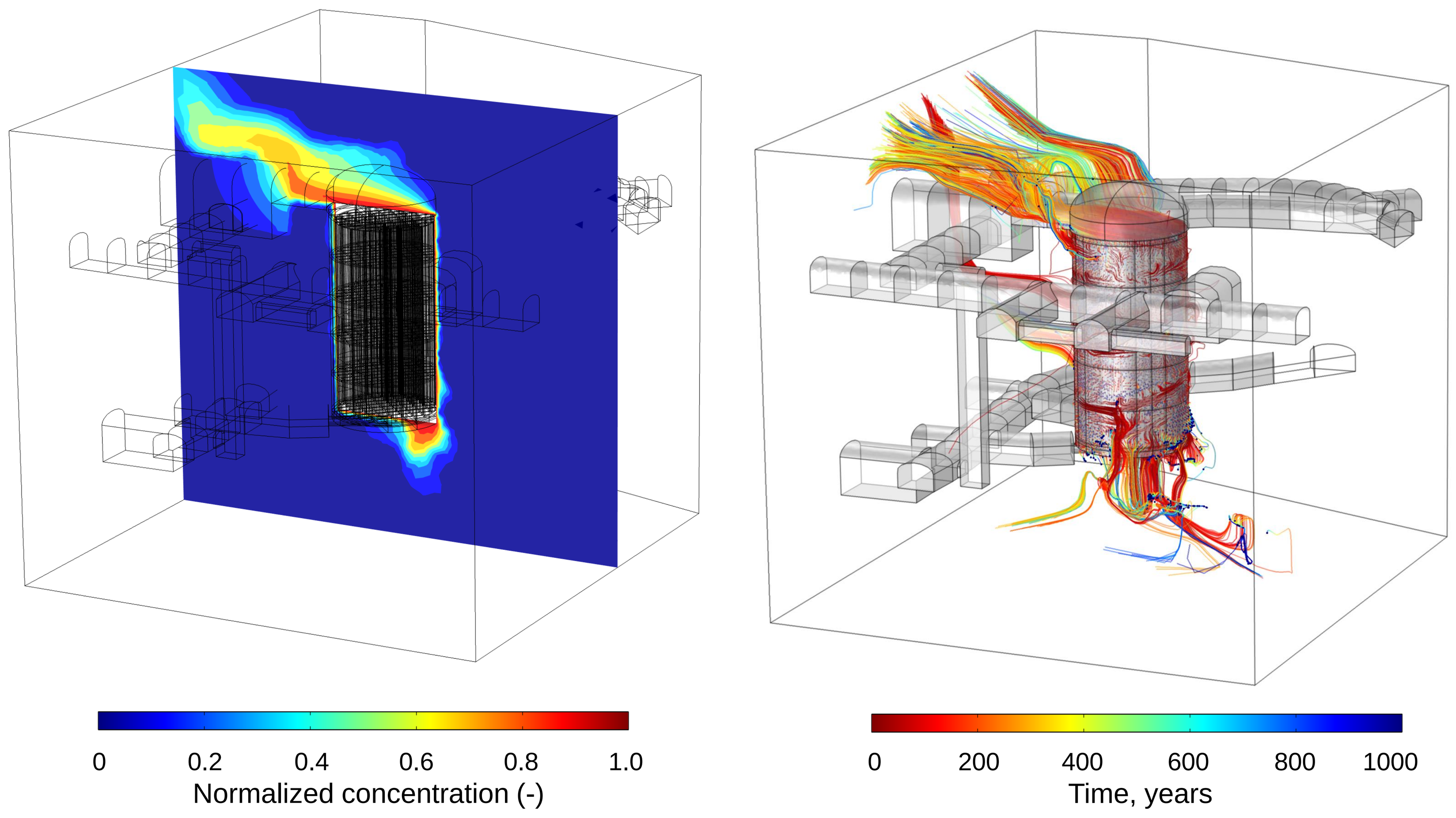

Figure 4. Transport of a conservative tracer released from the Silo to the geosphere. Concentration distribution of the tracer in a vertical plane (left) and footprints of particles released from the Silo walls colored by time-of-flight (right).

Conclusions

The models of the repository were successfully implemented in COMSOL. More than 50 cases of a combination of different material and flow conditions have been simulated. The results 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 (Figures 3 and 4) can be used to optimize the design of the barriers from a hydrogeological perspective. Knowledge gained allows for the evaluation of proposed engineering solutions with increased confidence.