DHI CASE STORY

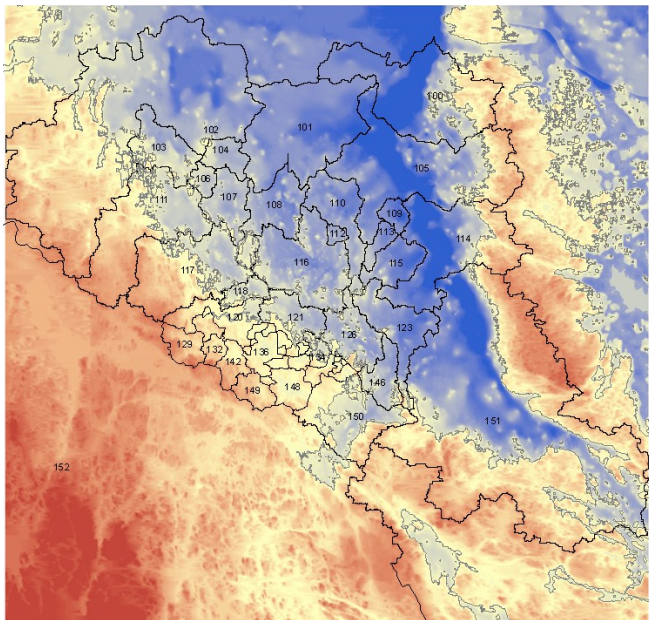
HELPING SWEDEN ENSURE THE SAFETY OF AN UNDERGROUND NUCLEAR REPOSITORY

Contributing to a comprehensive Environmental Impact Assessment

Nuclear energy is a major source of energy in Sweden. However, it can be difficult to safely store radioactive waste generated during the production process. To address this challenge, the Swedish Nuclear Fuel and Waste Management Company (SKB) decided to build a long-term nuclear repository in Forsmark, Sweden. SKB needed to complete a comprehensive Environmental Impact Assessment (EIA) to gain approval for the repository. We contributed to their EIA by modelling the possible pathways of radionuclides (radioactive contaminants) through the marine ecosystem, in the event of a future leak from the repository. This enabled SKB to evaluate bioconcentration factors (the extent to which pollutants concentrate in organisms) in the marine environment and calculate the potential risks to humans.

SAFE STORAGE OF NUCLEAR WASTE

Around 40% of Sweden's energy comes from nuclear energy production. However, spent nuclear fuel – a hazardous waste product of nuclear energy production – remains radioactive for at least 100,000 years. Safely storing spent nuclear fuel is therefore a challenge. As such, countries that use nuclear energy must devise ways to safely store the spent fuel for thousands of years.



Map of the Öregrundsgrepen, the archipelago outside the planned repository at Forsmark. The black lines delineate the sub-basins used in the dose calculations by SKB, and for which water exchange was calculated. Colours signify heights.

SUMMARY

CLIENT

Swedish Nuclear Fuel and Waste Management Company (SKB)

CHALLENGE

- Possible harm to the marine environment in the distant future, caused by spent nuclear fuel from a planned underground, long-term nuclear repository
- Need to determine the potential damage, in order to construct the repository sustainably and safely

SOLUTION

Using our MIKE by DHI software to model:

- coastal water circulation for conditions ranging from 6500 BC to 9000 AD
- radionuclide (radioactive contaminant) pathways in the marine ecosystem

VALUE

- Increased understanding of the three-dimensional (3D) water circulation under conditions that will occur thousands of years from now
- Enabling the completion of a comprehensive Environmental Impact Assessment (EIA) required to obtain permits for constructing the long-term nuclear fuel repository

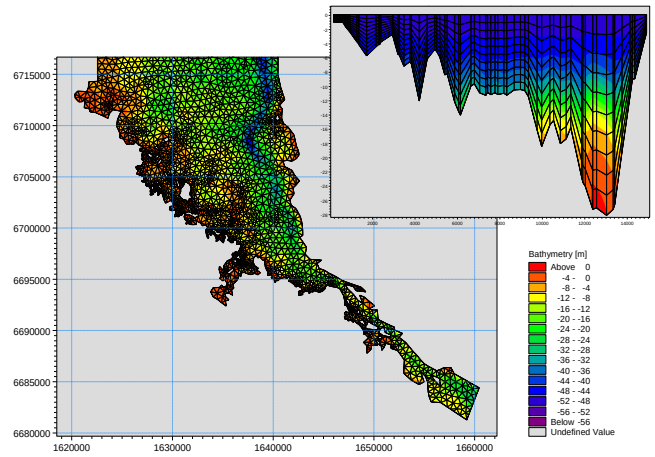
LOCATION / COUNTRY

Forsmark, Sweden

The Swedish Nuclear Fuel and Waste Management Company (SKB) is in charge of managing and disposing of Sweden's nuclear waste. To safely store spent nuclear fuel, SKB planned on constructing an underground long-term repository near Forsmark, Sweden. However, Forsmark is located near the Baltic Sea. If there are any leaks from the repository in the future, it could result in radionuclides reaching the marine environment, which could also impact humans.

To receive permission to build the repository, SKB needed an approved and accepted Environmental Impact Assessment (EIA). Without this, the long-term repository could not be constructed and the spent nuclear fuel would pile up in temporary repositories. For the EIA approval, it was necessary to determine dose loads – the amount of radionuclides the environment, and subsequently humans, could be exposed to if a leak occurred.

SKB needed to know how a release of spent nuclear fuel to the coastal waters would spread through the marine environment. This would enable them to determine the final impact on humans. To do this, SKB asked us to model the circulation of the water around the coastal archipelago off Forsmark under very different future conditions. We also developed a model of the pathways of radionuclides through the ecosystem, which could be used for comparison with other modelling efforts.



The model mesh and bathymetry as well as a cross-section showing the vertical resolution and a snapshot of the salinity stratification.

MODELLING RADIONUCLIDE PATHWAYS IN THE FAR FUTURE

We set up a three-dimensional (3D), high-resolution model of the coastal archipelago using our MIKE 3 FM model suite. We calibrated the 3D model against existing hydrographic measurements for present day conditions. We then modified the model bathymetry and topography based on careful estimates of land rise at intervals of 1000 years between 6500 BC and 9000 AD.

For each such scenario, we ran the model for a full year and determined the resulting circulation in the archipelago. We also modelled different climate scenarios based on existing knowledge of past and future climate trends. We then calculated the water exchange between given sub-areas in a way that could be used by SKB in their dose modelling.

The flexibility of our MIKE by DHI software and tailor-made programmes allowed us to quickly adapt when input data changed (for example, when the digital elevation models for future conditions were refined). The results of the circulation model were also used to drive the ecosystem model that we developed using ECO Lab – a part of our MIKE software suite. The ecosystem model described the possible pathways of radionuclides through the marine ecosystem. It also included the transport and mixing determined by the circulation model.

CONTRIBUTING TO A COMPREHENSIVE EIA

All of our work was subject to a very strict quality assurance system. As part of that system, we submitted the modelling results to an external review panel of experts. They were subsequently published as part of the very comprehensive EIA carried out by SKB. Using our results, SKB could:

- evaluate previously determined bioconcentration factors
- feed their own dose models for calculating the risks to humans – for example, from eating fish caught in the archipelago

At the end of the project, we were invited to collaborate on a special issue of the journal AMBIO entitled 'Humans and ecosystems over the coming millennia: a biosphere assessment of radioactive waste disposal in Sweden'. The results can be found in the article 'Water exchange on a geological timescale – examples from two coastal sites in the Baltic Sea'.

PROJECT PUBLICATIONS:

- Water Exchange on a Geological Timescale – Examples from Two Coastal Sites in the Baltic Sea - *http://link.springer.com/content/pdf/10.1007%2Fs13280-013-0396-4.pdf*
- High-resolution hydrodynamic modelling of the marine environment at Forsmark between 6500 BC and 9000 AD - *http://www.skb.se/upload/publications/pdf/R-10-09.pdf*
- Models for transport and fate of carbon, nutrients and radionuclides in the aquatic ecosystem at Öregrundsgrepen - *http://www.skb.se/upload/publications/pdf/R-10-10.pdf*

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