Using COMSOL for optimal design of engineering barriers of nuclear waste repositories

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Introduction

The Swedish Nuclear Fuel and Waste Management Co (SKB) is responsible for final disposal of spent fuel and radioactive waste. SKB operates SFR, an underground repository for low- and intermediate waste in crystalline rock. The repository is currently located under the sea (due to land rise the shoreline will move so that the facility will be under land in the future).

As part of the long term safety assessment the evolution of groundwater flow within the repository needs to be estimated considering different options for the design of the engineered barriers. The goal is to predict the effects of flow and transport on the stored waste over 10^4 - 10^5 years for each case to help in the decision-making process of design engineers.

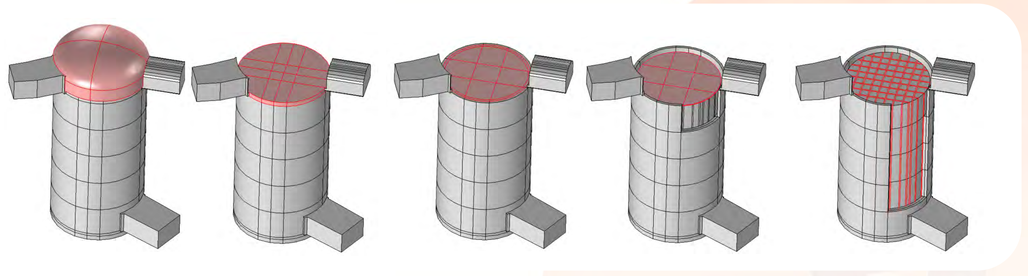
The objective of this work is to study the effects of the different materials in the tunnels used as barriers for the nuclear waste, as well as the materials used to backfill the tunnels after the operational phase, once all the waste has been deposited.

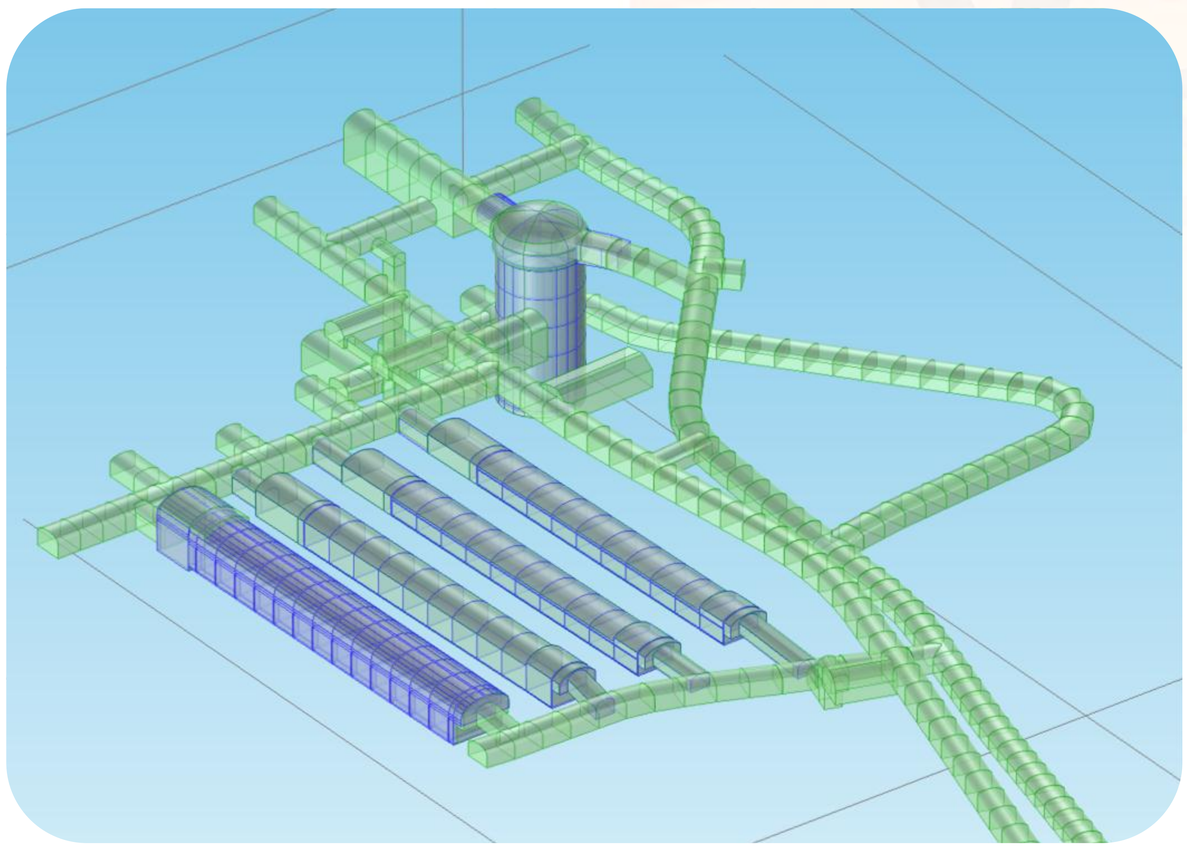
Region-Scale Flow Modelling

The 3D groundwater flow for different shoreline positions has been simulated using the Finite Volume software DarcyTools (Svensson et al. 2010), specialized in the simulation of flow and transport in porous and fractured media at the km-scale, explicitly considering the effect of fracture zones. The results of this large-scale model have been used as input for the detailed Comsol model.

Repository-Scale Flow Modelling

Each storage vault is modelled separately in Comsol and imported into a repository-scale model. These models contain a high degree of geometric and structural detail.



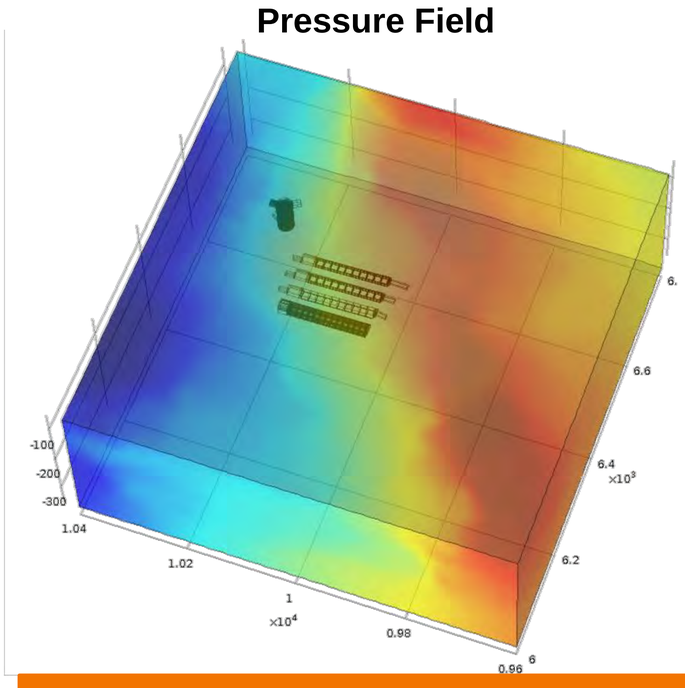


Control-Volumes

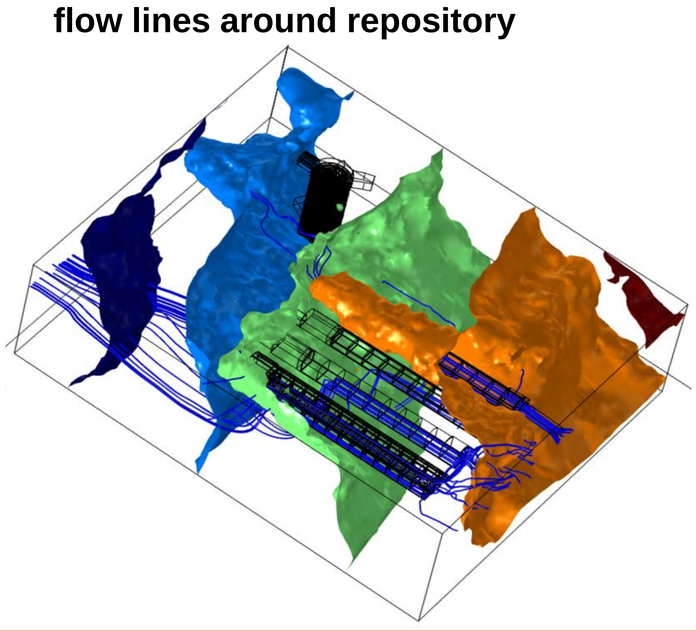
For certain predefined control-volumes the mass flows are being calculated. To be able to deal with the large amount of data (hundreds of control volumes, millions of elements, several scenarios) produced by the Comsol flow simulations, the flexible Comsol Java API is used. The different mass flows entering and leaving specified control-volumes are calculated automatically.

Results for Different Climate Scenarios

Pressure Field

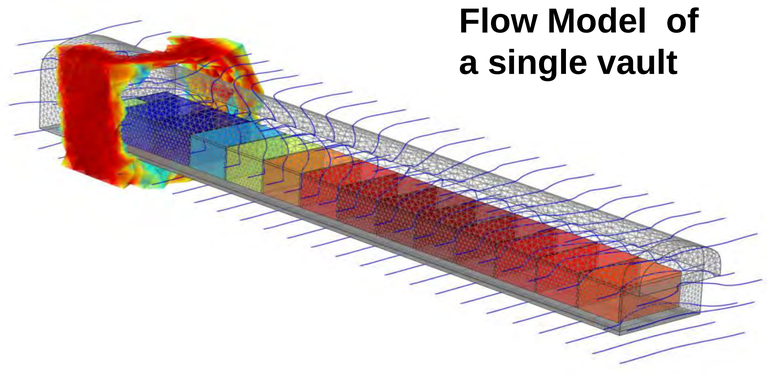


Hydraulic head iso-surfaces & flow lines around repository



For each climate scenario, the calculated steady-state flow field in the geosphere obtained with DarcyTools is used as input in Comsol for detailed groundwater flow modelling within the repository. Simulations are carried out using the Subsurface Flow Module

Flow Model of a single vault



Conclusions

The repository scale flow simulations done with Comsol Multiphysics provide an increased understanding in the performance of the engineering barriers. Detailed information about the flow through specific waste packages can be studied using the control volume mass flows to help design engineers in selecting the best set of backfill materials that minimize the groundwater flow through the waste packages.

References:

[1] Svensson U, Kuylenstierna, H-O, Ferry M, 2010. DarcyTools version 3.4. Concepts, Methods and Equations. SKB report R-07-38.

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