R-05-57

The Forsmark repository

Modelling changes in the flow, pressure and salinity fields, due to a repository for spent nuclear fuel

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November 2006

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Abstract

Water inflow to an open repository may change the pressure and salinity in a large volume around the repository. The effect can reach the surface and may cause a drawdown of the ground water table and very salt water from below the repository may be transported up to repository level.

A numerical simulation model which simulates these effects is developed and tested. By employing a number of advanced modelling techniques (unstructured grids, free surface algorithm, matrix exchange, etc) it is demonstrated that realistic simulations can be performed. An application to the Forsmark repository is carried out and site specific results are discussed.

The main conclusion of the study is that the inflow to the open repository is very small indeed (< 10 1/s). This is due to the model of the fracture network and rock block properties adopted. An estimate of the resaturation time of the backfill shows that it is in the range of 15 to 50 years.

Sammanfattning

Inflöde till ett djupförvar ger förändringar i tryck- och saltfältet i en stor volym runt förvaret. Vid markytan kan en sänkning av grundvattenytan bli resultatet. Under förvaret kan en uppåtgående transport, som kan öka salthalten på förvarsnivå, förväntas.

En numerisk modell som beskriver dessa effekter har utvecklats och testats. Genom att utnyttja en rad avancerade tekniker (ostrukturerade beräkningsnät, algoritm för fri grundvattenyta, matrisutbyte, m m) kan realistiska simuleringar erhållas. En tillämpning på ett tänkt förvar i Forsmark visar detta.

Den viktigaste slutsatsen från arbetet är att inflödet till det öppna förvaret kan förväntas vara mycket litet (< 10 1/s). Anledningen till detta är den låga hydrauliska konduktivitet i omgivande berg och sprickzoner. En uppskattning av tidsskalan för återfuktning av fyllnadsmaterialet i tunnlarna, indikerar att tidsskalan ligger i intervallet 15 till 50 år.

Contents

1 Introduction

1.1 Background

A repository for spent nuclear fuel will have atmospheric pressure in the tunnels during the excavation and operational phases. In order to reduce the resulting water inflow grouting will be carried out. Unless the inflow is totally eliminated (which is not feasible) a disturbance in the pressure and salinity fields will result.

From several points of view it is of interest to be able to predict these disturbances:

- The ground water table will be lowered due to the tunnel inflow. The water level in lakes and wells is thus affected as well as the flow rate in streams.
- The engineered barriers are known to be affected by the salinity of the surrounding water. It is expected that water from below the tunnel will be transported to the tunnel, carrying water with high salinity (upconing). Also the oxygen saturated water from the ground surface may affect the engineered barriers.
- From a construction point of view it is essential to know the expected inflow to the repository; this in order to perform suitable grouting, design pump systems, etc.

After the closure of the repository a resaturation phase starts. Also this phase and the coupling to the host rock is of interest to simulate. Finally, one needs to consider the possible transport of radionuclides from the repository to ground level. This transport will however not be considered in this report.

Considering all these aspects and the complex geometry of a repository it is realized that the simulation task is far from trivial. A model that resolves the processes around the tunnels (on a metre scale) as linked to regional scales (on the km scale) is needed.

1.2 Objectives

The main objectives of the study are to calculate:

1. Inflow of the tunnels.
2. Upconing of saline water to the repository.
3. Resaturation time after closure.
4. Turnover of water in the upper bedrock and soil.
5. Near-surface drawdown:
   – Extent of influence area and drawdown within it.
   – Effects on wells in rock and overburden.
6. Effects on surface hydrology:
   – Surface water levels.
   – Discharges in water courses.
7. Sensitivity analysis of the hydraulic conductivity of the backfill.

The first three objectives will be in focus in this report. A secondary objective is to demonstrate new methodology, as embodied in the code DarcyTools version 3.0.

1.3 Scope

In order to meet the objectives a number of advanced modelling techniques are needed. The most important of these are:

- A computational grid that can resolve the geometry of the repository, as embedded in a regional scale model. In this report an unstructured grid will be introduced as a solution to this problem.
- A method to handle a free ground water surface.
- The repository geometry is given in form of high resolution CAD files. These files need to be imported to the code and the computational grid is to be constructed in a way that resolves the geometry.
- The salinity distribution is in focus in the study. The gravitational effects due to the varying salinity as well as the exchange with immobile volumes (including the rock matrix) should be accounted for.
- Grouting will reduce the hydraulic conductivity close to the repository walls. This skin effect needs to be simulated in a realistic manner.
- The resaturation phase calls for a two-phase analysis. In this report a simpler alternative will be tested.

These features are considered to be essential parts of a realistic problem formulation and the modelling task is therefore also a feasibility study.

Some issues that are not considered in this study include: thermal effects and transport of radionuclides from the repository to ground level. It should further be noted that comprehensive calibration and sensitivity studies are outside the scope of the present project.

2 Site description

2.1 General

The Forsmark area is located near the Forsmark nuclear power plant, in northern Uppland, on the east cost of Sweden, see Figure 2-1. In this figure also the Regional model domain is introduced; this domain is also the largest one considered in this study. The dimensions of the Regional model area are: 15 km (north-east), 11 km (north-west) and 2.1 km (depth).

An outline of the repository is shown in Figure 2-2. The repository is located at a depth of about 400 metres. The layout of the repository is done with respect to major deformation zones in the area.

Figure 2-1. Overview of the Forsmark area and the Forsmark model area.

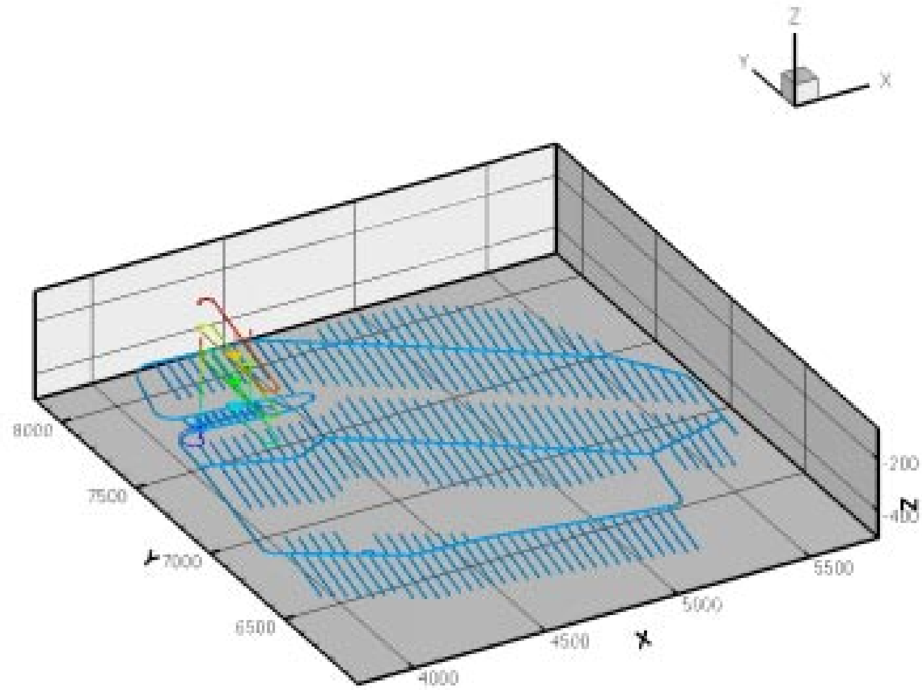


Figure 2-2. *Layout of the repository. Position in the horizontal plane (top) and a perspective view. The x and y coordinates in this, and the following figures, refer to the local system in the regional model. The y-direction points to north-west.*

2.2 Site data

The general conditions and data for the model set-up are given in /Follin et al. 2005/ and /SKB 2005/. Some of the main points are:

- The model domain coordinates are those of the Regional model.
- The elevation of the top surface of the model was provided by SKB.
- The deterministic fracture network, and the rock volumes in between, should be identical with the multicomponent Continuous Porous Medium (CPM) base case defined in the Site-descriptive model /SKB 2005/.
- The tunnel layout is presented in /Brantberger et al. 2006/ and is provided by SKB in form of a CAD file (STL-format).
- Initial conditions should be based on the results from the Site-descriptive model.
- Boundary conditions:
  – Prescribed net precipitation (165 mm/year) above sea level, fixed pressure and salinity below.
  – Salinity at bottom boundary fixed to 10%.
  – Hydrostatic conditions on all lateral boundaries.
  – Atmospheric pressure in tunnels.

A brief introduction to the base case model mentioned above is given by Figure 2-3. The key deformation zones are the Singö deformation zone (SDZ), The Eckartfjärden deformation zone (EDZ) and the dipping zones A1 and A2. In addition to these a set of smaller zones is also represented in the base case model. In between these zones the base case defines continuous porous medium (CPM) blocks, called CPM1, CPM2 and CPM3. The repository is located in CPM3. The blocks CPM2 and CPM3 are shown in Figure 2-4; as can be seen CPM3 extends under CPM2. As CPM3 has a very low conductivity (10^{-11} m/s), it will prove that the properties of CPM3 is a major controlling factor for the repository.

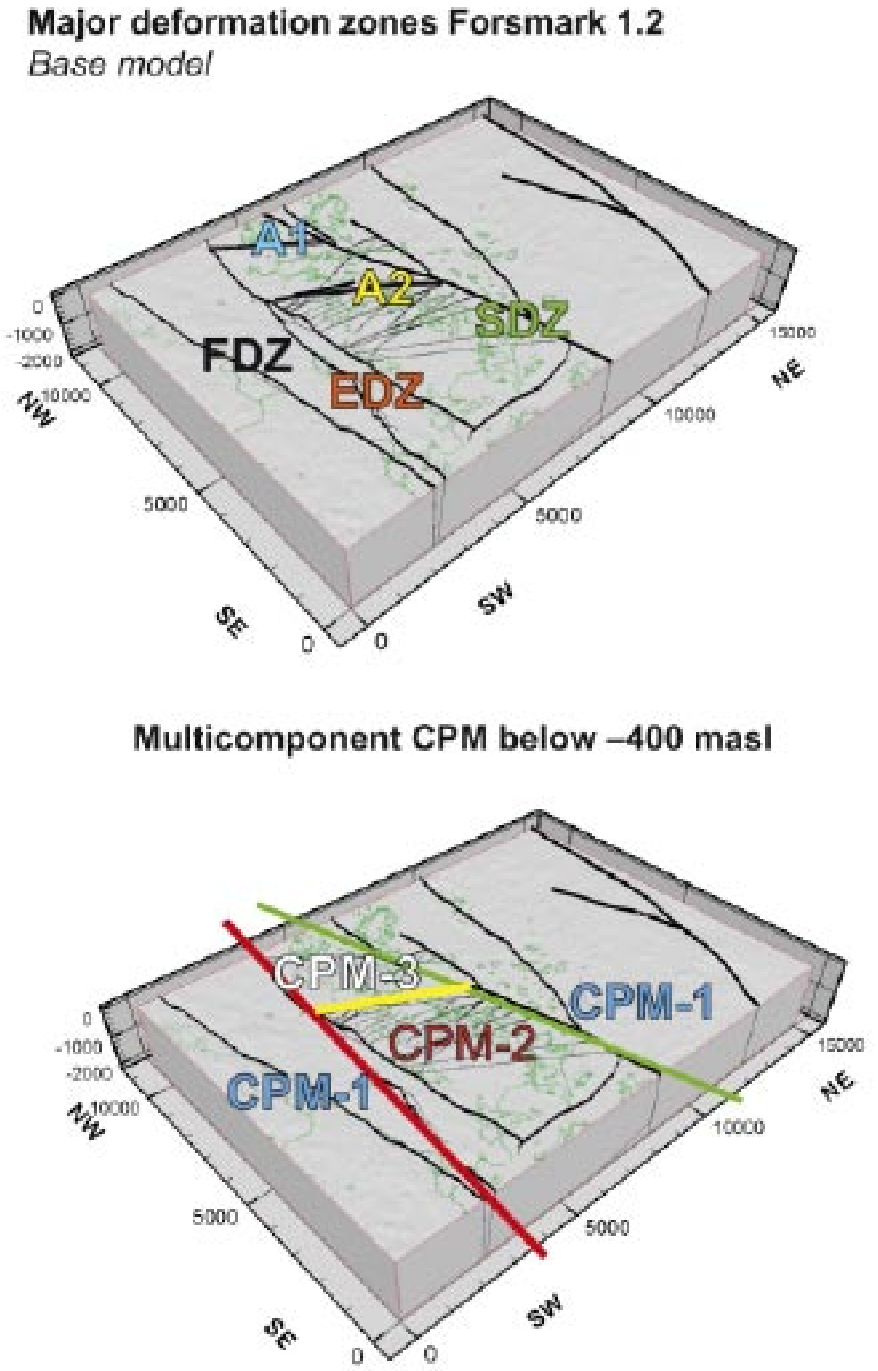


Figure 2-3. *The base case model. Deformation zones (top) and rock blocks in between the zones /SKB 2005/.*

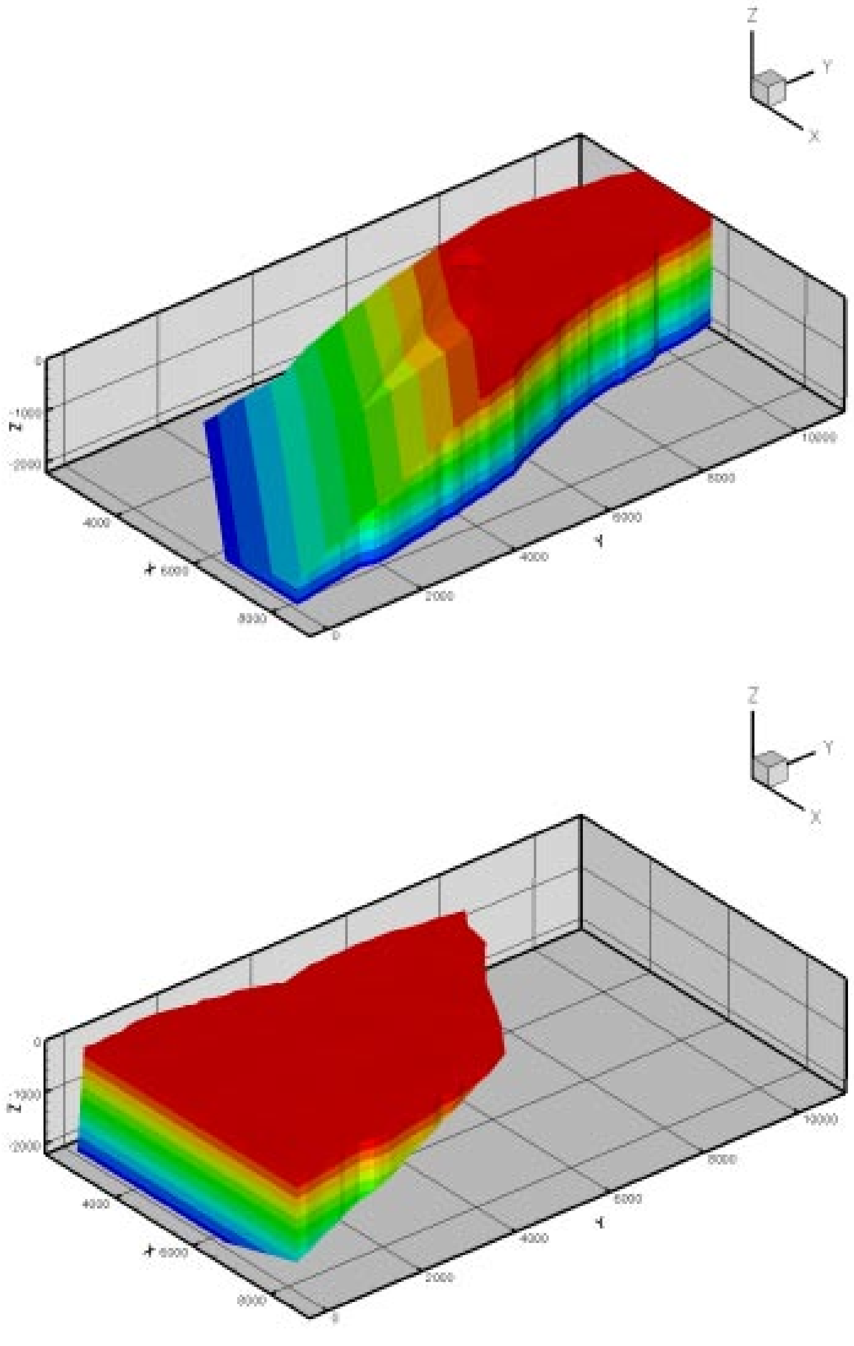


Figure 2-4. Outline of rock volumes CPM3 (top) and CPM2. Colour indicates vertical coordinate. The y-coordinate points in the north-west direction.

3 Mathematical model

For a general description of the basic assumptions and mathematical formulation of DarcyTools, the reader is referred to /Svensson et al. 2006/. In this section some problem specific settings and assumptions will be discussed.

3.1 Properties

As mentioned, the properties should be the same as used in the Site-descriptive model and will for this reason not be discussed here. The present set-up, in contrast to the models used in the Site-descriptive modelling, employs a free surface algorithm. As a consequence the near ground properties need to be calibrated, in particular the hydraulic conductivity. Also the drawdown above the repository requires some considerations regarding the conductivity. In Table 3-1 the settings used are summarized. It should be emphasised that this study has not included any "fine trimming" of the surface hydrology part of the model and the values adopted are therefore mainly based on earlier experience and some test simulations. One such "earlier experience" is given by the site model described in /Svensson 1997/, which also applied a free surface condition. The conductivities in the depth interval 20 to 350 metres are due to the defined base case. It is however presently unclear how deep this layer should be and the base case only gives an interval (300 to 400 metres).

Table 3-1. Properties. As the basic fracture network is imported from the Site-descriptive model, only additional properties are given here.

Property	Depth	Values
Porosity (–)	0 → 20 m	$n = 0.05 \times 10^{-depth/20}$ min value = 10^{-3}
	20 m →	min value = 10^{-5}
Conductivity (m/s)	0 → 20 m	$k = 5 \times 10^{-3} \times 10^{-depth/3}$ min value = 10^{-6} $k_{river} = 2$ $k_z = 5 \times 10^{-6}$, constant
	20 m → 350 m	$k_{z,\min} = 5 \times 10^{-8} \times (10^{-1.7 \times (depth-20)/330})$
	350 m →	$k_{\min} = 1 \times 10^{-9}$ (CPM1) $k_{\min} = 5 \times 10^{-10}$ (CPM2) $k_{\min} = 1 \times 10^{-11}$ (CPM3)
Specific Storativity (m^{-1})	above sea level	$S_s = 10^{-3}$
	below sea level	$S_s = 10^{-3} \times 10^{-depth/20}$ min value = 10^{-6}

3.2 Equations

The following equations and algorithms are employed:

- Conservation of mass, including the effects of a variable density and specific storativity.
- A transport equation for salinity.
- The Darcy equation including the gravitational term.
- The subgrid model FRAME, based on the multi-rate diffusion model, is used for both salinity and the precipitation tracer.
- The ground water table is tracked with a free surface algorithm that can handle both natural conditions and the drawdown due to the repository.
- A tunnel routine puts atmospheric pressure in all computational cells in contact with the repository. All cell walls of these cells have a specified maximum conductivity.

For a detailed account of equations and algorithms, see /Svensson et al. 2006/.

3.3 Software

DarcyTools version 3.0 is used in the study. This is the second major project using version 3.0 and the project thus also serves as an evaluation of version 3.0. The reason for using the software is that the unstructured grid option (not available in earlier versions) is needed to resolve the geometry of the repository. Version 3.0 also allows direct import of CAD files in STL format, which is utilized in the present study.

4 Results

4.1 Fractures, properties and grid

It is perhaps a bit unusual to include properties and grid in the result section. However, as the study is partly a feasibility study and the grid resolution is a major new element of the model, it can be justified. As will be shown, also the representation of properties can be classified as a result in itself.

The grid in the horizontal plane is shown in Figure 4-1. Both the grid making up the upper boundary above sea level ("the land cells") and the grid at 415 metres below sea level are shown in the figure. The largest cell size is 128 metres, the surface topography is resolved by a cell size of 64 metres and streams by cells with a dimension of 32 metres. Around the repository a grid size of 32 metres is used. In Figure 4-2 this area is enlarged and one can see the tunnel system. Figure 4-3 gives a further enlargement and one can now discern the smallest cell size used, which is 4 metres. This high resolution is needed to resolve the deposition holes individually. A vertical section through the repository is shown in Figure 4-4. From a depth of 2,100 metres a cell size of 128 metres is used; however from 500 metres depth and upwards the maximum size is 32 metres. The vertical resolution close to the top boundary is 2 metres. In total about 0.8 million cells are required to specify the problem as outlined.

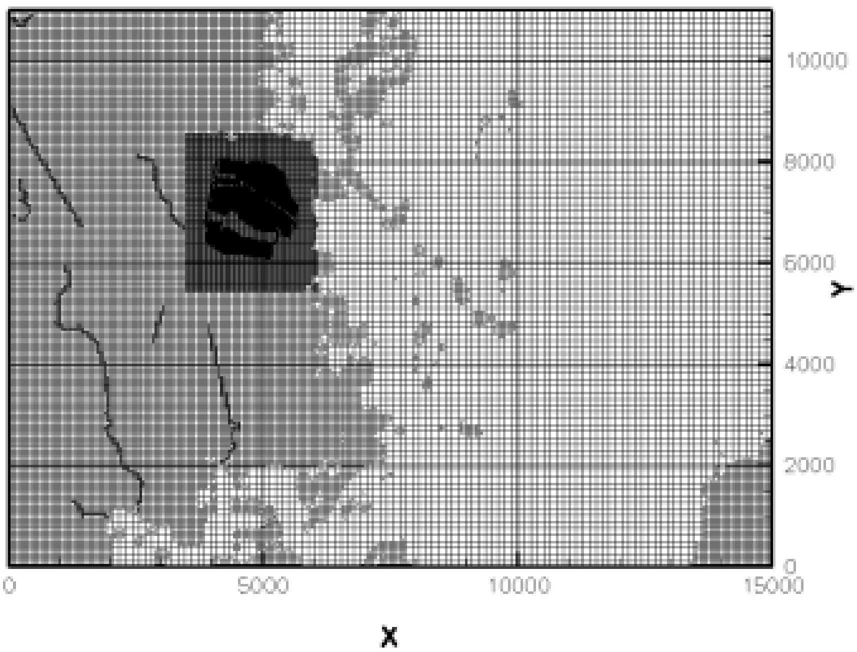


Figure 4-1. *Computational grid. Horizontal plane at ground level and 415 metres below sea level. The y-coordinate points in the north-west direction.*

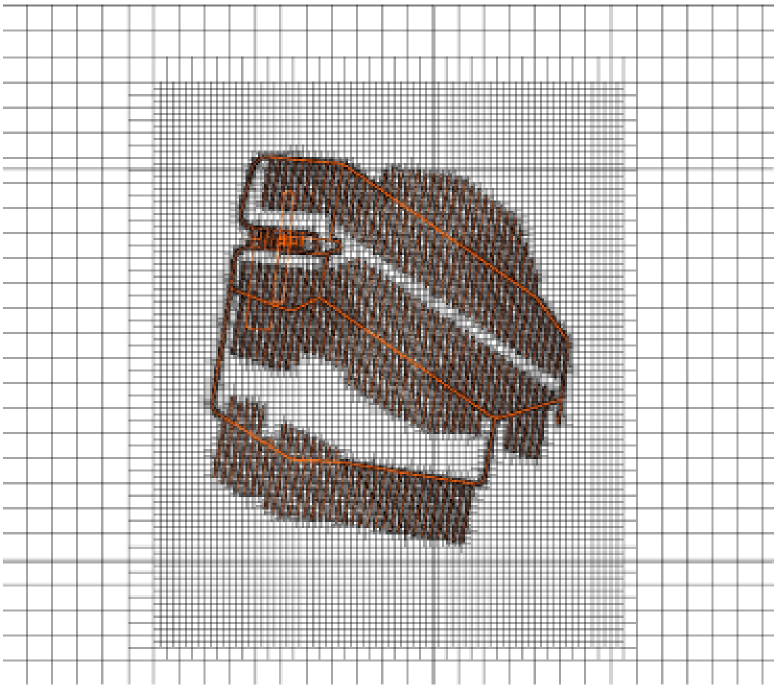


Figure 4-2. *Enlargement of Figure 4-1, with focus on the repository. Depth = 415 metres (metres below sea level).*

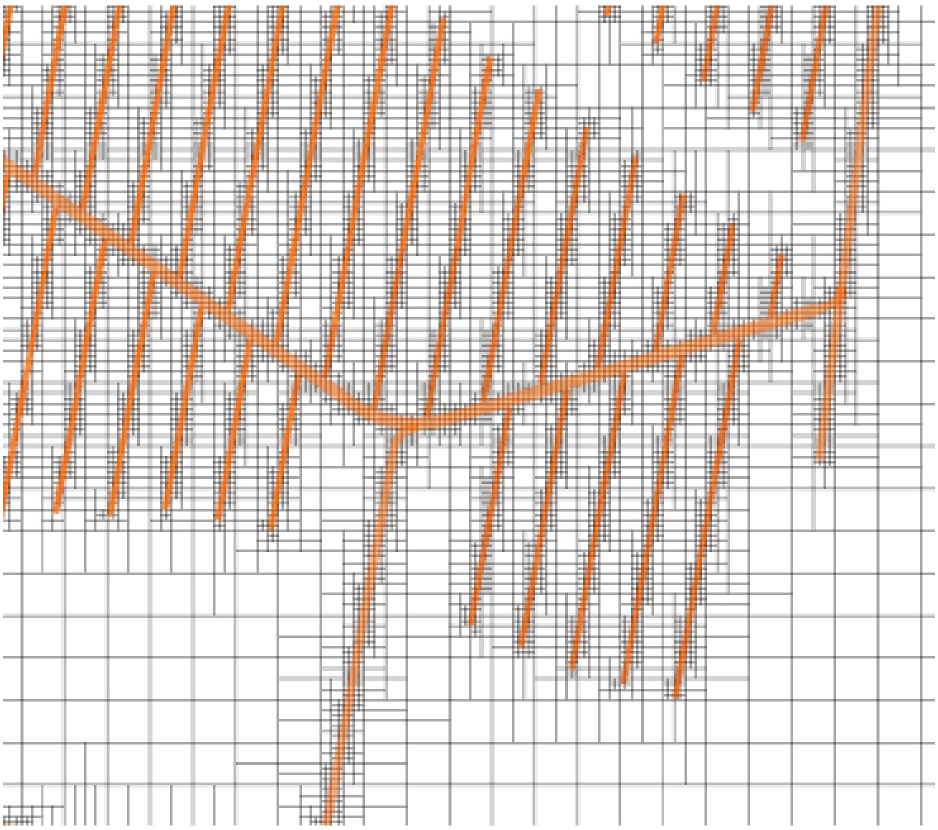


Figure 4-3. *Enlargement showing the south-east part of the repository. Depth = 415 metres (metres below sea level).*

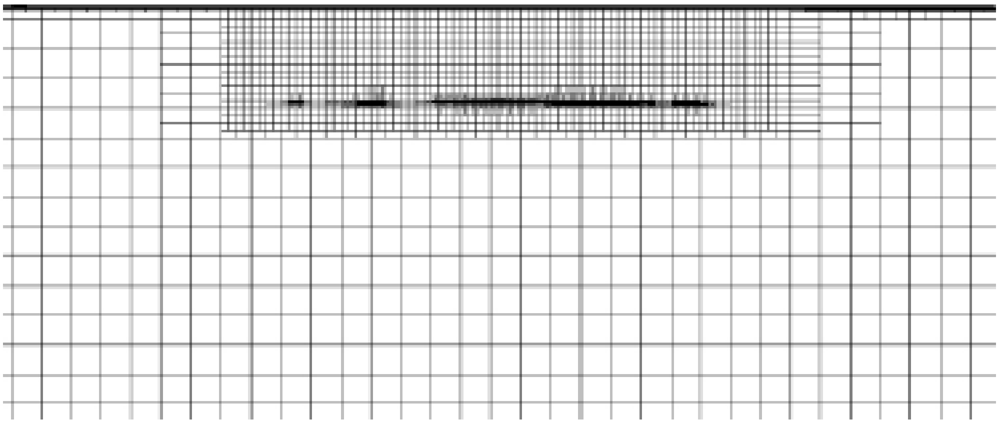


Figure 4-4. *Vertical section (south-west to north-east) through the repository area.*

The repository is located in volume CPM3, which has a background conductivity of 10^{-11} m/s. Considering this, it is clear that the inflow to the repository is governed by zones and fractures in contact with the repository. In Figure 4-5, the vertical permeability field around the repository is illustrated by two vertical sections and a horizontal plane at a depth of 415 metres below sea level. As can be seen, a few zones are crossing the southern part of the repository, while no zones are found in the northern part. Another illustration of the fracture crossings is given by Figure 4-6. The fractures crossing have a transmissivity of 10^{-7} m^2/s, or lower, and it is quite clear already from these illustrations that the total inflow to the repository will be small. It should also be mentioned that parts of the repository above a depth of 100 metres below sea level are not included in the analysis. This is due to the method used to calculate the inflow to the tunnel (can be improved).

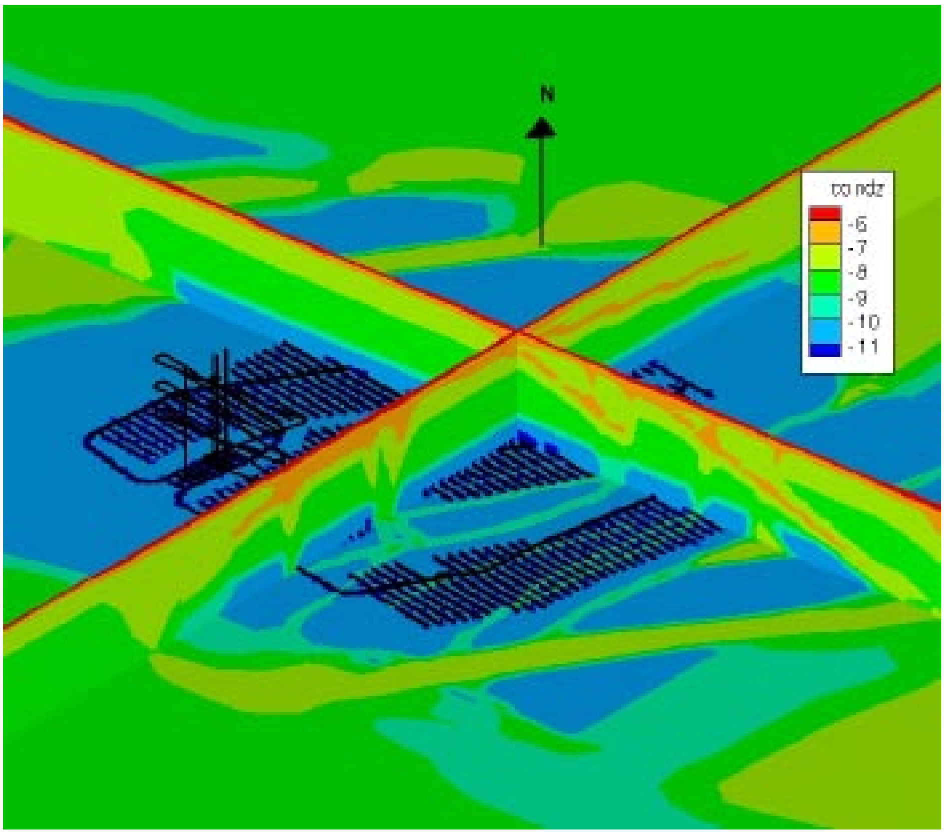


Figure 4-5. *The log_{10} vertical conductivity in two vertical sections and one horizontal (at 415 metres below sea level) plane around the repository.*

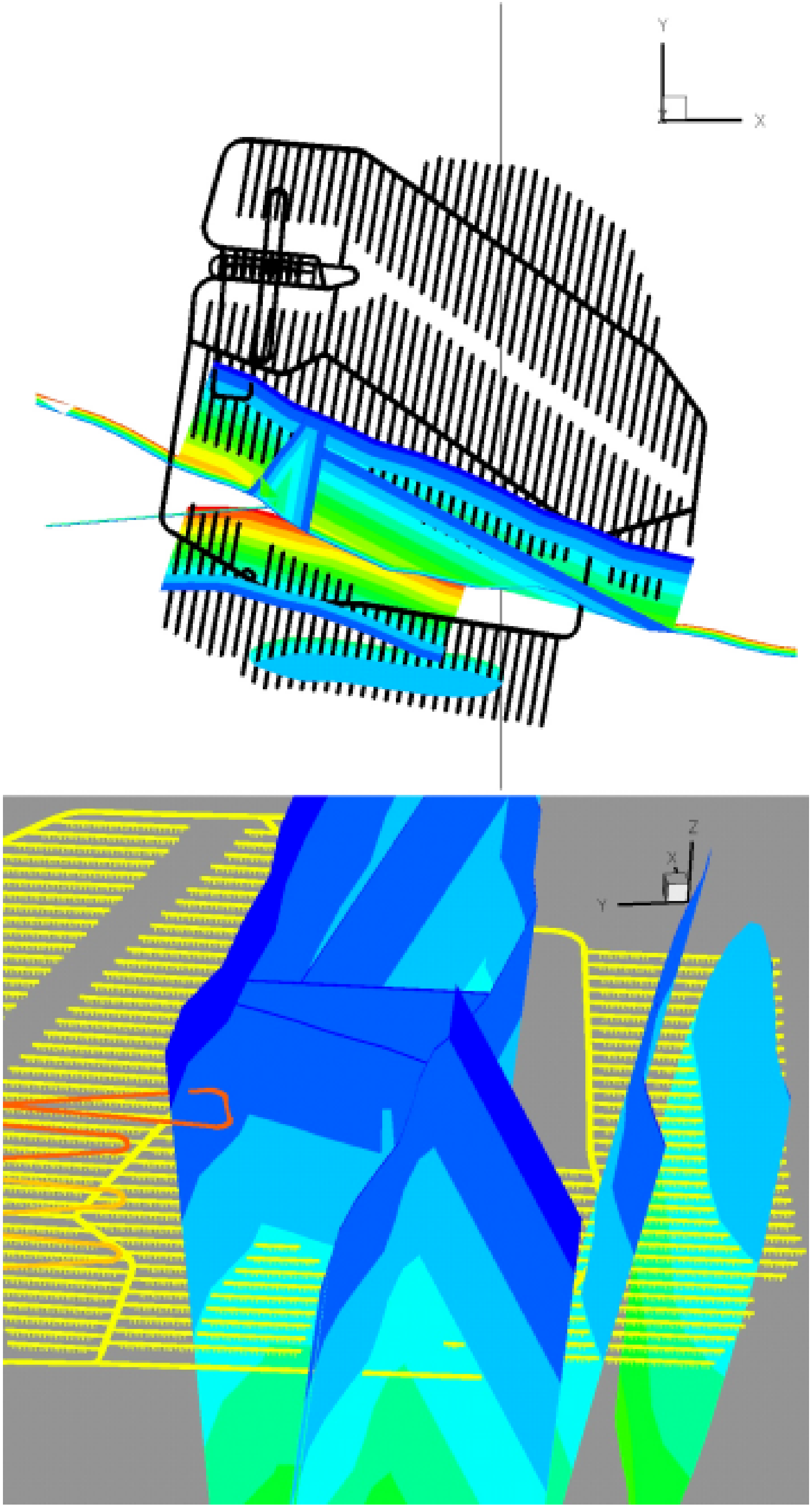


Figure 4-6. *Illustration of the fracture zones that are in contact with the repository. Horizontal plane (top) and a perspective view. The zones are coloured with respect to vertical coordinate. The y-coordinate points to north-west.*

4.2 Natural conditions

The natural, or undisturbed, conditions are needed as a reference when the tunnel effects are estimated. Another argument for studying the undisturbed situation is that the surface hydrology part of the model should be calibrated for undisturbed conditions. Due to time constraints this will however not be undertaken in the present study, instead some estimates based on earlier experiences are used.

The saturation level at ground level is shown in Figure 4-7, together with the flow vectors of the streams. In the streams that discharge water from Bolundsfjärden and Fiskarfjärden the flow rates were calculated to 26 and 34 l/s, respectively. Field data indicate that the flow in these streams is very irregular, but the magnitude seems to be in agreement with the present estimates.

The salinity distribution in two vertical sections is shown in Figure 4-8. The depth of the fresh water is found to increase towards main land.

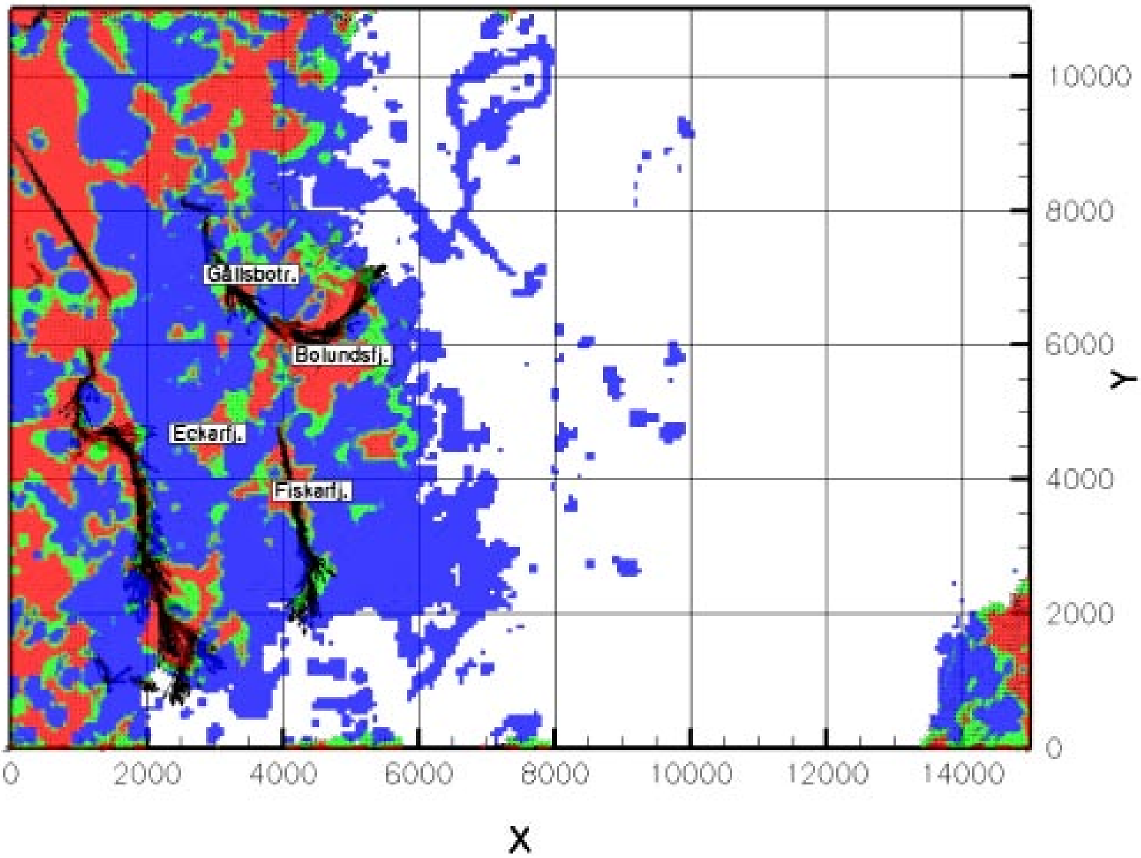


Figure 4-7. *The saturation level at ground level. Red colour indicates fully saturated conditions, blue a groundwater table lower than two metres below ground and green colour indicates that the groundwater table is between 0 to 2 metres below ground level.*

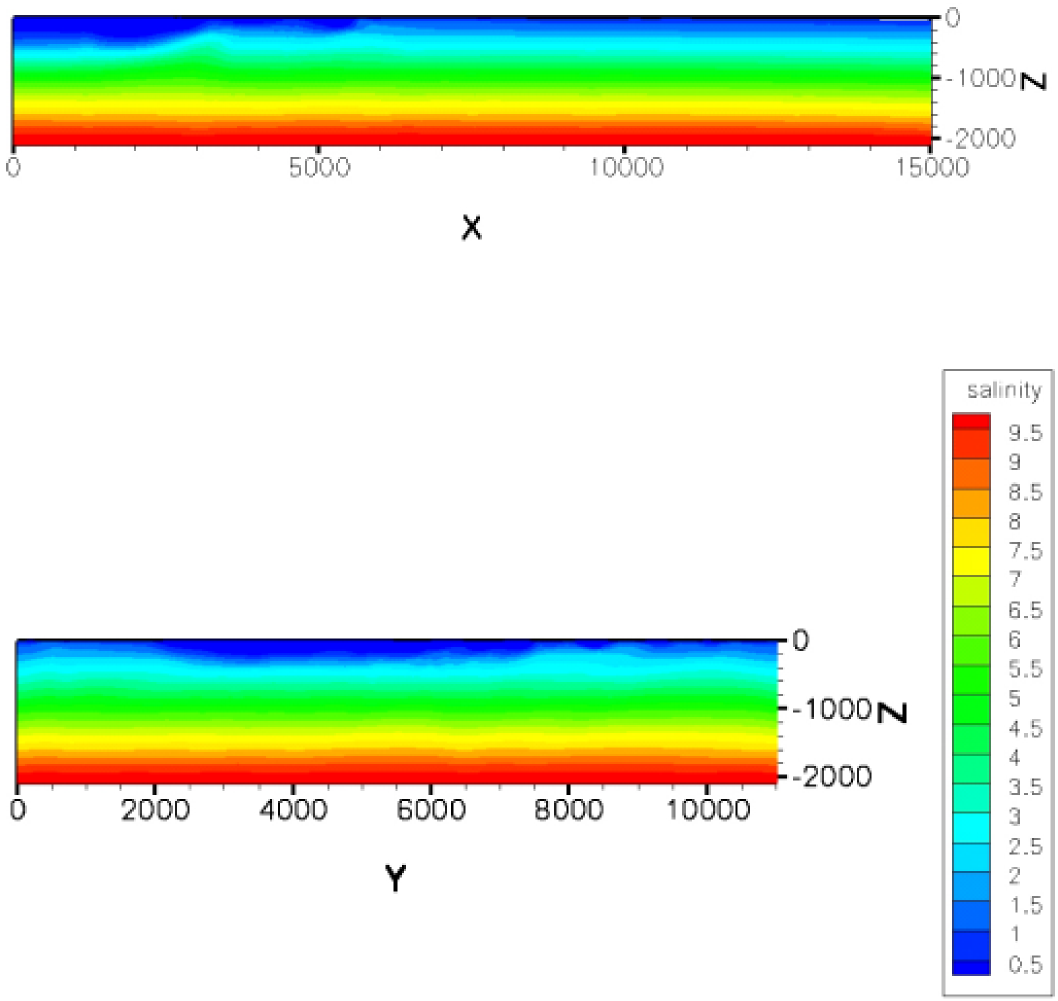


Figure 4-8. *Salinity (in %) distribution in a west-east (top) and south-north vertical section through the repository.*

In the simulations discussed, the net recharge was set to 205 mm/year, uniformly distributed in the horizontal plane. In reality one can expect that the recharge varies with respect to land use, vegetation, etc. A test of this effect was carried out, by introducing a recharge with a certain spatial distribution, provided by the surface hydrology model MIKE SHE (Bosson 2005, pers. communication). The distribution is shown in Figure 4-9 and the corresponding ground level saturation pattern is found in Figure 4-10. By comparing this figure with Figure 4-7, it can be concluded that the effect of a spatially varying recharge on the saturation at ground level is small.

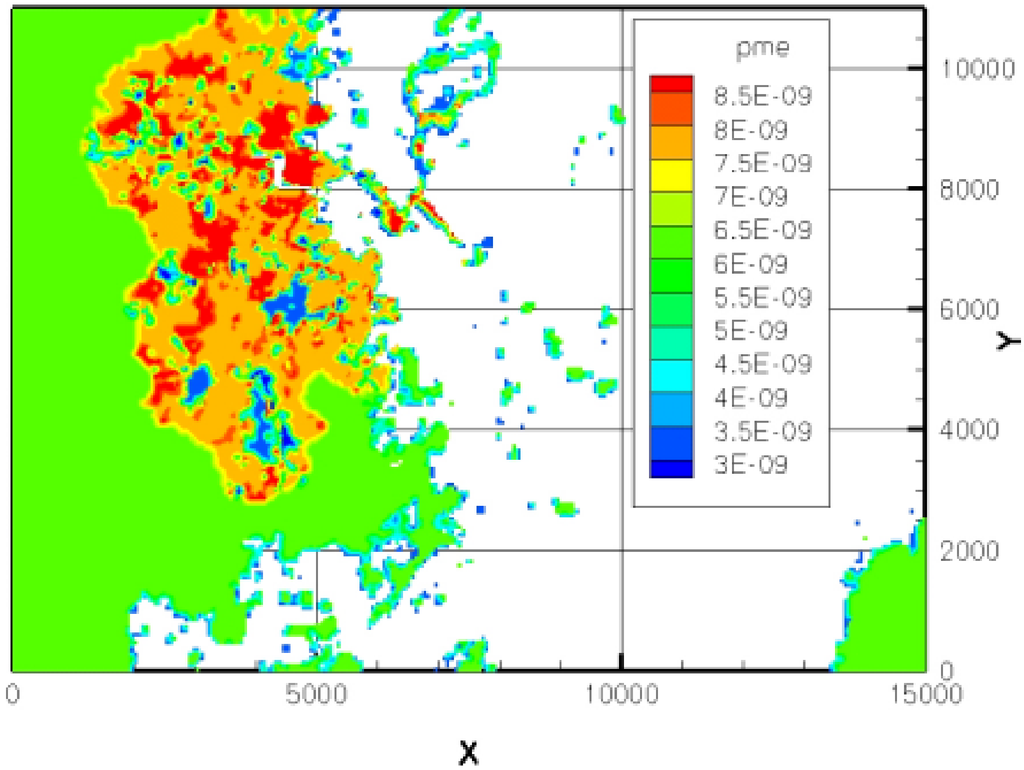


Figure 4-9. *Spatial distribution of recharge (in m/s). The area with a variable recharge is the area considered by the surface hydrology model; outside this area a constant recharge is used. In the legend pme means "precipitation minus evapotranspiration".*

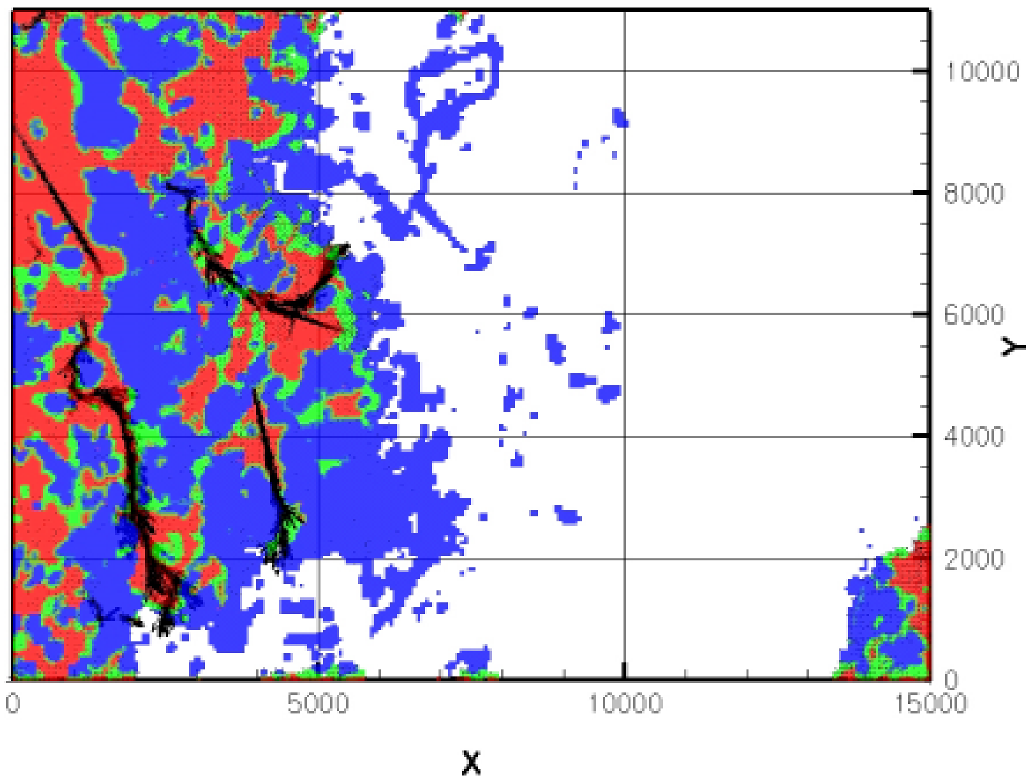


Figure 4-10. *The saturation level at ground level for a recharge with a spatial distribution. For further legend, see Figure 4-7.*

4.3 Open repository

It has been specified that simulations of the open repository should be done for three different time periods (parts of the system open and other parts backfilled). However, scoping calculations indicated that the total inflow to the system is small, even for the case with the whole system open and no grouting. There is hence no reason to consider a partly open repository.

The total inflow to the complete repository is given in Table 4-2, for a range of grouting alternatives. The resistance due to grouting was specified as a maximum allowed conductivity for all cells in contact with the repository. A maximum conductivity of 10^{-7} m/s thus implies that all conductivities larger than this value are reduced to 10^{-7} m/s. Table 4-2 clearly shows that the total inflow is very small for the adopted model of the fracture network and rock blocks ("the base case").

The effect on the salinity field can be studied in Figure 4-11. Only the case with no grouting is illustrated, as the effect is small even for this case.

Table 4-2. Total inflow, as a function of applied grouting.

Maximum allowed conductivity [m/s]	Inflow [l/s]
∞	4.0
10^{-7}	4.0
10^{-9}	1.9
10^{-11}	0.05

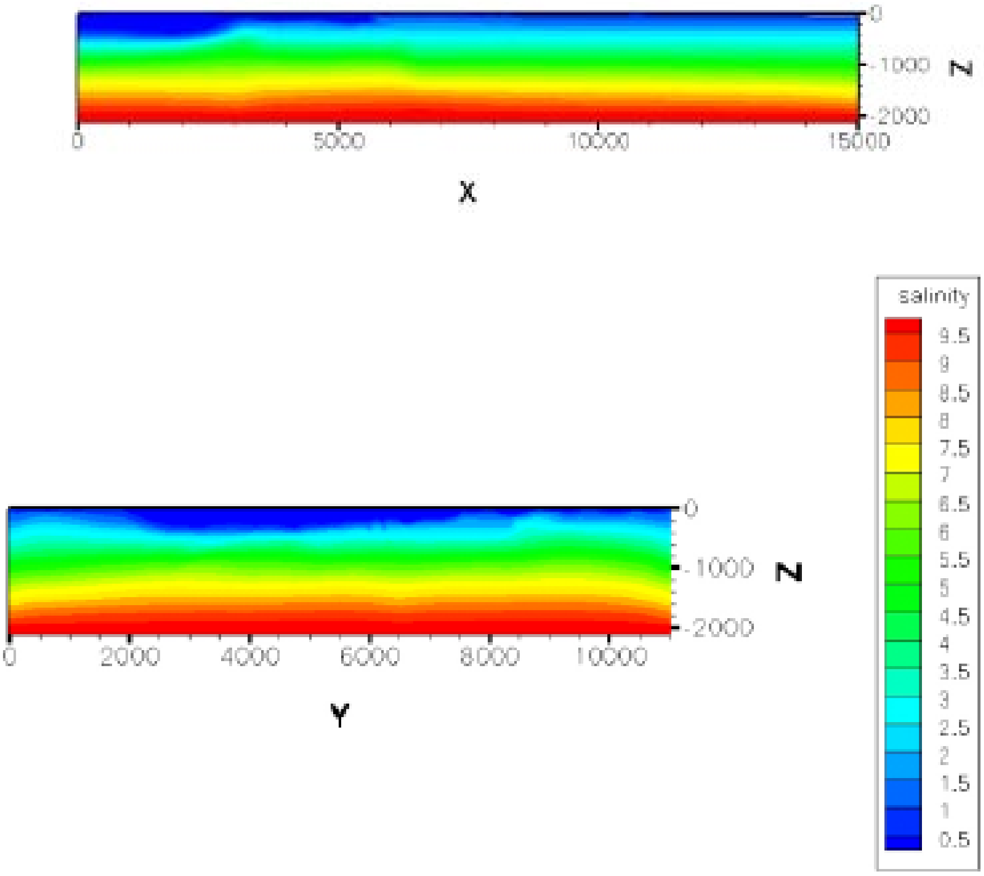


***Figure 4-11.** Salinity (in %) distribution in a west-east (top) and south-north vertical section through the repository. Repository present, with no grouting applied.*

One of the few effects of different grouting levels is illustrated in Figure 4-12. If no grouting is applied, the pressure will be nearly uniform in the repository area, while the background pressure dominates when grouting is significant. The pressure effect is hence large at repository level and one may ask how close to ground level this effect can be identified. In Figure 4-13 the pressure field, at a depth of 50 metres below sea level, for undisturbed conditions is compared to the case with an inflow of 4.0 1/s. The repository is located at $x \approx 4{,}000$ metres and $y \approx 7{,}000$ metres. In this area we find that the head difference ($p/\rho_0 g$) is about 1 to 2 metres. As the conductivity increases towards ground level, it is not surprising to find that the ground water table is insignificantly affected by the repository.

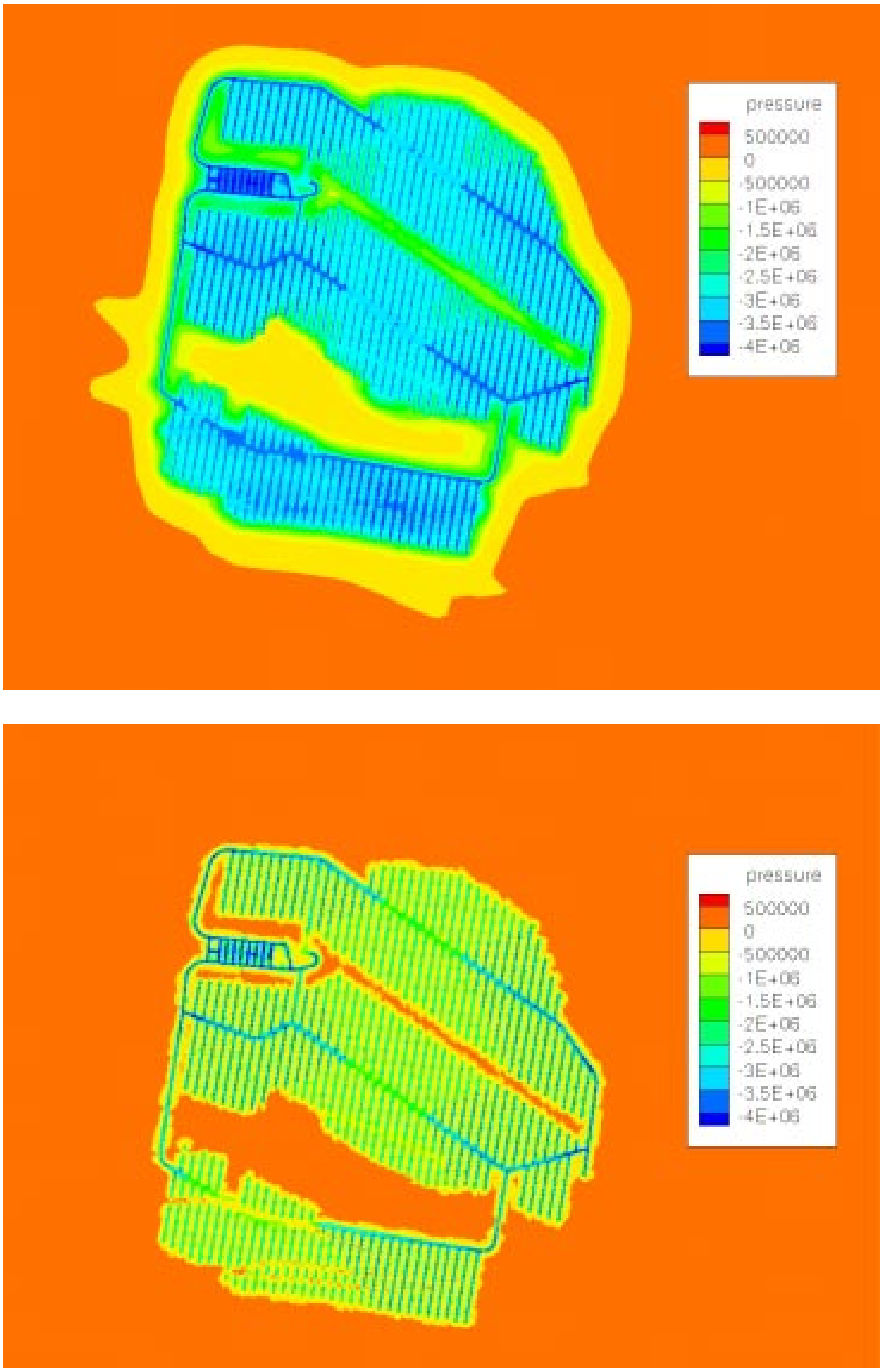
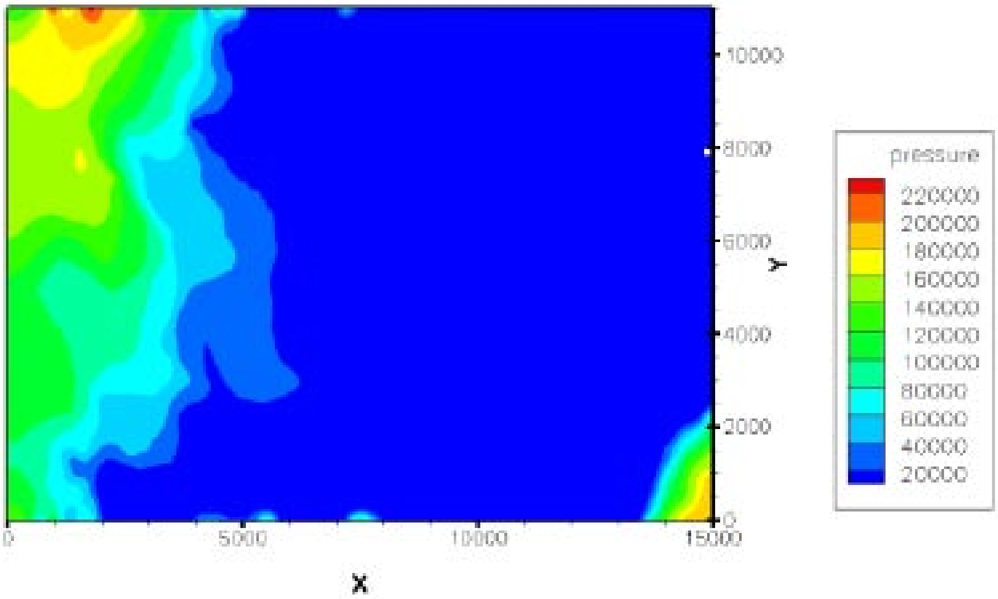


Figure 4-12. *Pressure (excluding the hydrostatic component) (in Pa) distribution around the repository, at 415 metres below sea level. No grouting applied (top) and maximum conductivity specified to 10^{-11} m/s.*



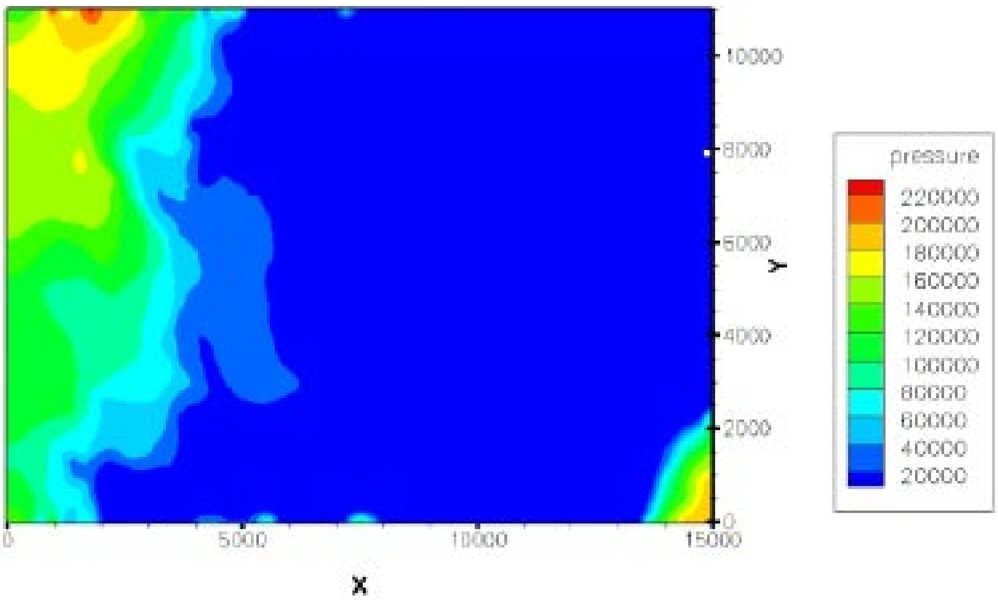


Figure 4-13. *Pressure (excluding the hydrostatic component) (in Pa) distribution at a depth of 50 metres below sea level for undisturbed conditions (top) and with repository present.*

4.4 Resaturation phase

On of the objectives of the present work is to estimate the time for resaturation of the backfill. When the backfill is placed in the tunnels, one can expect that the voids are partly filled with water and partly with air. During the saturation process the trapped air thus has to escape somehow (dissolved in the water or rising in form of air bubbles) and the pore space is filled with water. This is a two-phase problem. An illustration of the process is given in Figure 4-14. The transport of water is governed by two processes, a Darcy-flux with a conductivity which is a function of the saturation level and a suction present in the unsaturated part. DarcyTools does not account for two-phase flow and a method that simulates the process by a single-phase approach is therefore sought for. In Figure 4-14 such an approach is illustrated. The storativity term is used to “create” new open volume and a modified conductivity is employed. As we know the total pressure rise (from atmospheric to hydrostatic pressure at repository depth) a suitable storativity coefficient can be chosen. In a two-phase simulation the reduction of the

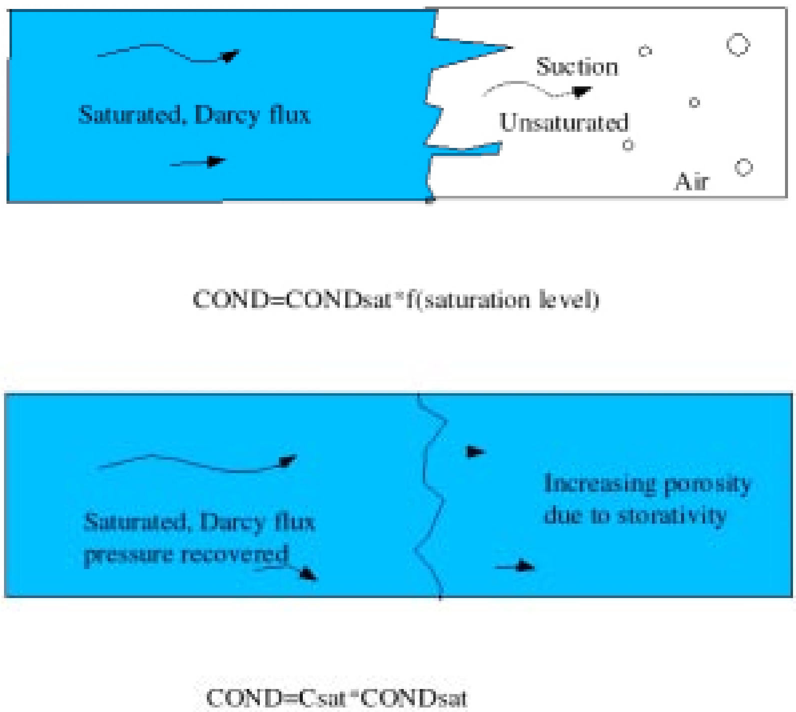


Figure 4-14. *The saturation process. Illustration of physical processes (top) and the approach tested in the present work.*

conductivity due to the saturation level, may be several orders of magnitude. In the suggested method we expect c_{sat} to be smaller than 1.0, but the reduction should be less dramatic as the suction is neglected and now has to be accounted for by the Darcy-flux. The coefficient c_{sat} has to be found from a calibration and can of course not be expected to be general, i.e. it needs to be calibrated for conditions similar to the application in mind.

In /Börgesson et al. 2005/ two-phase simulations of the saturation of a rock-backfill system are presented. Comparisons with cases ab4, ab5, ac4 and ac5, in this report, will be done, as these cases use a backfill conductivity of 5×10^{-11} m/s and a rock conductivity that varies from 2.5×10^{-11} to 5×10^{-10} m/s. The cases can be considered as one-dimensional (in cylindrical coordinates). At one boundary a pressure is specified and a flow starts from this end, through the rock and eventually into the backfill part. The saturation at the other boundary (in the backfill) is then recorded. In the simulations the pressure was raised to 5,000 *kPa* and the time to full saturation was noted. For further detailes about the two-phase simulations, see /Börgesson et al. 2005/.

The simple method, outlined in Figure 4-14, was applied to the same cases with the objective to find a suitable c_{sat}. It was found that $c_{sat} = 0.8$ produces saturation times which compare well with the ones given by /Börgesson et al. 2005/, see Figure 4-15. In this figure both the time to reach 90 and 99% pressure recovery is presented.

Next applications to Forsmark conditions are considered. Two 2D cases are studied, one resembling the situation when a fracture zone crosses the tunnel and the other without a fracture zone. As these cases are still idealized no salinity effects were included.

The case without a zone crossing is perhaps closer to the situation considered above, as it will be assumed that the saturation front moves radially. An outline of the situation studied is given by Figure 4-16. The centre of the tunnel is located at a depth of 400 metres and the domain size 1,000×1,000 metres. The rock surrounding the tunnel has a conductivity of 10^{-11} m/s (Rock Block CPM3) and the conductivity of the backfill is 5×10^{-11} 0.8×10^{-10} m/s. The distance to the more permeable rock above the tunnel is uncertain and we will study the resaturation time as a function of the distance h. In Table 4-3 the time scales t_{90} and t_{99} are given as a function of h. It is found that the resaturation time is of the order 15 to 50 years.

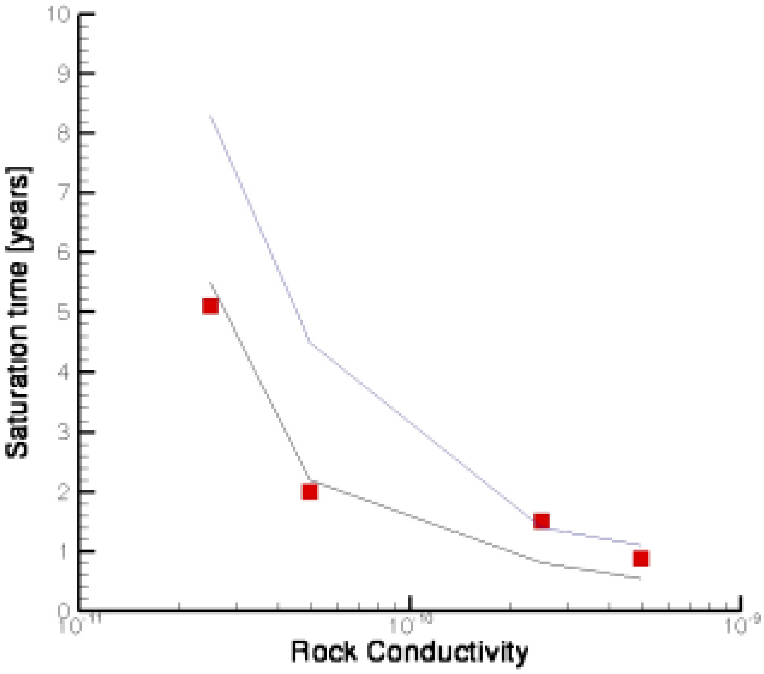


Figure 4-15. Saturation times for four cases presented in /Börgesson et al. 2005/. Black line gives t_{90}, blue line t_{99} and symbols the results by /Börgesson et al. 2005/.

Table 4-3. Saturation times for the case outlined in Figure 4-16.

Distance to permeable layer [h]	Inflow to open tunnel [l/s]	t_{90} years	t_{99} years
100	5.6×10^{-6}	33	52
50	6.7×10^{-6}	27	42
25	8.3×10^{-6}	22	34
10	12.0×10^{-6}	15	24

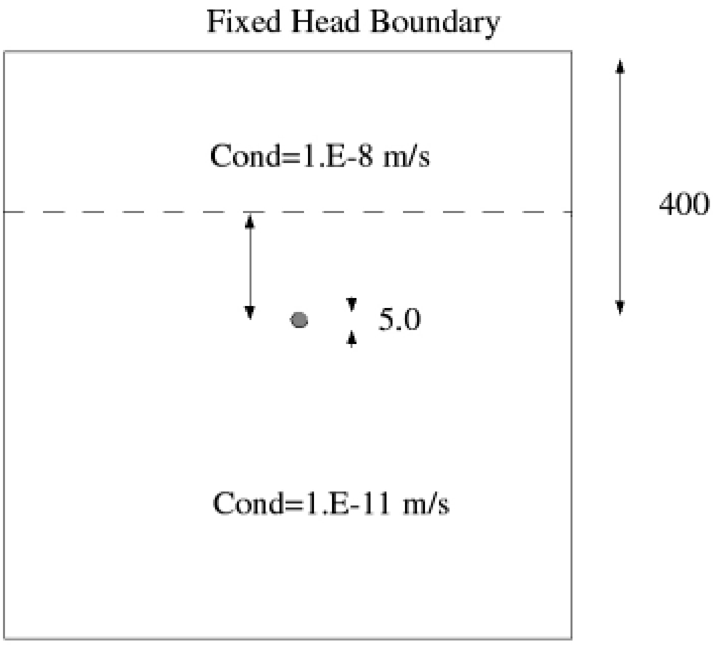


Figure 4-16. A 2D vertical section illustrating radial saturation for Forsmark conditions.

An illustration of the process can be found in Figure 4-17. As can be seen, the minimum pressure head is –280 metres and the process has thus advanced a bit from the initial –400 metres (Note that the hydrostatic pressure component has been removed). The flow vectors also indicate that the porosity is increasing (simulating the escaping air) as all flow vectors point towards the centre of the tunnel.

The next case attempts to simulate the axial resaturation front, resulting from a fracture zone crossing the tunnel, see Figure 4-18. The fracture zone transmissivity is put to 10^{-7} m^2/s, the backfill conductivity is once again 0.8×10^{-10} m/s and the surrounding rock has a conductivity of 10^{-11} m/s. A fixed pressure at ground level recharges the fracture zone. The pressure and flow fields after 40 and 500 years can be studied in Figure 4-19. After 40 years the minimum pressure head is still –400 metres, while it has increased to –380 metres after 500 years. The tentative conclusion is hence that axial resaturation is slower than radial for the Forsmark conditions.

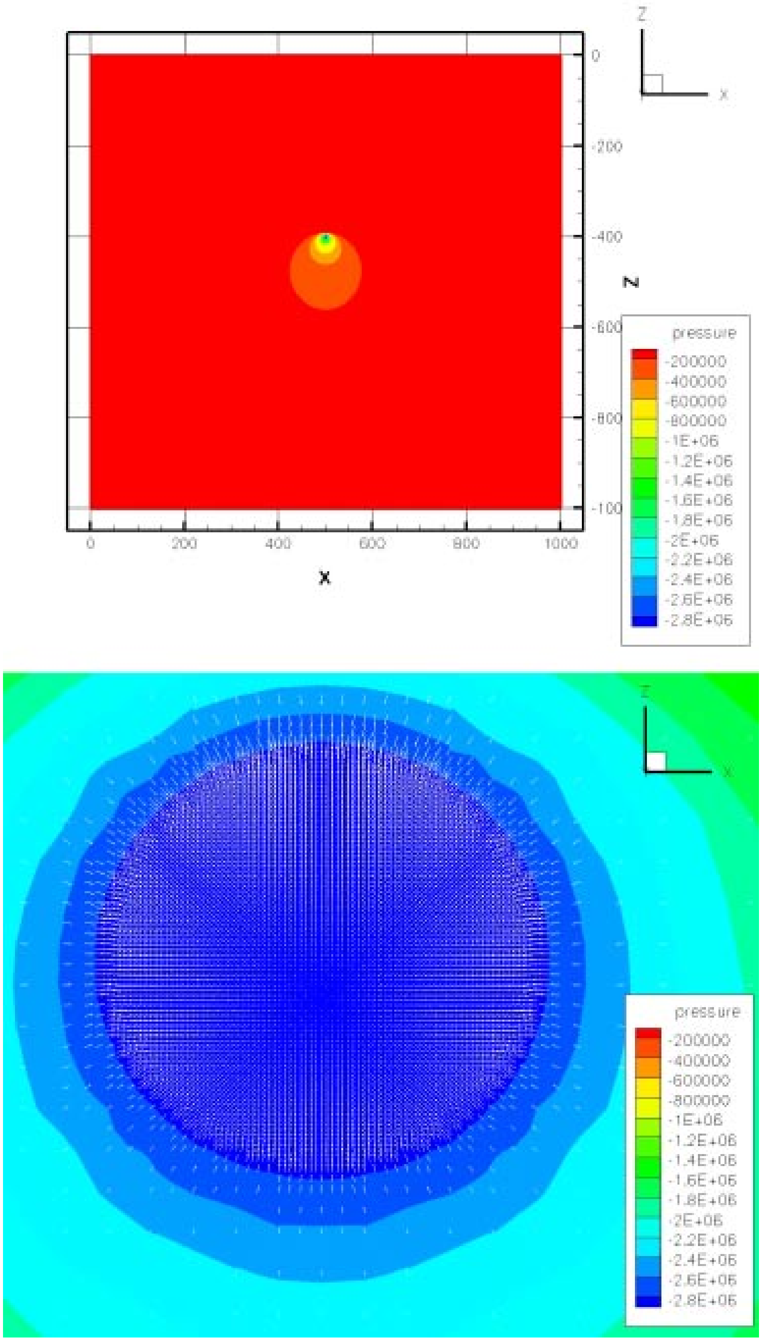


Figure 4-17. *Radial saturation. Pressure (excluding the hydrostatic component) (in Pa) distribution in whole domain (top) and pressure and flow vectors in and around the tunnel.*

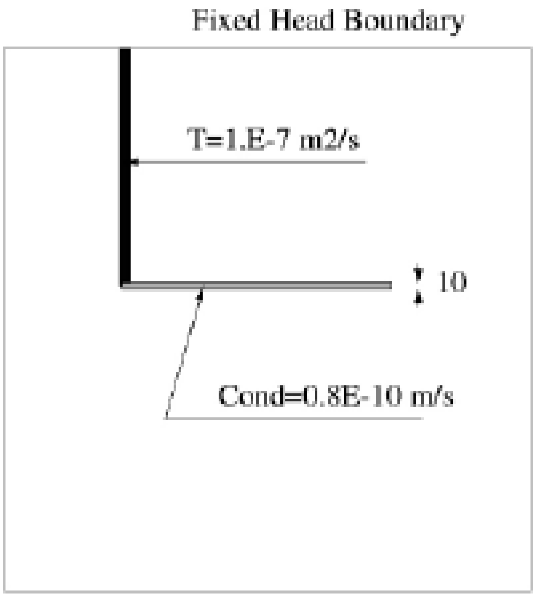


Figure 4-18. *A 2D vertical section illustrating axial saturation for Forsmark conditions.*

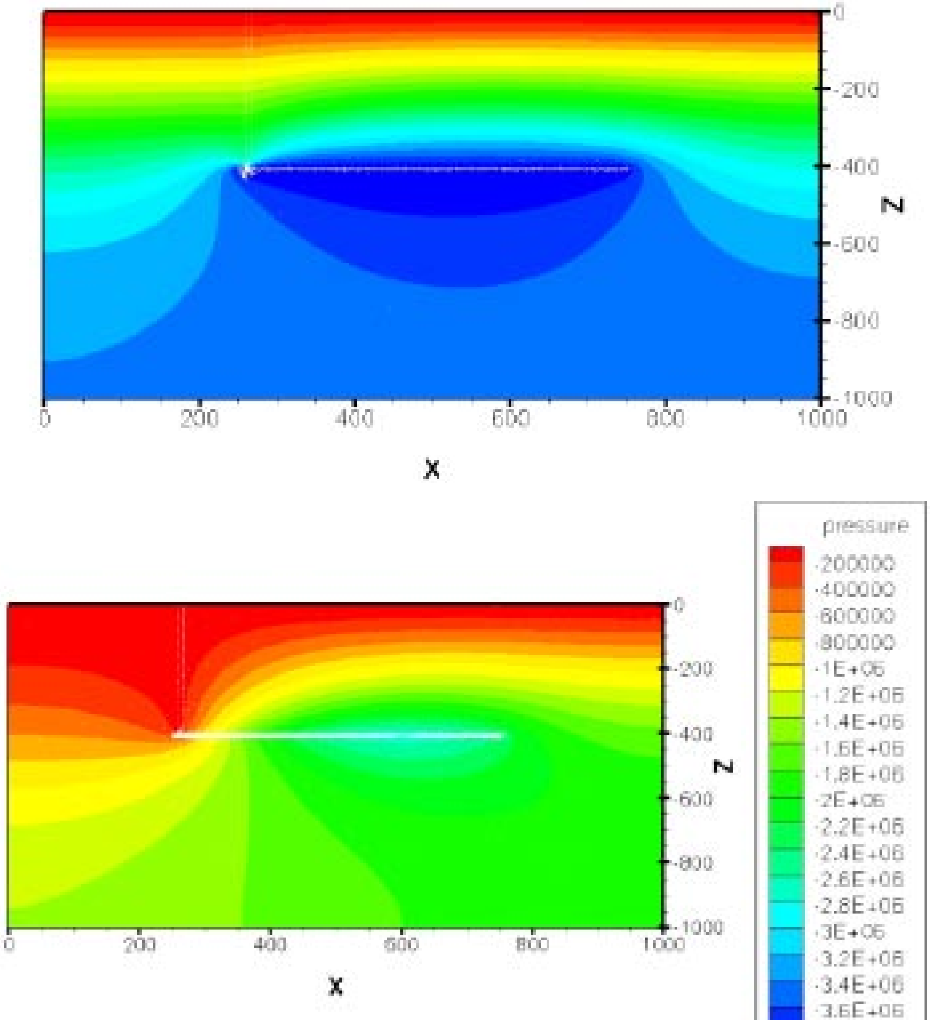


Figure 4-19. *Axial saturation. Pressure (excluding the hydrostatic component) (in Pa) and flow vectors after 40 (top) and 500 years.*

5 Discussion

Most of the objectives listed for this study concern a disturbance caused by an inflow to the tunnel. For the base case fracture network and rock block properties, the simulations do however indicate that the inflow is very small indeed and consequently the disturbances are also insignificant. For this reason the discussion about uncertainties will be a discussion about the relevance of the base case model; this discussion should be the concern of the Site-descriptive model and is hence considered to be outside the scope of the present project. So, instead of "uncertainties" the discussion section will focus on some of the developments utilized in this report; what they are, and how the methods can be further refined.

- Surface hydrology. In this project a spatially varying recharge was imported. A possible continuation of this approach could be to import a "ground surface conductivity factor", which should allow for a spatially varying conductivity in the top few metres of the soil cover. The present model has been demonstrated (see Figure 4-7) to generate lakes at the correct positions. However, it is realized that to be able to predict water levels and outflows from lakes a detailed analysis of the representation of topography in the model is required. The levels and outflows may be totally determined by a threshold value. In hindsight, it is realized that the topography representation in the present model is too coarse.
- Resaturation. A new method to simulate the backfill resaturation process has been tested in this project. It is too early to conclude anything about the potential, but if it proves useful it can probably be used in 3D high resolution models without problems. One should further note that the suction pressure and a conductivity that is a function of the local saturation level can be introduced, while still staying within the single phase constitutive equations. It is the use of the storativity term that is the "key trick".
- Tunnel inflows. The grouting effect is now simulated by "a maximum allowed conductivity in the cells in contact with the repository". This method ensures that all flow paths to the tunnel are controlled and setting the maximum value to zero gives zero inflow to the tunnel. However, one may argue that the cell size has nothing to do with the penetration length of the grout. Instead it may be more realistic to specify the penetration length and test all conductivities within this volume. Such a development is not difficult to implement, if considered needed. Presently the total inflow to the repository is the only output parameter. It may be of interest to have the distribution along all tunnels and deposition holes, not only of the inflow but also of the related salinity and concentration of other scalar quantities (for example "water types").

These are some of the current issues of development. Considering these in the further work will improve simulation capabilities; however, the main uncertainty is due to the conceptualization and knowledge of the host rock.

6 Conclusions

The outcome of the study can be viewed from two aspects; the capability and development of the simulation tool (important for future tasks) and the results concerning the Forsmark repository. The first aspect is considered to be covered by the discussion section and here we focus on the conclusions regarding the Forsmark repository.

- The total inflow is expected to be very small (< 10 1/s) and all corresponding effects (upconing, drawdown, etc) are accordingly small. This result is attributed to the model of the fracture network and rock blocks adopted.
- The resaturation time of the backfill is calculated to 15 to 50 years. It is expected that the wetting front is dominated by a radial inflow. It should be pointed out that the method used to obtain the resaturation time is not based on standard techniques and needs further testing and development.

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