International
Progress Report

IPR-08-03

Äspö Hard Rock Laboratory

Planning Report for 2008

Svensk Kärnbränslehantering AB

January 2008

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Äspö Hard Rock
Laboratory

The Äspö Hard Rock Laboratory
Planning Report for 2008

This report presents the planned activities for the year 2008. The report is revised annually and details the programme carried out in the Äspö Hard Rock Laboratory as described in SKB's Research, Development and Demonstration Programme 2007, and serves as a basis for the management of the laboratory. The role of the Planning Report is to present the plans and scope of work for each project. Thereby the quarterly Status Reports may concentrate on work in progress and refers to this Planning Report for scope of work over the year. Background information on the projects is given in the Annual Report as well as findings and results.

Svensk Kärnbränslehantering AB

Anders Sjöland

Executive Secretary of the Technical-Scientific Council

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1 General

1.1 Background

The Äspö Hard Rock Laboratory (HRL), located in the Simpevarp area in the municipality of Oskarshamn, constitutes an important part of SKB's work with design and construction of a deep geological repository for final disposal of spent nuclear fuel. This work includes the development and testing of methods for use in the characterisation of a suitable site. One of the fundamental reasons behind SKB's decision to construct an underground laboratory was to create an opportunity for research, development and demonstration in a realistic and undisturbed rock environment down to repository depth. Most of the research is concerned with processes of importance for the long-term safety of a future final repository and the capability to model the processes taking place. Demonstration addresses the performance of the engineered barriers and practical means of constructing a repository and emplacing the high-level nuclear waste.

The underground part of the laboratory consists of a tunnel from the Simpevarp peninsula to the southern part of Äspö where the tunnel continues in a spiral down to a depth of 460 m, see Figure 1-1. The total length of the tunnel is 3,600 m where the main part of the tunnel has been excavated by conventional drill and blast technique and the last 400 m have been excavated by a tunnel boring machine (TBM) with a diameter of 5 m. The underground tunnel is connected to the ground surface through a hoist shaft and two ventilation shafts.

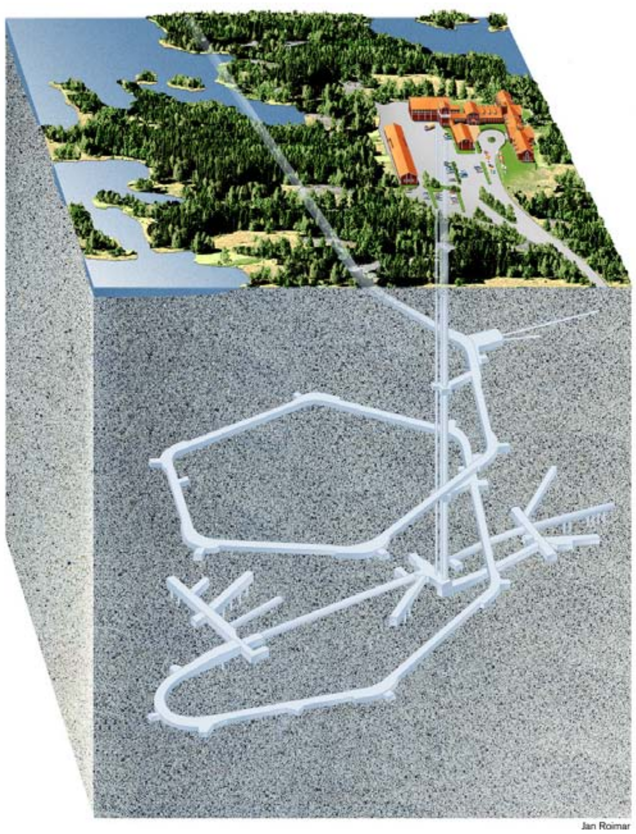


Figure 1-1. *Overview of the Äspö HRL facilities.*

1.2 Goals

To meet the overall time schedule for SKB's RD&D work, the following stage goals were initially defined for the work at the Äspö HRL:

1. *Verify pre-investigation methods*. Demonstrate that investigations on the ground surface and in boreholes provide sufficient data on essential safety-related properties of the rock at repository level.

2. *Finalise detailed investigation methodology*. Refine and verify the methods and the technology needed for characterisation of the rock in the detailed site investigations.

3. *Test models for description of the barrier functions at natural conditions*. Further develop and at repository depth test methods and models for description of groundwater flow, radionuclide migration and chemical conditions during operation of a repository as well as after closure.

4. *Demonstrate technology for and function of important parts of the repository system*. In full scale test, investigate and demonstrate the different components of importance for the long-term safety of a final repository and show that high quality can be achieved in design, construction and operation of repository components.

Stage goals 1 and 2 have been concluded at Äspö HRL and the tasks were transferred to the Site Investigations Department of SKB which has performed site investigations at Simpevarp/Laxemar in the municipality of Oskarshamn and at Forsmark in the municipality of Östhammar.

In order to reach present goals (3 and 4) the following important tasks are today performed at the Äspö HRL:

- Develop, test, evaluate and demonstrate methods for repository design and construction as well as deposition of spent nuclear fuel and other long-lived waste.
- Develop and test alternative technology with the potential to reduce costs and simplify the repository concept without sacrificing quality and safety.
- Increase the scientific understanding of the final repository's safety margins and provide data for safety assessments of the long-term safety of the repository.
- Provide experience and train personnel for various tasks in the repository.
- Provide information to the general public on technology and methods that are being developed for the final repository.
- Participate in international co-operation through the Äspö International Joint Committee (IJC) as well as bi- and multilateral projects.

1.3 International participation in Äspö HRL

The Äspö HRL has so far attracted considerable international interest. During 2008, eight organisations from seven countries will in addition to SKB participate in the Äspö HRL or in Äspö HRL-related activities. For each partner the co-operation is based on a separate agreement between SKB and the organisation in question.

The participating organisations are:

- Agence Nationale pour la Gestion des Déchets Radioactifs (Andra), France.
- Bundesministerium für Wirtschaft und Technologie (BMWi), Germany.
- Central Research Institute of Electric Power Industry (CRIEPI), Japan.
- Japan Atomic Energy Agency (JAEA), Japan.
- Nuclear Waste Management Organisation (NWMO), Canada.
- Posiva Oy, Finland.
- Nationale Genossenschaft für die Lagerung Radioaktiver Abfälle (Nagra), Switzerland.
- Radioactive Waste Repository Authority (RAWRA), Czech Republic.

Andra, BMWi, CRIEPI, JAEA, NWMO and Posiva together with SKB form the Äspö International Joint Committee (IJC), which is responsible for the co-ordination of the experimental work arising from the international participation. Task Forces are another form of organising the international work. Several of the international organisations in the Äspö co-operation participate in the two Äspö Task Forces on (a) Modelling of Groundwater Flow and Transport of Solutes and (b) Engineered Barrier Systems.

SKB also takes part in several international EC-projects and participates in work within the IAEA framework.

1.4 Allocation of experimental sites

The rock volume and the available underground excavations are divided between the experiments performed at the Äspö HRL. It is essential that the experimental sites are allocated so that interference between different experiments is minimised. The allocation of some of the experimental sites within the Äspö HRL is shown in Figure 1-2.

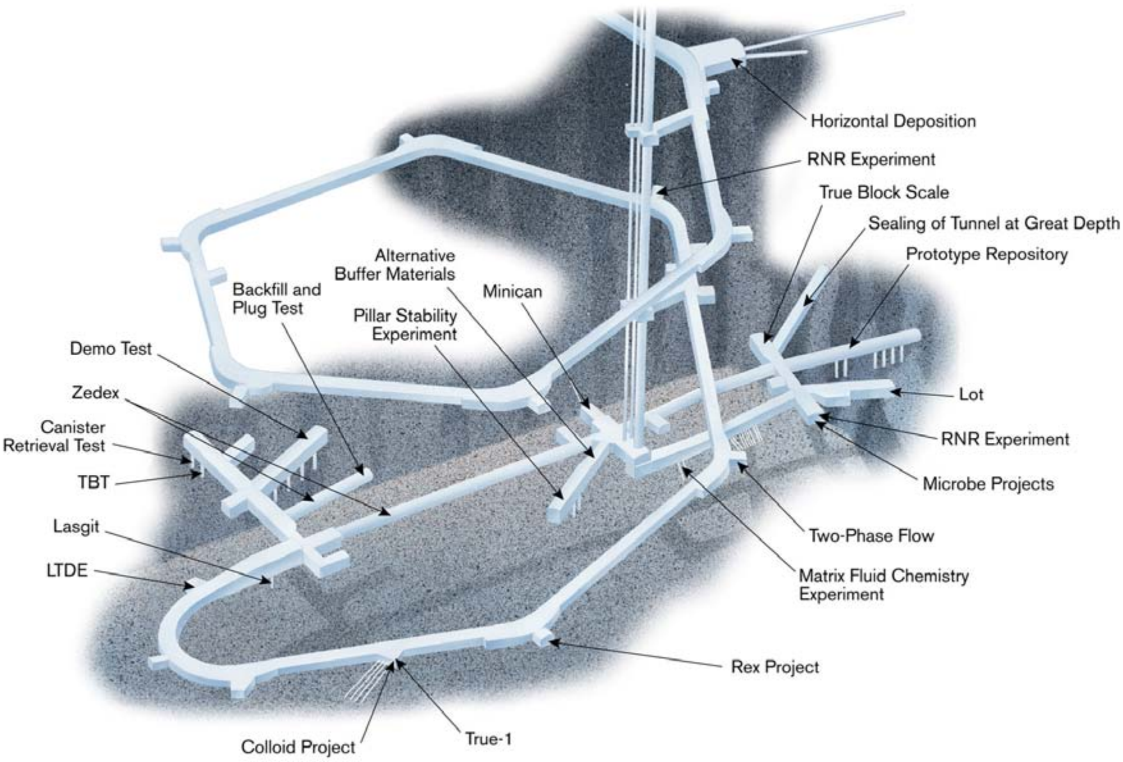


***Figure 1-2**. Allocation of some of the experimental sites from -220 m to -450 m level.*

1.5 Reporting

Äspö HRL is an important part of SKB's RD&D-Programme. The plans for research and development of technique during the period 2008–2013 are presented in SKB's RD&D-Programme 2007 /SKB 2007/. The information given in the RD&D-Programme related to Äspö HRL is detailed in the Äspö HRL Planning Report. This plan is revised annually and the current report gives an overview of the planned activities for the calendar year 2008. Detailed account of achievements to date for the Äspö HRL can be found in the Äspö HRL Annual Reports that are published in SKB's Technical Report series. In addition, Status Reports are prepared quarterly.

Joint international work at Äspö HRL, as well as data and evaluations for specific experiments and tasks, are reported in Äspö International Progress Report series. Information from Progress Reports is summarised in Technical Reports at times considered appropriate for each project. SKB also endorses publications of results in international scientific journals.

Data collected from experiments and measurements at Äspö HRL are mainly stored in SKB's site characterisation database, Sicada.

2 Geoscience

2.1 General

During the pre-investigations for the Äspö HRL in the late 1980's the first geoscientists came to Äspö. Most of them were consultants which mainly worked off-site. A new site organisation was developed when the underground laboratory was taken into operation 1995. Posts as site geologist and site hydrogeologist were then established. These posts have been broadened with time, and today the responsibility of the holder involves maintaining and developing the knowledge and methods of the scientific field as well as scientific support to various projects conducted at Äspö HRL. Geoscientific research and activities are conducted in the fields of geology, hydrogeology, geochemistry (with emphasis on groundwater chemistry) and rock mechanics.

Geoscientific research is a part of the activities at Äspö HRL as a complement and an extension of the stage goals 3 and 4, see Section 1.2. The overall aim is to prepare for future experiments at Äspö HRL. Studies are performed in both field and laboratory experiments, as well as by modelling work. The objectives are to:

- Establish and develop geoscientific models of the Äspö HRL rock mass and its properties.
- Establish and develop the knowledge of applicable measurement methods.

The main task within the geoscientific field is the development of an Äspö Site Descriptive Model (SDM) integrating the information from the fields of geology, hydrogeology, geochemistry and rock mechanics. The activities further aim to provide basic geoscientific data to the experiments and to ensure high quality of experiments and measurements related to geosciences.

2.2 Geology

Geological work at Äspö HRL is focused on several main fields. Major responsibilities are mapping of tunnels, deposition holes and drill cores as well as continuous updating of the geological three-dimensional model of the Äspö rock volume and contribution with input knowledge in projects and experiments conducted at Äspö HRL. Also, development of new methods in the field of geology is a major responsibility.

2.2.1 Geological Mapping and Modelling

Mapping of the tunnel floor of the TASQ-tunnel

All rock surfaces and drill cores at Äspö are mapped. This is done in order to increase the understanding of geometries and properties of rock types and structures, which is subsequently used as input in the 3D-modelling together with other input data.

Modelling tasks are performed both in the general geological 3D-model of the Äspö rock volume (the former GeoMod-project) and in more detailed scale on smaller rock volumes.

Present status

At present no exposed rock surfaces or drill cores from Äspö rock volume are unmapped. The latest surface that has been mapped is the floor of the TASQ tunnel (sections 45-59 m and 71-81 m). The section 45-59 m has already been digitised and adherent data entered into the rock characterisation system TMS (Tunnel Mapping System). There are, however, earlier mappings that still have not been entered into the TMS. The second TMS station is no longer in use since very little work was performed on it and the computer could be used for other purposes.

The work with the detailed 3D structural geological and hydrogeological model of the -450 m level is now at the reporting stage. The model will be based on available data from earlier investigations.

Scope of work for 2008

Geological mapping of the TASS-tunnel will be one of the major tasks during 2008. The excavation of the tunnel will be made in steps. After each step (drilling, blasting and unloading) front mapping will take place and after a number of rounds walls, roof and floor will be mapped. The TASS-tunnel will be used to test methods and grouting materials to be used for sealing of tunnels at great depth, see Section 4.10.

The work with “old” tunnel and deposition hole mappings not yet digitised and geological data not entered into the rock characterisation system TMS will continue. The maintenance of the TMS will continue and it is still suggested that the TMS shall be upgraded to at least Microstation V8 or maybe even better to version XM.

2.2.2 Rock Characterisation System

TASQ-tunnel, the computer work by ATS to collect laser scanning data

The project Rock Characterisation System (RoCS) is conducted as an SKB-Posiva joint-project and is a feasibility study concerning geological mapping techniques is performed besides the regular mapping and modelling tasks.

The purpose is to investigate if a new system for rock characterisation has to be adopted when constructing a final repository. The major reasons for the RoCS project are aspects on objectivity of the data collected, traceability of the mappings performed, saving of time required for mapping and data treatment and precision in mapping. These aspects all represent areas where the present mapping technique may not be adequate.

In this initial feasibility study-stage, the major objective is to establish a knowledge base concerning existing and possible future methods and techniques to be used for a mapping system suitable for SKB's and also Posiva's requirements.

Present status

The first part of the feasibility study, establishing of the technical state-of-the-art, is completed. Tests of data collection methods have been performed using both digital photogrammetry and laser scanning. Also, several complementary techniques, like geophysical survey methods, have been investigated, as well as software applications. The authors of the report suggest that laser scanning together with digital photography should be a part of the new rock characterization system /Magnor et al. 2007/. At the time being there is more than a year delay of the project.

Laser scanning combined with high resolution digital photography of the entire TASQ-tunnel were executed during the first half of the year of 2006. Although this scanning event is only partially a concern of the RoCS-project the results will be of great interest for the project.

Scope of work for 2008

The former RoCS project will continue as a part of the ordinary tasks within the discipline at Äspö HRL. For example a foundation for decision making about how to continue with RoCS will be presented. The idea is that RoCS will now concentrate on the characterization of the rock and thus, at least for the time being, leave other disciplines outside.

Most of the results from the laser scanning have been delivered and the final report will be completed in 2008.

2.3 Hydrogeology

The objectives of the hydrogeological work are to:

- Establish and develop the understanding of the hydrogeological properties of the Äspö HRL rock mass.
- Maintain and develop the knowledge of applicable measurement methods.
- Ensure that experiments and measurements in the hydrogeological field are performed with high quality.

The main task is the development of the integrated Äspö Site Descriptive Model. An important part of the site description is the numerical groundwater model which is to be continuously developed and calibrated. The intention is to develop the model to a tool that can be used for predictions, to support the experiments and to test hydrogeological hypotheses. Another part of the work with the site description is the continued development of a more detailed model of hydraulic structures at the main experimental levels below -400 m.

2.3.1 Hydro Monitoring Programme

The hydro monitoring programme is an important part of the hydrogeological research and a support to the experiments undertaken in Äspö HRL. The monitoring of water level in surface boreholes started in 1987 while the computerised Hydro Monitoring System (HMS) was introduced in 1992.

The HMS collects data on-line of pressure, levels, flow and electrical conductivity of the groundwater. The data are recorded by numerous transducers installed in boreholes and in the tunnel. The number of boreholes included in the monitoring programme has gradually increased, and comprise boreholes in the tunnel in the Äspö HRL as well as surface boreholes on the islands of Äspö, Ävrö, Mjälen, Bockholmen and some boreholes on the mainland at Laxemar. To date the monitoring programme comprises a total of about 140 boreholes (about 40 surface boreholes and 100 tunnel boreholes). Many boreholes are equipped with inflatable packers, dividing the borehole into sections. Water seeping into the tunnel is diverted to trenches and further to 25 weirs where the flow is measured.

Weekly quality checks of preliminary groundwater head data are performed. Absolute calibration of data registered with HMS is performed three to four times per year. This work involves comparison with groundwater levels checked manually in boreholes.

The data collected in HMS is transferred to SKB's site characterisation database, Sicada.

Present status

The measuring system is at present working satisfactorily. During 2007, the installation of transducers for measurements of temperature, humidity and pressure of tunnel air has continued. A maintenance programme for the tunnel boreholes has been developed and a study about renovation of cored surface boreholes has been performed. Instrumentation, measurement methods and the monitoring during 2006 is described in a report /Nyberg et al. 2007/.

Scope of work for 2008

The activities during 2008 comprise operation, maintenance and documentation of the HMS system. In particular the management organisation will be improved. Equipment that is out of order will be exchanged or renovated, and the measuring points from the previous years will be maintained. However, automatic monitoring in surface boreholes is successively replaced by monthly manual levelling. Semi-automatic transfer of data from HMS to Sicada three to four times annually will be implemented.

2.4 Geochemistry

The major aims within geochemistry are to:

- Establish and develop the understanding of the hydrogeochemical properties of the Äspö HRL rock volume.
- Maintain and develop the knowledge of applicable measuring and analytical methods.
- Ensure that experimental sampling programmes are performed with high quality and meet overall goals within the field area.

The overall main task is development of the integrated Site Descriptive Model of the Äspö HRL. The use of the achieved knowledge will facilitate the understanding of the geochemical conditions and the development of underground facilities in operation. The intention is to develop the model as to be used for predictions, to support and plan experiments and to test hydrogeochemical hypotheses. In general hydrogeochemical support is provided to active and planned experiments at Äspö HRL.

2.4.1 Monitoring of Groundwater Chemistry

Water sampling in a tunnel at Äspö HRL.

During the Äspö HRL construction phase, different types of water samples were collected and analysed with the purpose of monitoring the groundwater chemistry and its evolution as the construction proceeded. The samples were obtained from boreholes drilled from the ground surface and from the tunnel. At the beginning of the Äspö HRL operational phase, sampling was replaced by a groundwater chemistry monitoring programme, with the aim to sufficiently cover the evolution of hydrochemical conditions with respect to time and space within the Äspö HRL.

The monitoring programme is designed to provide information to determine where, within the rock mass, the hydrogeochemical changes are taking place and at what time stationary conditions are established.

Present status

The sampling campaign is performed once a year. Water samples are taken from varying depths in the Äspö HRL and also from some boreholes drilled from the surface. All projects at Äspö HRL can request additional sampling of their sites to be coordinated within the monitoring programme. Examples of additional parameters that have been added to the monitoring programme are biogeochemical parameters such as ATP (adenosine triphosphate, an important biological molecule) and redox sensitivity. The monitoring programme is under development and further parameters are foreseen to be added. The main purpose is to find reasonable parameters that are of interest for the projects and to follow the different experimental activities at Äspö HRL.

Scope of work for 2008

The main issues for 2008 are to develop the analytical programme and work related to the integrated Site Descriptive Model for Äspö HRL. In addition, dependent on the development of future experimental sites at Äspö HRL additional sampling campaigns may be needed. Other tasks to be performed during 2008 are:

- Test and evaluate sampling methodologies for gas components and isotopes.
- Intensified measurements of nanoparticles in the groundwater.
- Development of sampling methods for groundwater in conjunction with excavation of new experimental sites.
- Test sampling methods for different types of objects e.g. tunnel boreholes with or without packed-off sections, surface boreholes and deposition holes.

2.5 Rock mechanics

Cross section through spalled zone in the Pillar Stability Experiment (APSE) /Andersson 2007/

Rock mechanic studies are performed with the aims to increase the understanding of the mechanical properties of the rock but also to recommend methods for measurements and analyses.

This is done by laboratory experiments and modelling at different scales and comprises:

- Natural conditions and dynamic processes in natural rock.
- Influences of mechanical, thermal and hydraulic processes in the near-field rock including effects of the backfill.

Present status

One of the key issues within the rock mechanics part of the final repository project is the overall capability to model and predict the mechanical behaviour of highly stressed massive rock, such as the rock in the peripheries of deposition holes. Calculations have shown that the thermally-induced tangential stresses on the boundary of the KBS-3 deposition holes will exceed the crack-initiation stress after a little less than one year of heating.

In addition to the possible specific problem of thermally induced spalling there are more general questions relating to fracturing of intact rock that may have to be addressed in the safety assessment SR-Site, and more generally within the Nuclear Fuel Project (KBP). It is therefore decided that SKB shall carry out a code development approach sufficient to meet the requirements for SR-Site and KBP, as well as to fill in gaps in accordance to SKB's Research, Development and Demonstration Programme 2007 /SKB 2007/.

Scope of work for 2008

A field test, including three or four pairs of heated half-scale KBS-3 holes will be carried out as a series of demonstration experiments within a separate project in the APSE tunnel at Äspö HRL during 2008. The field test will be conducted in parallel with the numerical modelling project and will, if successful, be an important source of experimental data for verification of the modelling approaches being developed. The field test and the model project aim at resolving the same fundamental problem, but can be run at different levels of interaction, i.e. should one of the two approaches turn out to be unsuccessful, the other one will be a backup.

3 Natural barriers

3.1 General

To meet Stage goal 3, experiments are performed to further develop and test methods and models for description of groundwater flow, radionuclide migration and chemical conditions at repository depth.

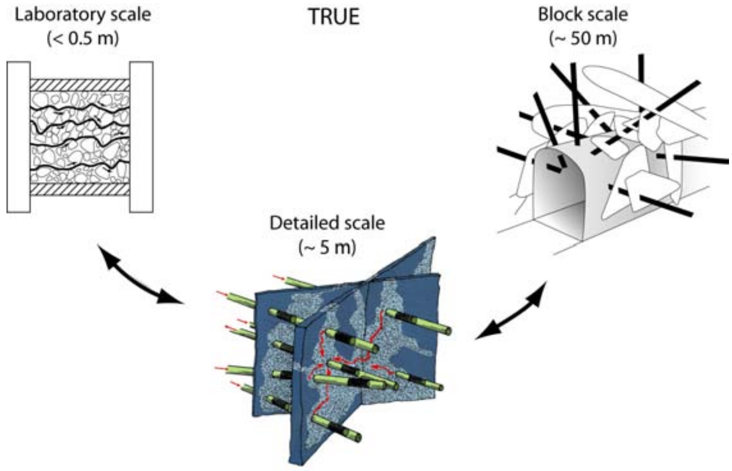
The experiments are related to the rock, its properties and in situ environmental conditions. The programme at Äspö HRL includes projects with the aim to evaluate the usefulness and reliability of different conceptual and numerical models and to develop and test methods for determination of parameters required as input to the models. The overall purposes are to:

- Improve the scientific understanding of the final repository's safety margins and provide input data for assessments of the repository's long-term safety.
- Obtain the special material needed to supplement data from the site investigations in support of an application for a siting permit for the final repository.
- Clearly present the role of the geosphere for the barrier functions: isolation, retardation and dilution.

The ongoing experiments and projects within the Natural Barriers at Äspö HRL are:

- Tracer Retention Understanding Experiments.
- Long Term Sorption Diffusion Experiment.
- Colloid Project.
- Microbe Projects.
- Matrix Fluid Chemistry Continuation.
- Radionuclide Retention Experiments.
- Padamot.
- Fe-oxides in fractures.
- Swiw-tests with Synthetic Groundwater.
- Task Force on Groundwater Flow and Transport of Solutes.

3.2 Tracer Retention Understanding Experiments



Tracer tests with non-sorbing and sorbing tracers are carried out in the True family of projects. These are conducted at different scales; laboratory scale (< 0.5 m), detailed scale (<10 m) and block scale (up to 100 m) with the aim to improve understanding of transport and retention in fractured rock. The work includes building of hydrostructural models and conceptual microstructure models. Numerical models are used to assess the relative contribution of flow-field related effects and acting processes (diffusion and sorption) on in situ retention.

The first in situ experiment (True-1) /Winberg et al. 2000/ performed in the detailed scale and the True Block Scale series of experiments /Winberg et al. 2003/ have come to their respective conclusion.

Complementary field work and modelling have been performed as part of two separate, but closely coordinated, continuation projects.

The True Block Scale Continuation (BS2) project aimed at obtaining additional understanding of the True Block Scale site /Andersson et al. 2007/. A further extension of the True Block Scale Continuation, (BS3), involves production of two series of peer-reviewed scientific papers accounting for the overall True findings, and in particular those of BS1 and BS2.

In the True-1 Continuation and Completion projects the objectives are to obtain insight in the internal structure of the investigated feature and to study fixation of sorbing radioactive tracers. Prior to the resin injection in Feature A, complementary hydraulic and tracer tests are performed to better understand Feature A and its relation to the surrounding fracture network. In addition, a dress rehearsal of in situ resin injection is realised through a characterisation project focused on fault rock zones. Additional work includes complementary laboratory sorption investigations on fracture rim and fault gouge materials, plus a series of three scientific articles on the True-1 experiment.

3.2.1 True Block Scale Continuation

The True Block Scale Continuation (BS2) project has its main focus on the existing True Block Scale site. The overall objective of BS2 can be summarised as: “Improve understanding of transport pathways at the block scale, including assessment of effects of geometry, macro-structure and micro-structure”. Special consideration has in this context been put on the possibility to explore the role of more low-permeable parts of the studied fracture network, including background fractures, the latter without developed wall rock alteration and fault gouge signatures. The results on BS2 have demonstrated successful performance and evaluation of transport experiments in a part of the True Block Scale site where experiments have not been performed previously. This success is largely attributed to transfer of the accumulated wealth of geoscientific understanding collected during the preceding stages of the True Project /Andersson et al. 2007/.

Following BS2, a second step of continuation of the True Block Scale project (BS3) has been launched. This step does not include specific experimental components and emphasise consolidation and integrated evaluation of all relevant True data and findings collected so far. This integration is not necessarily restricted to True Block Scale, but can also incorporate True-1 and True-1 Continuation results.

Present status

At this time two incomplete manuscripts of the first series (Sorptive tracer tests in single to multiple fractures in crystalline rock at Äspö) are available:

I Predictive modelling

II Effective retention properties

The first paper accounts for methodology and procedures for performed blind predictions and comparison between predictions and experimental data. The second paper deals with evaluation of the tracer tests and assessment of effective retention properties.

Scope of work for 2008

During 2008 the series of scientific articles, indicated above, will be completed and submitted. Start-up of work will focus on the second series of papers which is aimed at the broader scientific community. The papers address "Multiple evidence of retention in crystalline rocks", "Synthesis of True results and implications for predictive modelling of tracer transport in crystalline rock" and overall "Synthesis of True results on retention properties/parameters".

3.2.2 True-1 Continuation

The objectives of True-1 Continuation are to:

- Obtain insight into the internal structure of the investigated Feature A, in order to allow evaluation of the pore space providing the observed retention in the experiments performed.
- Provide an improved understanding of the constitution, characteristics and properties of fault rock zones (including fault breccia and fault gouge).
- Provide quantitative estimates of the sorption characteristics of the altered rim zone and fault rock materials of fault rock zones.

The True-1 Continuation project is an extension of the True-1 experiments, and the experimental focus is primarily on the True-1 site. The continuation includes performance of the planned injection of epoxy resin in Feature A at the True-1 site with subsequent overcoring and analysis (True-1 Completion, see Section 3.2.3). Additional activities include: (a) test of the developed epoxy resin technology to fault rock zones distributed in the access tunnel of the Äspö HRL (Fault Rock Zones Characterisation project), (b) laboratory sorption experiments for the purpose of verifying Kd-values calculated for altered wall rock and fault gouge, (c) writing of scientific papers relating to the True-1 project. A previously included component with the purpose of assessing fracture aperture from radon data has been omitted due to resources prioritisation.

Present status

Progress during the past year has primarily been related to the True-1 Completion and the completion of the three articles on True-1, two published in Water Resources Research and the third pending. The progress in finalising the Fault Rock Zones characterisation project and the complementary laboratory sorption experiments on rim zone and fault gouge material has been seriously hampered by the fact that resources are consumed by the site investigations/site modelling projects.

Scope of work for 2008

During 2008 the reporting of the Fault Rock Zones and Complementary laboratory sorption subprojects will be finalised. The third paper in the series reporting the True-1 experiments will be published.

3.2.3 True-1 Completion

True-1 Completion is a sub-project of the True-1 Continuation project and constitutes a complement to already performed and on-going projects. The main activity within the project is the injection of epoxy with subsequent over-coring of the fracture and following analyses of pore structure and, if possible, identification of sorption sites. Furthermore, several complementary in situ experiments were performed prior to the epoxy injection with the aim of securing important information from Feature A and the True-1 site. The general objectives of True-1 Completion are to:

- Perform epoxy injection and through the succeeding analyses improve the knowledge of the inner structure of Feature A and to improve the description and identification of the immobile zones that are involved in the noted retention.
- Perform complementary tests with relevance to the on-going SKB site investigation programme, for example in situ Kd- and Swiw-test (single well injection withdrawal).
- Improve the knowledge of the immobile zones where the main part of the noted retention occurs. This is performed by mapping and mineralogical-chemical characterisation of the sorption sites for Cs.
- Update the conceptual micro structural and retention models of Feature A.

Present status

The main activities during the spring and summer of 2007 were the epoxy injection and following over-coring of the boreholes KXTT3 and KXTT4 at the True-1 site. The objective of the epoxy was twofold, first to keep the core intact without breakage in the target features during over-coring and retrieval, secondly to facilitate the subsequent analyses of the core. The amount of epoxy possible to inject in the two target sections were considered to be sufficient to stabilise the target structures. However, the forces acting on the core during drilling and/or retrieving were too high in order to keep the core intact around the fractures in the target section.

Despite the broken cores of KXTT3 and KXTT4, they are still considered to provide a lot of valuable information in coming analysis. However, the original plan was based on intact cores, why the fall of 2007 had to be used for extended reconstruction and characterisation of the cores and for reviewing of the analysis plan. In addition, the hydraulic and tracer tests performed during 2006 were evaluated during 2007.

Scope of work for 2008

The main tasks for 2008 are analyses of target structures from boreholes KXTT3 and KXTT4 by image analysis, microscopy and chemical analysis. Furthermore, the plan is to update the conceptual models and to finalise the True-1 Completion project within 2008. However, the heavy engagement within the site investigation programmes of the project participants will continue to pose a clear risk for delays, which might result in that the project will proceed into 2009.

3.3 Long Term Sorption Diffusion Experiment

Drilling of sample cores from matrix rock surrounding the test section in the small diameter extension borehole (left) and sample core A6, about 18 cm long, drilled from the fracture surface on the core stub (right).

This experiment is performed to investigate diffusion and sorption of solutes in the vicinity of a natural fracture into the matrix rock and directly from a borehole into the matrix rock. The aims are to improve the understanding of diffusion and sorption processes and to obtain diffusion and sorption data at in situ conditions.

A core stub with a natural fracture surface is isolated in the bottom of a large diameter telescoped borehole and a small-diameter borehole is drilled through the core stub and beyond into the intact unaltered bedrock.

Tracers were circulated over a period of 6 ½ months after which the borehole was over cored. This activity is followed by analyses of tracer content.

Small diameter (24 mm) sample cores have been extracted from the 1.1 m long and 278 mm diameter large core retrieved from the over coring. Sample cores have been extracted both from the fracture surface on the core stub and from the matrix rock surrounding the test section in the small diameter (36 mm) extension borehole.

Present status

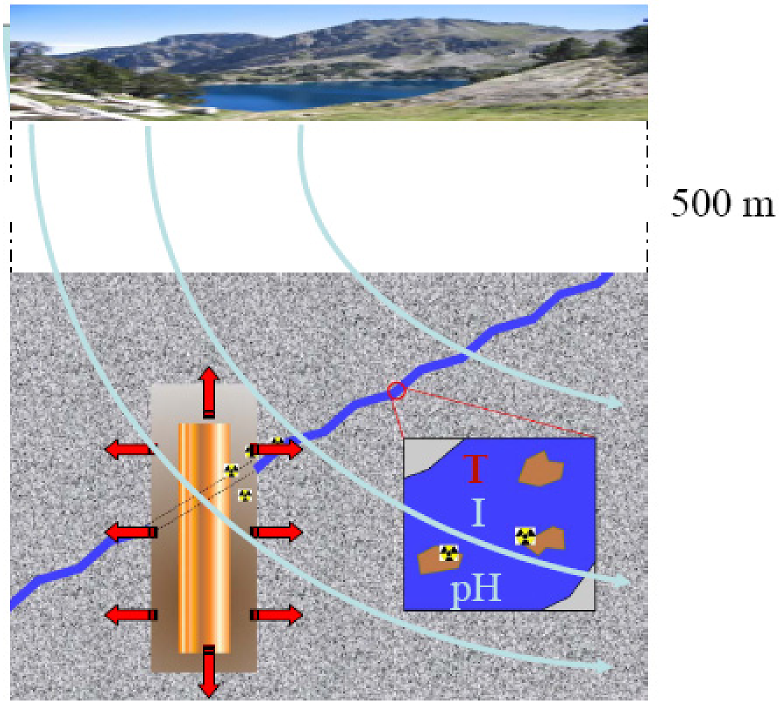
In total 18 cores were drilled on the fracture surface, covering about 34% of the fracture surface on the core stub, and 16 cores drilled in the matrix rock surrounding the test section. The sample cores have been geologically mapped in detail and measured with gamma spectrometry (HPGe). Further, work has started to cut the sample cores into thin slices to allow determination of penetration profiles. Preparations are on-going for laboratory experiments with specimens from the experimental site.

Scope of work for 2008

Tracer content in the slices cut from the sample cores will be determined by γ-spectrometry, mass-spectrometry and liquid scintillation analysis methods. The sorption on the fracture surface on the core stub and axial diffusion-sorption through the fracture rim into the intact matrix rock will be studied by performing analyses of the determined penetration profile of the different tracers used. Sorption on matrix rock surface and radial diffusion-sorption directly into unaltered matrix rock will also be studied, utilising the same methodology.

Laboratory experiments will be performed with specimens from the core of the small diameter extension borehole, the replica core stub and the pilot borehole core. Same tracer cocktail as for the in situ experiment will be used. The results from the laboratory experiments and the experiments performed at AECL during 2005, will be used to compare laboratory derived diffusion and sorption coefficients for the investigated rock fracture system with the sorption behaviour observed from the in situ experiment. In addition, the representativeness of laboratory scale sorption results also for larger scales will be evaluated.

3.4 Colloid Project



The Colloid Project is a continuation of the Colloid Dipole Project which is ending in the beginning of 2008 with a final report. The overall goal for the Colloid Project is to answer the questions when colloid transport has to be taken into account in the safety assessment, and how the colloid transport can be modelled.

In the beginning of the lifetime of a deep repository, in bedrock with groundwater of high ionic strength, bentonite and natural colloids are not stable, and colloid transport can be neglected. Of special concern is bentonite erosion, since that could give loss of material leading to a decrease of the barrier function of the bentonite buffer.

In the scenario of intrusion of dilute glacial water the conditions for colloids stability drastically changes. The transport might be the limiting factor in this scenario and has to be taken into account.

In the case of a leaching canister, the bentonite colloids can possibly facilitate the transport of sorbed radionuclide towards the biosphere. In the project, also the transport of organic colloids and other natural colloids are studied and their effect on especially actinide mobility.

The ambition is further to include studies on the transport of colloids which are formed in the spent nuclear fuel.

Present status

To be able to answer the questions when colloid transport has to be taken into account into the safety assessment, and how the colloid transport should be modelled, a lot of problems have to be solved. A very important issue is how long the colloids can stay in solution i.e. how stable they are. If they are unstable, the colloids will not contribute significantly to the transport.

During the years of 2004-2007 fundamental work has been performed to understand how bentonite colloid stability is affected by especially the groundwater composition, but also the effect of temperature in the beginning of the life time of the repository, as well as the impact of ionising radiation. Ionic strength and pH are dominant factors, and the individual impacts on bentonite colloid stability is known from the literature, however, correlation effects are not well known. Therefore focus has been to study individual effects and combined effects of different factors on bentonite colloid stability.

In the project transport experiments have been performed, especially in the centimetre to meter scale. In these experiments the effect of colloid conformation, size, width of size distributions etc have been studied. In natural flow the transport is very slow and a large part of the colloids injected, filter out. In higher flows the transport is significant, however, a large part of the colloids are never recovered. Maybe this indicates that the bentonite colloids will over a long time period, clog the system, and hinder further transport.

Modelling efforts are performed on the colloid transport data. The vision is to be able to model colloid transport in any aperture distribution, in any flow, in fractures with varying mineralogy and surface roughness, as well as with bentonite colloids as well as other natural colloids such as organic degradation products, or mineral oxides etc. All the results and data from 2004-2007 are under evaluation and will be included in a final report for this phase, expected to be finished in the first quarter of 2008.

Scope of work for 2008

During 2008 further experiments in the laboratory will be performed to deepen the knowledge in bentonite colloid stability. For example, the nature of irradiated bentonite colloids will be explored to see if the surface properties will change after exposure of ionizing radiation. New techniques will be used to try to catch how bentonite colloids actually appear in solution, and how their confirmation changes with the surrounding environment.

Transport experiments will be performed in well characterised bore cores from Äspö, where bentonite colloid transport at different conditions will be studied, as well as the impact on radionuclide transport. Experiments will be performed in both oxidising and in as reducing environment as possible. Both redox sensitive and non redox sensitive radionuclides will be used. To mimic intrusion of glacial water in the fractures in the bedrock different flows of dilute waters will be used. In addition, one experiment will be conducted in saline water and with fulvic acid present, to see the impact of organic colloids on radionuclide transport. Fulvic acid, has been shown to be quite stable in Äspö waters, however, at very low concentrations naturally.

A bentonite erosion experiment is planned in the centimetre to meter scale in a granite block. Five bentonite plugs will be placed into fractures, and an even flow with dilute water will be pumped through the block. The bentonite will be marked, to be able to catch low concentrations of bentonite downstream the plugs, however, how they will be marked is not yet set. After a certain time, the block will be opened, and post-mortem analysis will be performed to see where bentonite colloids have been transported, if there has been bentonite erosion.

The project will also participate in bentonite colloid transport experiments in the field scale, at the Grimsel test site in Switzerland. Pure transport experiments as well as bentonite erosion experiments will be performed in this collaboration.

3.5 Microbe Projects

Microorganisms interact with their surroundings and in some cases they greatly modify the characteristics of their environment. Several such interactions may have a significant influence on the function of a future deep repository for spent fuel /Pedersen 2002/. There are presently four specific microbial process areas identified that are of importance for proper repository functions and that are best studied at the Microbe Laboratory. They are: bio-mobilisation of radionuclides, bio-immobilisation of radionuclides, microbial effects on the chemical stability of deep groundwater environments and microbial corrosion of copper.

The study of microbial processes in the laboratory gives valuable contributions to our knowledge about microbial processes in repository environments. However, the concepts suggested by laboratory studies must be tested in a repository like environment. The reasons are several. Firstly, at repository depth, the hydrostatic pressure reaches close to 50 bars, a setting that is very difficult to reproduce in the microbiology laboratory. The high pressure will influence chemical equilibrium and the content of dissolved gases. Secondly, the geochemical environment of deep groundwater, on which microbial life depends and influence, is complex. Dissolved salts and trace elements, and particularly the redox chemistry and the carbonate system are characteristics that are very difficult to mimic in a university laboratory. Thirdly, natural ecosystems, such as those in deep groundwater, are composed of a large number of different species in various mixes /Pedersen 2001/. The university laboratory is best suited for pure cultures and therefore the effect from consortia of many participating species in natural ecosystems cannot easily be investigated there. The limitations of university laboratory investigations arrayed above have resulted in the construction and set-up of an underground laboratory in the Äspö HRL tunnel. The site is denoted the Microbe Laboratory and is situated at the -450 m level.

Six underground circulation systems with flow cells for biofilm development have been installed in the Äspö HRL at 450 m depth /Nielsen et al. 2006/. They connect directly to aquifers at the in situ pressure of approximately 30 bars. The systems can be isolated from the aquifer and groundwater with indigenous microbes is then circulated through the flow cells without contact with the aquifer. In the open mode, biofilms develop on the surfaces in the flow cells. When the systems are turned to the closed mode, the in situ pressure, and the anaerobic and reduced conditions are kept as in the open mode. These systems were used to investigate the effect of hydrogen on growth and activity during 2006. Publication is in progress. All three systems increased initially in cell numbers and the hydrogen added system increased most. This trend was consistent also for acetate and sulphide production. Acetate is produced by autotrophic acetogens. The cell numbers decreased after about a month time, but the production of sulphide and acetate continued. This may look controversial at first, but we are convinced this is an effect from virus predation. When the cell numbers approached one million cells per litre groundwater, it seems as if the viruses became very contagious and forced the numbers back towards the numbers observed at start. The two most important results consequently are: 1) Hydrogen stimulates microbial growth and activity. 2) Virus predation control microbial populations in the underground. The DNA of the biofilms has been extracted, cloned and sequenced. Microscopic investigations revealed significant differences in morphology as a result of the treatments. The acetate system developed very large cells with an unusual, worm-like morphology, while the hydrogen system fostered thin, *Hyphomicrobium* like biofilms. The control showed a mix of these morphologies. When the clone libraries are established, we will use quantitative polymerase chain reaction (Q-PCR) to determine the amounts of different species. Methods for genetic characterisation will be continuously adapted. Circulation experiments with various combinations of energy sources will be continued and followed with microelectrodes, cultivations, DNA sequence determinations and with functional and species specific genetic probes.

3.5.1 The Microbe Laboratory

The Microbe Laboratory has been installed in the Äspö HRL for studies of microbial processes in groundwater under in situ conditions.

The Microbe site is on the -450 m level (image above) where a laboratory container with benches, and an advanced climate control system is located.

Three boreholes, KJ0050F01, KJ0052F01 and KJ0052F03, intersecting water conducting fractures are connected to the Microbe Laboratory via tubing. Each borehole has been equipped with a circulation system offering 2,112 cm^2 of test surface.

The major objectives are to:

- Offer proper circumstances for research on the effect of microbial activity on the long-term chemical stability of the repository environment.
- Provide in situ conditions for the study of bio-mobilisation of radionuclides.
- Present a range of conditions relevant for the study of bio-immobilisation of radionuclides.
- Enable investigations of bio-corrosion of copper under conditions relevant for a high level radioactive waste repository.
- Constitute a reference site for testing and development of methods used in the site investigations.

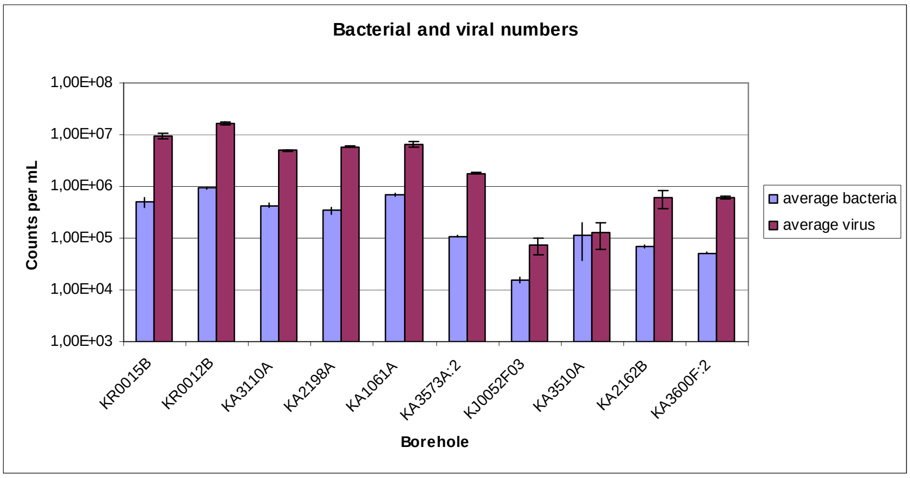
Present status

The microbe site has acted base for several different microbiological tunnel research activities during 2007. The Prototype Repository has been sampled and analysed repeatedly. The Minican experiment was also analysed with the Microbe site as base laboratory. Three new circulation systems have been constructed and installed. They will be employed during 2008.

Scope of work for 2008

Two main activities are planned for 2008. They both aim at the collection of data for modelling of microbiological processes. Natural biofilms will be analysed in the Micomig project and redox related processes, including sulphide production, will be studied in the Micored project.

3.5.2 Micored



Microorganisms can have an important influence on the chemical situation in groundwater. Especially, they may execute reactions that stabilise the redox potential in groundwater at a low and, therefore, beneficial level for the repository.

It is hypothesised that hydrogen and possibly also methane from deep geological processes contributes to the redox stability of deep groundwater via microbial turnover of this gas. These metabolisms will generate secondary metabolites such as ferrous iron, sulphide, acetate and complex organic carbon compounds.

The work within the Micored project will:
• Clarify the contribution from microorganisms to stable and low redox potentials in near-and far-field groundwater.
• Demonstrate and quantify the ability of microorganisms to consume oxygen in the near-and far-field areas.
• Explore the relation between content and distribution of gas and microorganisms in deep groundwater.
• Create clear connections between investigations of microorganisms in the site investigations for a future repository and research on microbial processes at Äspö HRL.

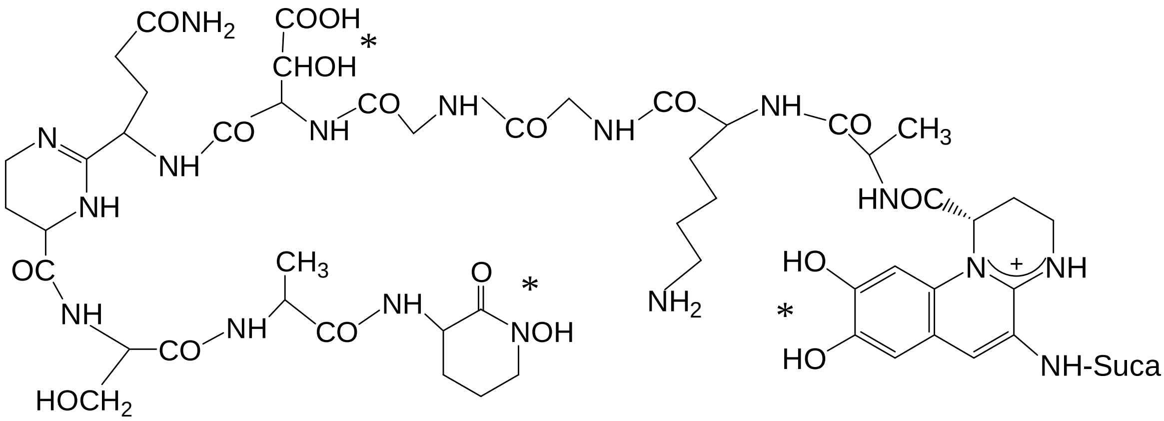
Present status

The micro-diversity of sulphate reducing bacteria has been investigated, with emphasis on *Desulfovibrio aespoeensis*. More than five closely related strains were discovered. The presence of a diverse suite of virus that attack bacteria was found in groundwater from -70 to -450 m level in the Äspö tunnel (diagram above). Several viruses that are specific for *Desulfovibrio aespoeensis* have been isolated. The discovery of naturally occurring viruses in groundwater at numbers approaching a maximum of ten billion particles per litre of groundwater adds a new and very important dimension to modelling of microbial processes – predation. In addition, these numbers of phages, typical phage size is a couple of hundred nano-meters, contribute significantly to the number of colloids in groundwater.

Scope of work for 2008

The circulation systems at the Microbe Laboratory will be used to collect data for modelling work. The data will include growth and activity of naturally occurring microorganisms at the level -450 m and the influence from various sources of energy for metabolism, viruses and available electron acceptors. The effect of microbial activity on groundwater geochemistry will also be analysed.

3.5.3 Micomig



It is well known that microbes can mobilise trace elements. Firstly, unattached microbes may act as large colloids, transporting radionuclides on their cell surfaces with the groundwater flow. Secondly, microbes are known to produce ligands that can mobilise soluble trace elements and that can inhibit trace element sorption to solid phases.

A large group of microbes catalyse the formation of iron oxides from dissolved ferrous iron in groundwater that reaches an oxidising environment with oxygen. Such biological iron oxide systems (Bios) will have a retardation effect on many radionuclides.

Biofilms in aquifers will influence the retention processes of radionuclides in groundwater. Recent work indicates that biofilms may enhance or retard sorption, depending on the radionuclide in question.

The work within Micomig will:
• Evaluate the influence from microbial complexing agents on radionuclide migration.
• Explore the influence of microbial biofilms on radionuclide sorption and matrix diffusion.

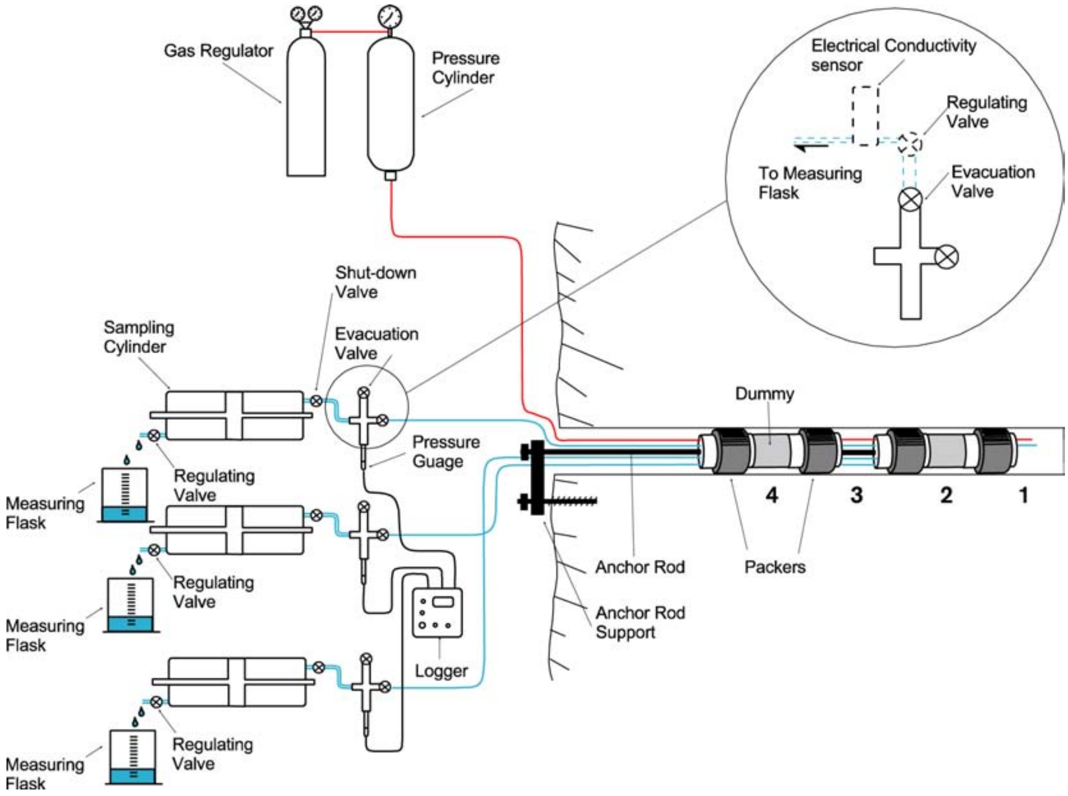
Present status

The siderophore production by *Pseudomonas stutzeri* was studied with liquid chromatography and mass spectrometry /Essén et al. 2007/. The methods developed can be used to explore the presence of naturally occurring microbes in deep groundwater. Further, the binding of Curium to pyoverdins, produced by *Pseudomonas fluorescens* was analysed /Moll et al. 2007/.

Scope of work for 2008

Water-conducting fractures intersected by the Äspö tunnel will be over-cored and analysed for the presence of biofilms. Biofilm organisms will be characterised with cultivation and molecular DNA methodology. Bio-markers for past and present microbiological activities will be studied as well. The possible influence of fracture material and biofilms on trace element sorption will be addressed as well.

3.6 Matrix Fluid Chemistry Continuation



The main objectives of the Matrix Fluid Chemistry experiment are to understand the origin and age of fluids/groundwater in the rock matrix pore space and in micro-fractures, and their possible influence on the chemistry of the groundwater from the more highly permeable bedrock.

Matrix fluids are sampled from a borehole drilled into the rock matrix. Fluid inclusions in core samples have also been studied to determine their contribution, if any, to the composition of the matrix fluids/groundwater.

A first phase of the project is finalised and reported /Smellie et al. 2003/. The major conclusion is that pore water can successfully be sampled from the rock matrix and there is no major difference in chemistry compared to groundwater from more highly conductive fracture zones in the near-vicinity.

Present status

The reporting is in progress of both the hydraulic testing programme that was carried out in the matrix borehole and was completed in 2006 and the analytical data for matrix pore water collected at the end of 2005.

Scope of work for 2008

Planned work for 2008 involves to:

- Complete report of the hydraulic testing programme.
- Complete report on analytical data for matrix pore waters.
- Produce a synthesis report to conclude the 'Matrix Fluid Chemistry Continuation' project.

3.7 Radionuclide Retention Experiments

Radionuclide Retention Experiments are carried out with the aim to confirm results of laboratory studies in situ, where natural conditions prevail concerning e.g. redox conditions, contents of colloids, organic matter and bacteria in the groundwater. The experiments are carried out in special borehole laboratories, Chemlab 1 and Chemlab 2, designed for different kinds of in situ experiments. The laboratories are installed in boreholes and experiments can be carried out on for instance bentonite samples and on tiny rock fractures in drill cores.

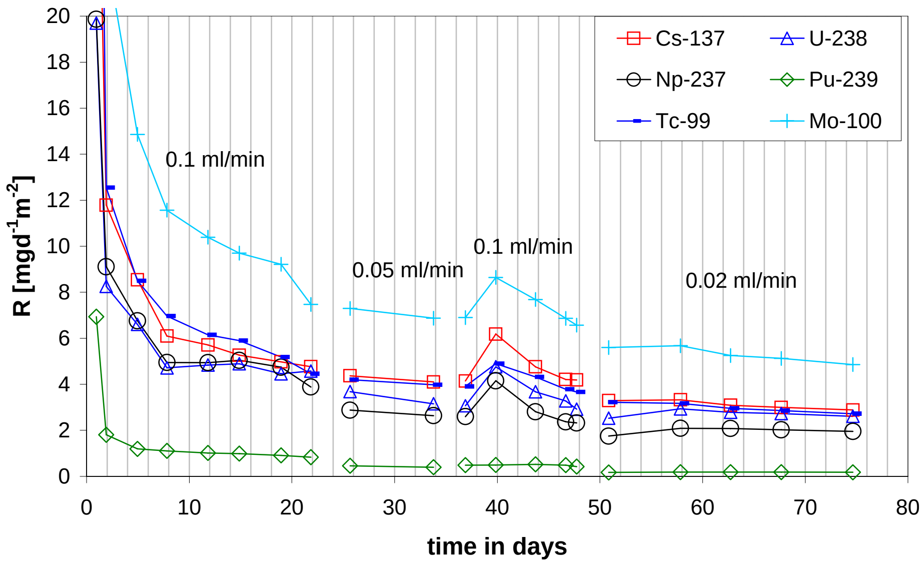
Experiments in Chemlab 1:

- Investigations of the influence of radiolysis products on the migration of the redox-sensitive element technetium in bentonite (finalised).
- Investigations of the transport resistance at the buffer/rock interface (planned. May be performed in Chemlab 2 or in another fashion in situ, depending on the outcome of the tests in laboratory).

Experiments in Chemlab 2:

- Migration experiments with actinides in a rock fracture (almost finalised).
- Study leaching of spent fuel at repository conditions (planned).

3.7.1 Spent Fuel Leaching



Dissolution rates based on different monitors. The spent fuel was leached with 10 mM $NaHCO_3$ under oxidising conditions. Constant dissolution rates could be achieved after some days.

In the Spent Fuel Leaching experiments, to be performed within the framework of the programme for in situ studies of repository processes, the dissolution of spent fuel in groundwater relevant for repository conditions will be studied. The objectives of the experiments are to:

• Investigate the leaching of spent fuel in laboratory batch experiments and under in situ conditions.

• Demonstrate that the laboratory data are reliable and correct for the conditions prevailing in the rock.

The in situ experiments will be preceded by laboratory experiments where the scope is both to examine parameters that may influence the leaching as well as testing the equipment to be used in the field experiments.

In the field experiments spent fuel leaching will be examined with the presence of H_2 (in a glove box situated in the gallery) as well as without the presence of H_2 (in Chemlab 2).

Present status

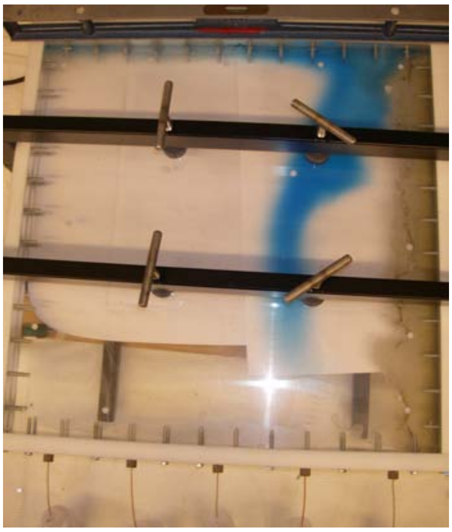
The experimental set-ups are designed. The laboratory experiments will be performed at Nuclear Chemistry at Chalmers University of Technology groundwater from Äspö HRL. The first contacts with the Swedish Radiation Protection authority (SSI) have been taken to get a permit to handle spent fuel and perform the experiments.

Scope of work for 2008

As soon as the project is approved, equipment for the experiments at Chalmers will be ordered and the experiments can start as soon as the equipment arrives. The experiments are planned to take 1-2 years.

The in situ experiment at Äspö HRL will probably start during spring 2008. Depending on the outcome of the first experiment, there is an option to perform a second experiment. Each experiment will last about 4-6 months.

3.7.2 Transport Resistance at the Buffer-Rock Interface



The equipment intended for the laboratory experiments. The equipment is currently used in another SKB project, Bentonite Erosion.

If a canister fails and radionuclides are released, they will diffuse through the bentonite buffer. If there is a fracture intersecting the deposition hole, the water flowing in the fracture will pick up radionuclides from the bentonite buffer.

The transport resistance is concentrated to the interface between the bentonite buffer and the rock fracture. The mass transfer resistance due to diffusion resistance in the buffer is estimated to only 6% and the diffusion resistance in the small cross section area of the fracture in the rock to 94% /Neretnieks 1982/. The aim of the Transport Resistance at Buffer-Rock Interface project is to perform studies to verify the magnitude of this resistance.

The experiment will be performed in the laboratory, where a fracture is simulated as a 1 mm space between two Plexiglas plates. The equipment includes a water pump for very low flow rates. The design of field experiments depends on the outcome of the laboratory experiments.

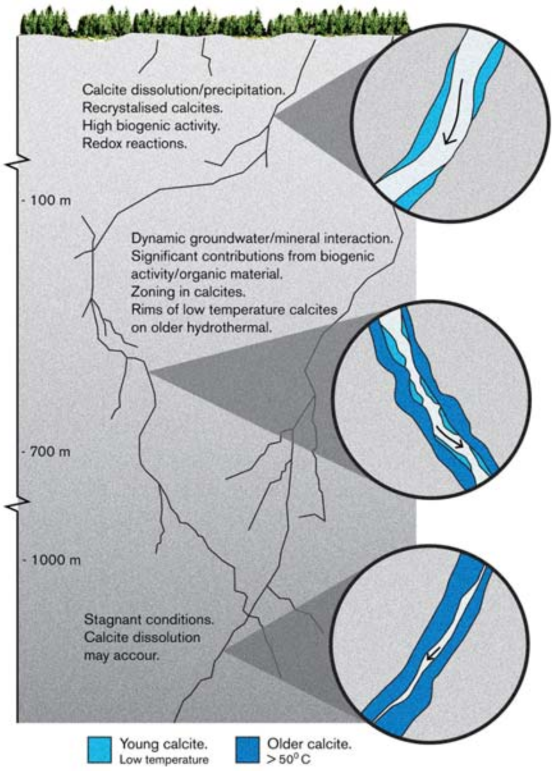
Present status

A project plan exists and a project decision has been taken. However, the resources needed for this project are currently used in another SKB project.

Scope of work for 2008

Attempts are made to recruit new staff that can perform the experiments. The plans for 2008 are uncertain, but there will not be any in situ experiment during the year.

3.8 Padamot



Potential calcite-groundwater interaction at various depths at Äspö.

Padamot (Palaeohydrogeological Data Analysis and Model Testing) investigates changes in groundwater conditions as a result of changing climate. Because the long term safety of an underground repository depends on the stability of the repository environment, demonstration that climatic impacts attenuate with depth is important. Currently, scenarios for groundwater evolution relating to climate changes are poorly constrained by data and process understanding.

The objectives of the Padamot project at Äspö are to:

- Improve understanding and prioritise palaeo-hydrogeological information for use in safety assessments.
- Collect chemical/isotopic data using advanced analytical methods.
- Integrate and synthesise results to constrain scenarios used in performance assessments.
- Disseminate the results to the scientific community.

The EC-part of the project was finalised and reported in 2005. The present project comprises analytical and modelling tasks mainly based on uranium series analyses. Material from borehole KAS17 at Äspö is used in this study.

Present status

A poster presentation with the title "Uranium series studies for the safety case of deep geological disposal of nuclear wastes" was given at the Migration conference in Munich in August 2007, and a manuscript with the same title has been prepared for publication. The paper deals with the fundamental principles for uranium series analyses applied on groundwater and mineral samples and focus on the problems and possibilities with the method.

Samples from KAS17 at Äspö are used in an inter-laboratory study. The samples have a suitable uranium content and the first preliminary results from Helsinki University show that both mobilisation and deposition is possible to trace. The samples from 19-21 m depth show the largest disequilibria. One advantage with the KAS17 samples is that they have not been mapped (no water and/or acid have been used on the drill core after the drilling).

Scope of work for 2008

The usefulness of uranium series analyses has been discussed for long time and a number of case studies (in Scandinavia and in the UK) show clearly that uranium series analyses describe mobilisation and deposition of uranium during the last 1 million years. Furthermore uranium mobilisation is dependent on redox conditions, which makes it a valuable tracer in studying redox conditions; e.g. if signs of uranium mobilisation are observed in reducing rocks one may conclude that the rocks have experienced a redox change in the past. However, preferential removal of ^{234}U can occur under reducing conditions resulting in significant decay series disequilibria.

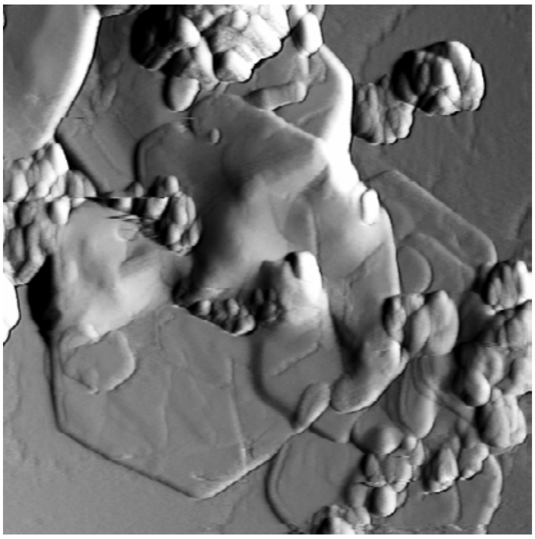
Usually near surface samples show mobilisation of uranium during oxidising conditions which can be followed by deposition deeper down. Clear signs of mobilisation and deposition are usually found in the upper 50 to 100 m. Depending on the hydrology, rock type, fracture coatings and fracture frequency the depth of the perturbed zone will vary from a few meters down to several hundred meters.

Analyses of fracture coatings from open fractures from surface to depth of ca 200 m will be carried out within the present project in order to test methodology (inter-laboratory study). Problems with sample disturbances will be addressed e.g. how to interpret results from deep samples showing recent mobilisation and deposition. The results may be right but it is important to also keep in mind that these samples are more easily disturbed, e.g. because:

- earlier stagnant conditions are changed, i.e. fracture may have been opened to larger flow than during undisturbed conditions
- drilling fluids (usually near-surface groundwaters) are introduced to deeper levels
- water and in worst case acid used during core logging may have destroyed the original signature.

The inter-laboratory study of fracture samples from KAS17 will continue with further analyses carried out at two laboratories (Helsinki University and Scottish Universities Environmental Research Centre) using different leaching schemes.

3.9 Fe-oxides in Fractures



Atomic Force Microscopy image of green rust sulphate. Image is 2.5 x 2.5 microns

Proof of reducing conditions at repository depth is fundamental for the safety assessment of radioactive waste disposals. Fe(II) - minerals are common in the bedrock and along fracture pathways and constitute a considerable reducing capacity together with organic processes. Another area of interest is the radionuclide retention capacity provided by Fe-oxides and -oxyhydroxides in terms of sorption capacity and immobilisation.

The basic idea of the project is to examine Fe-oxide fracture linings, in order to explore for suitable palaeo-indicators for their formation conditions, while at the same time learning about the behaviour of trace component uptake in general, both from the natural material as well as through testing of behaviour in controlled parametric studies in the laboratory.

Present status

The present aim of the "Continuation"' phase of the project is to establish the penetration depth of oxidising water below ground level. Oxidising waters may represent present-day recharge, or reflect penetration of glacial melt waters during the last glaciation.

Approximately 60 samples collected in September 2006 from drillcore material from the Laxemar area have been examined with optical microscopy and half have been selected for more detailed study. These samples have been characterised with X-ray diffraction and are presently undergoing analysis with Mössbauer spectroscopy (MS). Following MS the samples will be studied using electron microscopy (SEM).

Once the solid has been characterised completely, the material will be dissolved for Fe-isotope analysis and, possibly, for dating with uranium-decay series. For a few selected samples, a small amount of solid material will be saved with the aim of performing analysis of their oxygen isotope content.

Scope of work for 2008

Planned work for 2008 will be to complete the laboratory studies and to produce a report detailing sampling, laboratory experimental conditions as well as the interpretation and discussion of the results.

3.10 Swiw-tests with Synthetic Groundwater

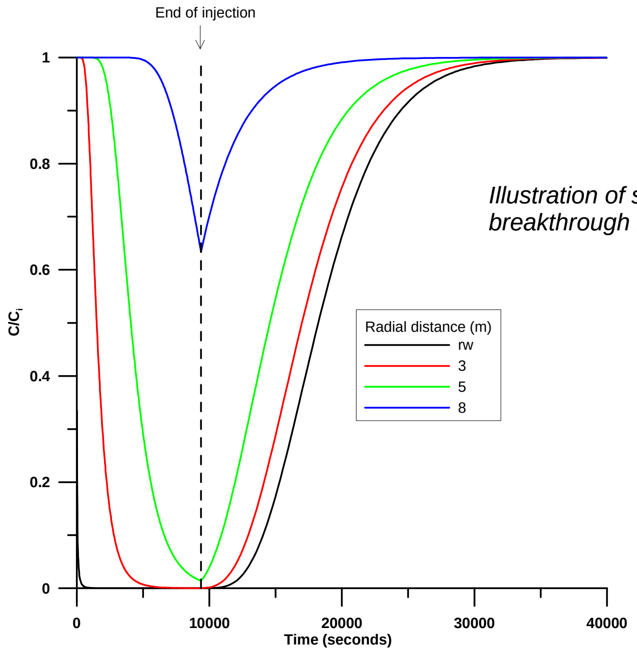


Illustration of solute-free water breakthrough in a single fracture

The Single Well Injection Withdrawal (Swiw) tests with synthetic groundwater constitute a complement to performed tests and studies on the processes governing retention, e.g. the True experiments as well as Swiw tests performed within the SKB site investigation programme.

The general objective of the Swiw test with synthetic groundwater is to increase the understanding of the dominating retention processes and to obtain new information on fracture aperture and diffusion. The basic idea is to perform Swiw tests with synthetic groundwater with a somewhat altered composition, e.g. replacement of chloride, sodium and calcium with nitrate, lithium and magnesium, compared to the natural groundwater at the site.

Sorbing as well as non-sorbing tracers may be added during the injection phase of the tests. In the withdrawal phase of the tests the contents of the "natural" tracers (chloride sodium and calcium) as well as the added tracers in the pumping water is monitored. The combination of tracers, both added and natural, may then provide desired information on diffusion, for example if the diffusion in the rock matrix or in the stagnant zones dominates.

Present status

The work within the Swiw project during 2007 constituted of a feasibility study. The objectives of the study were to investigate if True Block scale may be used as a test site, to investigate the possibility of producing synthetic groundwater of sufficient purity and amount and finally to perform scoping calculations in order to simulate and optimise the tests.

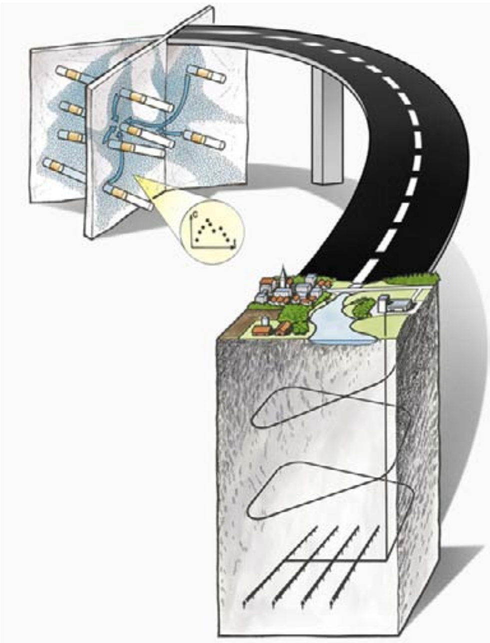
The original location in mind for the tests was the True Block Scale site and the well characterised Structures #19 and #20. The feasibility study shows that the site would be suitable for the tests. However, the on-going work with a new tunnel in the vicinity blocks the site for Swiw tests until the tunnel is completed (early 2009). At that point the hydraulic conditions at the site may be altered significantly so that performance of Swiw tests there may be unsuitable or impossible. Hence, a new site to perform the Swiw tests may be necessary to find.

The feasibility study shows that the combination of tracers and Swiw tests with and without waiting period presents new opportunities to investigate if the diffusion is dominated by fast or slow processes, i.e. if the diffusion is dominated by stagnant zones or rock matrix. The study also shows that it is possible to produce synthetic groundwater of sufficient purity and amount.

Scope of work for 2008

The first tasks for 2008 will be to decide where to perform the experiments and to produce a project plan accordingly to the decision. The following time table will depend on the decision. If the decision is to use True Block Scale, no field activities may be carried out until early 2009 when the new tunnel is finished. If the decision is to use some other test site, the first half of 2008 will be used for selection, preparation and characterisation of the site. In this case, field experiments within the Swiw test with synthetic groundwater will start during the second half of 2008.

3.11 Task Force on Modelling of Groundwater Flow and Transport of Solutes



The Äspö Task Force on Modelling of Groundwater Flow and Transport of Solutes is a forum for the organisations supporting the Äspö HRL to interact in the area of conceptual and numerical modelling of groundwater flow and transport of solutes in fractured rock.

The Task Force shall propose, review, evaluate and contribute to the modelling work in the project. In addition, the Task Force shall interact with the principal investigators responsible for carrying out experimental and modelling works for Äspö HRL.

The work within the Task Force constitutes an important part of the international co-operation within the Äspö HRL.

Present status

In the Task Force, work has been in progress in Task 6 - Performance Assessment Modelling Using Site Characterisation Data, and in Task 7, which addresses a long-term pumping test in Olkiluoto, Finland. The status of the specific modelling tasks is given within brackets in Table 3-1. In addition, Task Force meeting 23 was held in Toronto, October 29-31.

Task 6 tries to bridge the gap between Performance Assessment (PA) and Site Characterisation (SC) models by applying both approaches for the same tracer experiment. It is hoped that this will help to identify the relevant conceptualisations (in processes/structures) for long term PA predictions and to identify site characterisation data requirements to support PA calculations. All, except one, of the sub-task reports 6D, 6E and 6F from the modelling groups have been printed and the review report for these sub-tasks is in the printing process. A summary of the outcome of Task 6 has been submitted to a scientific journal. In addition, four modelling groups have submitted papers to the same scientific journal and in conjunction with the summary paper.

Task 7 addresses modelling of the OL-KR24 long-term pumping test at Olkiluoto in Finland. The task will focus on methods to quantify uncertainties in PA-type approaches based on SC-type information; along with being an opportunity to increase the understanding of the role of fracture zones as boundary conditions for the fracture network and how compartmentalisation influence the groundwater system. The possibilities to extract more information from interference tests will also be addressed. Earlier it was decided at the meeting to divide Task 7 into several sub-tasks. A task description for the sub-task 7A has been sent out to the modellers and preliminary results from the modelling have been presented. Updated Task 7 information and data deliveries have been made. A workshop on Task 7 was held in June in Gothenburg.

Table 3-1. Task descriptions and status of the specific modelling sub-tasks.

6	**Performance Assessment (PA) modelling using Site Characterisation (SC) data.**
6A	Model and reproduce selected True-1 tests with a PA model and/or a SC model to provide a common reference. (External review report printed).
6B	Model selected PA cases at the True-1 site with new PA relevant (long term/base case) boundary conditions and temporal scales. This sub-task serves as means to understand the differences between the use of SC-type and PA-type models and the influence of various assumptions made for PA calculations for extrapolation in time. (External review report printed).
6C	Develop semi-synthetic, fractured granite hydrostructural models. Two scales are supported (200 m block scale and 2,000 m site-scale). The models are developed based on data from the Prototype Repository, True Block Scale, True-1 and Fracture Characterisation and Classification project (FCC). (External review report printed).
6D	This sub-task is similar to sub-task 6A and is using the synthetic structural model in addition to a 50 to 100 m scale True Block Scale tracer experiment. (Most modelling reports printed and final review report available).
6E	This sub-task extends the sub-task 6D transport calculations to a reference set of PA time scales and boundary conditions. (Most modelling reports printed and final review report available).
6F	Sub-task 6F is a sensitivity study, which is proposed to address simple test cases, individual tasks to explore processes and to test model functionality. (Most modelling reports printed and final review report available).
7	**Long-term pumping experiment.**
7A1	Hydrostructural model implementation. (Preliminary results were presented at the Task Force Workshop in June).
7A2	Pathway simulation within fracture zones. (Preliminary results were presented at the Task Force Workshop in June).
7A3	Conceptual modelling of PA relevant parameters from open hole pumping.
7A4	Quantification of compartmentalisation from open hole pumping tests and flow logging
7A5	Quantification of transport resistance distributions along pathways
7B	This sub-task is addressing the same as sub-task 7A but in a smaller scale, i.e. rock block scale. Sub-task 7B is using 7A as boundary condition
7C	Here focus is on deposition hole scale issues, resolving geomechanics, buffers, and hydraulic views of fractures
7D	Tentatively this Sub-task concerns integration on all scales

Scope of work for 2008

The main activities targeted to be accomplished during 2008 are summarised below:

- Organise the 24th International Task Force meeting in September, hosted by SKB.
- Organise a Task 7 workshop in May.
- Finalise printing modelling reports of sub-task 6D, 6E, 6F and 6F2.
- Publish the review and modelling papers of Task 6 in a scientific journal.
- Perform modelling and reporting within Task 7.
- Continue the external review of Task 7.
- Prepare for future tasks, e.g. a common task with the Task Force on Engineered Barriers Systems.

4 Engineered barriers

4.1 General

To meet stage goal 4, to demonstrate technology for and function of important parts of the repository barrier system, work is performed at Äspö HRL. This implies translation of current scientific knowledge and state-of-the-art technology into engineering practice applicable in a future repository.

It is important that development, testing and demonstration of methods and procedures, as well as testing and demonstration of repository system performance, are conducted under realistic conditions and at appropriate scale. A number of large-scale field experiments and supporting activities are therefore conducted at Äspö HRL. The experiments focus on different aspects of engineering technology and performance testing, and will together form a major experimental programme.

With respect to technology demonstration, important overall objectives of this programme are to:

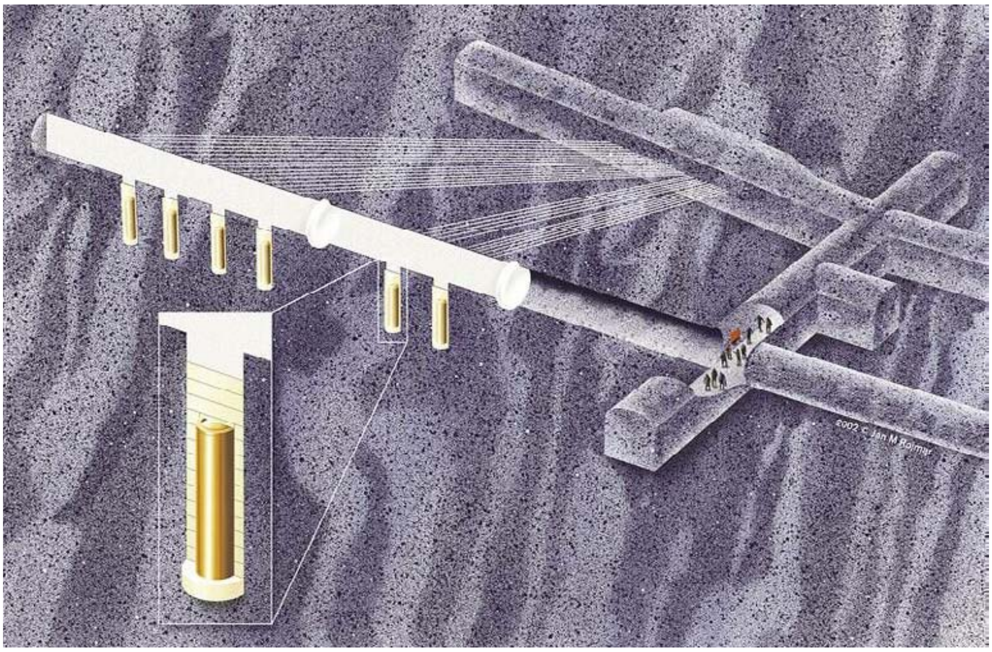
- Furnish methods, equipment and procedures required for excavation of tunnels and deposition holes, near-field characterisation, canister handling and deposition, backfill, sealing, plugging, monitoring and also canister retrieval.
- Integrate these methods and procedures into a disposal sequence, that can be demonstrated to meet requirements of quality in relation to relevant standards, as well as practicality.

With respect to repository function, the objectives are to test and demonstrate the function of the engineered barriers as well as the function of the integrated repository system.

The on-going experiments and projects within the Engineered Barriers at Äspö HRL are:

- Prototype Repository.
- Long Term Test of Buffer Material.
- Alternative Buffer Materials.
- Backfill and Plug Test.
- Canister Retrieval Test.
- Temperature Buffer Test.
- KBS-3 method with Horizontal Emplacement.
- Sealing of Tunnel at Great Depth.
- Large Scale Gas Injection Test.
- In situ Testing of Miniature Canisters.
- Rock Shear Experiment.
- Task Force on Engineered Barrier Systems.

4.2 Prototype Repository



The Prototype Repository is located in the TBM-tunnel at the -450 m level and includes six full scale deposition holes. The aims of the Prototype Repository are to demonstrate the integrated function of the repository components and to provide a full-scale reference for comparison with models and assumptions.

The Prototype Repository should, to the extent possible, simulate the real repository system regarding geometry, materials and rock environment.

Instrumentation is used to monitor processes and properties in the canister, buffer material, backfill and the near-field rock. The evolution will be followed for a long time.

The inner tunnel (Section I, canisters #1-#4) was installed and the plug cast in 2001 and the heaters in the canisters were turned on one by one. The outer tunnel (Section II, canisters #5-#6) was backfilled in June 2003 and the tunnel plug with two lead-throughs was cast in September the same year.

Present status

The surface between the rock and the outer plug was grouted in October 2004 and the drainage of the tunnel was closed at the beginning of November 2004. Subsequent the pore pressure in the backfill and the buffer increased and about one month after the closing of the drainage, damages of the heaters in two of the canisters were observed. The power to all of the heaters was then switched off, the drainage of the tunnel was opened again and an investigation of the canisters with damaged heaters started. The power to all the canisters except for canister #2 was switched on and the drainage of the tunnel was kept open. At the beginning of September 2005, new damages of the heaters in canister #6 was observed. The power to this canister was then switched off but at the beginning of November 2005 the power was switched on again. New damages of the heaters in canister #6 were observed at the beginning of August 2005 and the power to this canister was switched off during two months but is now switched on again.

The instruments in the two sections in buffer, backfill and rock are continuously reading. The date from the readings is presented in data reports (two per year). Chemical measurements in buffer, backfill and surrounding rock are on-going. Tests for evaluating the groundwater pressure and groundwater flow in the rock have also been performed. Acoustic measurements in the rock are on-going with the purpose to study how the temperature evolution is affecting the properties of the rock. A thermal FEM model for the Prototype Repository including the rock, backfill, buffer and the six canisters has been developed. A one dimension THM modelling of the buffer in deposition hole #1 and #3 has been finished.

Scope of work for 2008

The instrument readings in the two sections and the chemical measurements in buffer, backfill and surrounding rock will continue. In addition, new tests for evaluation of the hydraulic conditions in the rock will be made and the modelling teams will continue the comparison of measured data with predictions. THM modelling of the buffer and the backfill will continue. This work will be focused on homogenisation of the buffer in a deposition hole (1D-model) and on how the boundary conditions are affecting the saturation of the buffer (2D-model). Furthermore, the thermo-mechanical evolution of the Prototype Repository rock mass will be modelled in order to get additional perspectives on the possibility of spalling in KBS-3 deposition holes. According to the project plan the outer section will be excavated at the beginning of 2009. This work will be planned during 2008.

4.3 Long Term Test of Buffer Material

The project Long Term Test of Buffer Material aims to validate models and hypotheses concerning mineralogy and physical properties in a bentonite buffer.

Seven test parcels containing heater, central tube, clay buffer, instruments and parameter controlling equipment have been placed in boreholes with a diameter of 300 mm and a depth of around 4 m.

Temperature, total pressure, water pressure and water content, are measured during the heating period. At termination of the tests, the parcels are extracted by overlapping core-drilling outside the original borehole. The water distribution in the clay is determined and subsequent well-defined mineralogical analyses and physical testing of the buffer material are made.

The test parcels are also used to study other processes in bentonite such as cation diffusion, microbiology, copper corrosion and gas transport under conditions similar to those expected in a deep repository.

Present status

Four test parcels have been retrieved and analysed so far, see Table 4-1. The remaining three parcels are well functioning and have been heated to target temperatures for eight years. The latest parcel (A2) that has been retrieved has been analysed with respect to porewater chemistry and changes in mineralogy at laboratories in Finland, France, Germany, Sweden and Switzerland. Additional analyses have been made concerning bacteria, copper corrosion and cation diffusion. A workshop meeting was held in November where all results were presented. Individual contributions from the involved laboratories will be sent to the project administration and a common report including all analyses will be finalised before the end of March 2008.

A revised conceptual model of compacted bentonite has been developed in order to serve as a base for geochemical modelling. Detailed modelling of the mineralogical evolution in the A2 parcel has been initiated in the Task Force on Engineered Barrier Systems.

Scope of work for 2008

Water pressure, total pressure, temperature and moisture in the three remaining parcels are being continuously measured and stored every hour. The data are being checked monthly and the results are analysed more carefully in April and October.

The retrieval work of the next parcel, which likely will be the S2 parcel, is planned to start in April 2008 unless the result from the analyses of the A2 material motivates otherwise.

After retrieval of the next parcel, physical testing and chemical, mineralogical analyses of representative positions in the bentonite will be performed according to the test plan. The participating international research groups will be supplied with sufficient reference and thermally exposed material in order to make detailed mineralogical analyses. Additional tests and analyses will be made concerning bacterial activity, copper corrosion and cation diffusion.

Geochemical modelling will continue with the initial aim to describe the redistribution of the calcium minerals in the bentonite. Supporting laboratory experiments will also be performed.

Table 4-1. Buffer material test series.

Type	No.	max T (°C)	Controlled parameter	Time (years)	Remark
A	1	130	T, $[K^+]$, pH, am	1	Reported
A	0	120–150	T, $[K^+]$, pH, am	1	Reported
A	2	120–150	T, $[K^+]$, pH, am	5	Reporting in progress
A	3	120–150	T	5	On-going
S	1	90	T	1	Reported
S	2	90	T	5	On-going
S	3	90	T	>>5	On-going

A = *adverse conditions* *S* = *standard conditions* *T* = *temperature*

$[K^+]$ = *potassium concentration* *pH* = *high pH from cement* *am* = *accessory minerals added*

4.4 Alternative Buffer Materials

Installation of one of the three packages illustrating the mixing of the different compacted buffer discs.

In the Alternative Buffer Materials project different types of buffer materials are tested. The aim is to further investigate the properties of the alternatives to the SKB reference bentonite (MX-80). The project is carried out using material that according to laboratory studies are conceivable buffer materials. The experiment is carried out in the same way and scale as the Long Term Test of Buffer Material (LOT).

The objectives are to:

- Verify results from laboratory studies during more realistic conditions with respect to temperature, scale and geochemical circumstances.
- Discover possible problems with manufacturing and storage of bentonite blocks.
- Give further data for verification of thermo-hydro-mechanical (THM) and geochemical models.

The field tests started during 2006. Eleven different clays have been chosen to examine effects of smectite content, interlayer cations and overall iron content. Also bentonite pellets with and without additional quartz are being tested. The different clays are assembled in three packages.

Present status

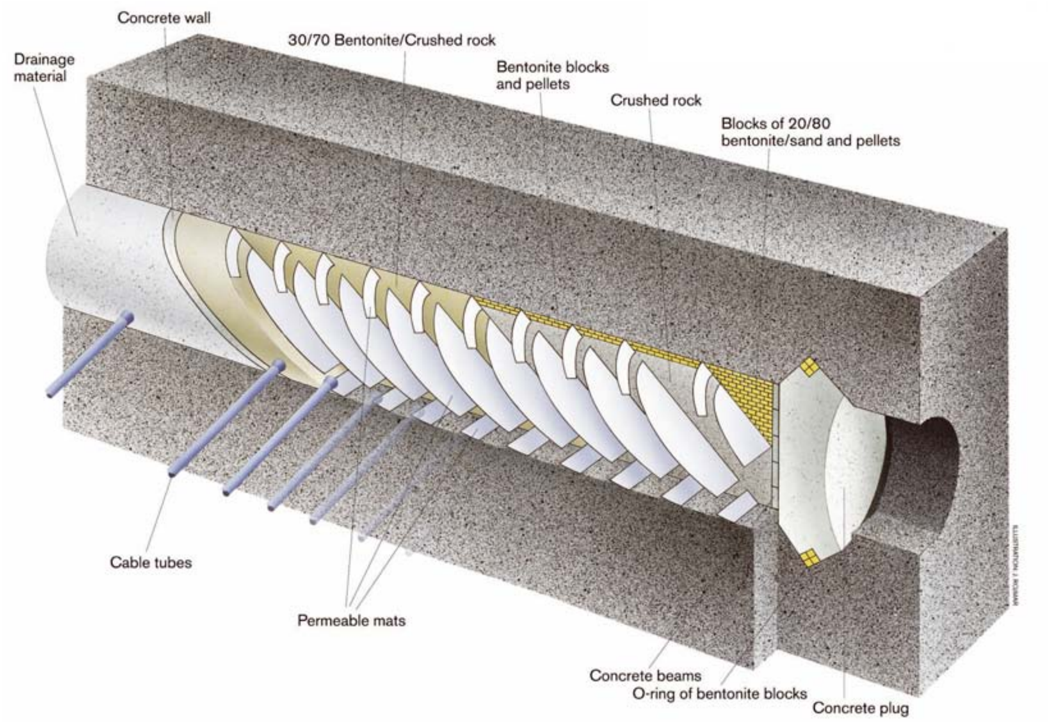
The packages were deposited and the operational phase was initiated in November 2006. During 2007 the power to the heaters has carefully been raised in steps to reach the goal temperature of 130 ºC. The goal temperature is expected to be reached in the two heated packages in December 2007.

Discussions with the participating project partners on the analysis program are in progress. An installation report has been written and is available in a draft version.

Scope of work for 2008

The first package is planned to be retrieved in 2008 and the second and third package will be in operation for another 2-5 years before retrieval. During 2008 analyses of the buffer materials in the retrieved package will be done.

4.5 Backfill and Plug Test



The Backfill and Plug Test includes tests of backfill materials, emplacement methods and a full-scale plug. The inner part of the tunnel is filled with a mixture of bentonite and crushed rock (30/70) and the outer part is filled with crushed rock and bentonite blocks and pellets at the roof.

The integrated function of the backfill material and the near-field rock in a deposition tunnel excavated by blasting is studied as well as the hydraulic and mechanical functions of the full-scale concrete plug.

The entire test set-up with backfill, instrumentation and casting of the plug was finished in the end of September 1999 and the wetting of the 30/70 mixture through filter mats started in late 1999.

The backfill was completely water saturated in 2003 and flow testing for measurement of the hydraulic conductivity has been running since late 2003.

In autumn 2006 activation of the four pressure cylinders mounted on the floor and in the roof started. These will be used for mechanical testing of the compressibility of the backfill during 2007.

Present status

During 2004 and 2005 the flow testing of the bentonite/crushed rock matrix were performed. Evaluation of the results shows that the field hydraulic conductivity is in the same range as expected from the laboratory tests but rather high close to the roof due to poor compaction and close to the floor, probably due to the blast disturbed zone in the rock. In late 2005 and in large part of 2006 measurements of hydraulic conductivity in single pointes by pressurising filter equipped tubes and measuring the water flow into the backfill were performed. The results largely confirmed the other measurements. In autumn 2006 activation of the pressure cylinders mounted on the floor and in the roof started. Theses tests were performed during 2007. Preliminary evaluation of the results show that the crushed rock backfill is very stiff especially close to the floor while the 30/70 backfill is looser than expected especially close to the floor. Evaluation of results is on-going.

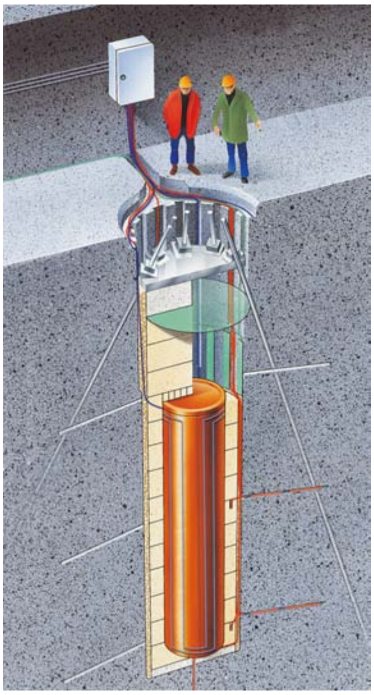
Scope of work for 2008

According to the time schedule, the Backfill and Plug Test was planned to be interrupted and the backfill excavated in autumn 2006. However, work prioritisation has delayed the activities and entailed postponement of the excavation.

The following activities will be accomplished during 2008:

- Evaluation of the results from the pressure cylinder tests.
- Hydraulic testing of the local hydraulic conductivity of the crushed rock with the so called “CT-tubes”.
- Continued data collection and reporting of measured water pressure, water flow and total pressure.
- Maintenance of equipment and supervision of the test.
- Supplementary modelling.
- Supplementary laboratory testing for modelling and understanding of the hydromechanical properties of the backfill materials.

4.6 Canister Retrieval Test



The Canister Retrieval Test is aiming at demonstrating the readiness for recovering of emplaced canisters also after the time when the bentonite is fully saturated.

In the Canister Retrieval Test two full-scale deposition holes have been drilled, at the -420 m level, for the purpose of testing technology for retrieval of canisters after the buffer has become saturated.

These holes have been used for studies of the drilling process and the rock mechanical consequences of drilling the holes.

Canister and bentonite blocks were emplaced in one of the holes in 2000 and the hole was sealed with a plug, heater turned on and artificial water supply to saturate the buffer started.

In January 2006 the retrieval phase was initiated and the canister was successfully retrieved on May 12th 2006. The saturation phase had, at that time, been running for more than five years with continuous measurements of the wetting process, temperature, stresses and strains.

Present status

The buffer was manually excavated down to half the canister height to allow buffer samples to be taken. The samples were than sawed in smaller parts and analysed. Initial analyses were conducted during 2006 to determine the water content and density. Further studies of the hydraulic conductivity, compressibility, chemical/biological composition have been conducted during the year 2007 and a report on the further studies is expected in the beginning of 2008.

Modelling of the buffer saturation and experiment progress is part of the Task Force on Engineered Barrier Systems and was initiated during 2007.

Removal of the remaining buffer, from half the canister height and down, was done with a disintegration method. The bentonite was dissolved with a saline solution and pumped out of the deposition hole. The method was successful and the canister was freed from the buffer.

The retrieved canister was sent to the Canister Laboratory in Oskarshamn for analyses of e.g. copper corrosion and deformation. Malfunction of the canister heaters are so far considered to be caused by the heater power cables. The status of the heaters is being investigated.

Scope of work for 2008

All analyses will be finalised and reported during 2008. A summary report of the experiences and analyses of malfunctioning heaters will also be written.

Canister studies will continue at the Canister Laboratory in Oskarshamn, this is however carried out as a separate project and will not be reported in the Canister Retrieval project.

4.7 Temperature Buffer Test

The French organisation Andra carries out the Temperature Buffer Test (TBT) at Äspö HRL in co-operation with SKB.

The aims of the TBT are to evaluate the benefits of extending the current understanding of the THM behaviour of engineered barriers during the water saturation transient to include high temperatures, above 100°C.

The scientific background to the project relies on results from large-scale field tests on engineered barrier systems, notably Canister Retrieval Test, Prototype Repository and Febex (Grimsel Test Site).

The test is located in the same test area as the Canister Retrieval Test, which is in the main test area at the -420 m level.

The TBT experiment includes two heaters in the axis of the deposition hole, one on top of the other, separated by a compacted bentonite block. The heaters are 3 m long and 610 mm in diameter and are constructed in carbon steel. Each one simulates a different type of confinement system: a bentonite buffer only (bottom section) and a bentonite buffer with inner sand backfill (upper section).

An artificial water pressure is applied in a slot between the buffer and rock, which is filled with sand and functions as a filter.

Present status

The experimental setup is characterised by stationary, well defined, boundary conditions. This implies that the experimental activities at the test site up till 2006 have been run mostly at a routine basis, while the focus has been on different modelling tasks and general successive evaluation of obtained results.

The evaluation of THM processes has been made through analysis of sensors data (for the latest report, see /Goudarzi et al. 2007/) and numerical modelling /Hökmark et al. 2007, Åkesson 2006a/. In addition, evaluation and numerical modelling of parallel lab-scale mock-up tests have been made /Åkesson 2006b/. The final evaluation of the field test will be made when data from the future dismantling and sampling will be available.

A number of experimental activities have been planned for the period up to year 2009. Three steps are identified for the activity planning of the upper package: (i) evaluation of the THM processes, (ii) a gas injection test and (iii) a retrieval test. For the lower package the evaluation of the THMC processes, with operation at high temperatures, is the main point of interest.

A requirement for the gas injection test is that complete water saturation of the upper package has been achieved. The hydration of the shield was therefore started during 2007. Some difficulties have been experienced during this activity due to high flow resistance of the sand shield injection points (or their neighbourhood). The hydration is nevertheless underway and is expected to be completed in the beginning of 2008.

In order to promote mineralogical alteration processes in the lower package, the thermal output from the heaters has been changed during 2007. The plan is to increase the output from the lower heater in steps from 1,600 W to 2,000 W and at the same time to decrease the output from the upper heater from 1,600 W to 1,000 W.

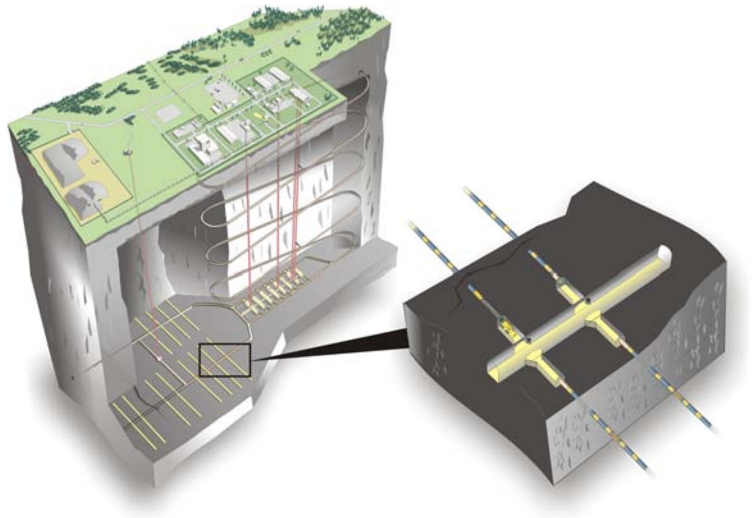
Scope of work for 2008

When the hydration of the shield is completed, preparations for the gas injection test will be made. The gas test will be preceded and followed by hydraulic tests, during which the integrity of the buffer is analysed by pressurising the shield with water and by measuring the inflow, thereby quantifying the hydraulic conductivity.

The gas injection test aims at revealing information on the behaviour of a bentonite buffer subjected to high gas pressures. The plan is to pressurise the sand shield, located between the upper heater and the buffer. The actual gas test will first and foremost be made by pressurizing the shield with water thereby compressing the remaining gas phase in the shield. If this is found to be insufficient, the shield will be directly pressurized with gas.

A retrieval test of the upper heater is planned after the gas injection test and scheduled for 2009. The goal is to test a retrieval technique facilitated by the sand shield, by accessing the heater through removing the sand with a vacuum technique.

4.8 KBS-3 Method with Horizontal Emplacement



The possibility to modify the reference KBS-3 method and make serial deposition of canisters in long horizontal deposition holes (KBS-3H), instead of deposition of single canisters in vertical deposition holes (KBS-3V), is studied in this project. The KBS-3H project is a joint project between SKB and Posiva.

One reason for proposing the change is that the deposition tunnels in KBS-3V are not needed if the canisters are disposed in long horizontal deposition holes and the excavated rock volume and the amount of backfill can be considerably reduced. This in turn reduces the environmental impact during the construction of the repository and also the construction costs.

The site for the demonstration of the method is located at -220 m level. A niche with a height of about 8 m and a bottom area of 25×15 m forms the work area. Two horizontal deposition holes have been excavated, one short with a length of about 15 m and one long with a length of about 95 m. The deposition equipment will be tested in the long hole and the short hole will be used for testing of different drift components.

The KBS-3H project is partly financed by the EC-project Esdred – Engineering studies and demonstration of repository designs.

Present status

The KBS-3H deposition equipment have been tested and demonstrated in the 95 m long deposition hole at the -220 m level. The equipment is working well but some improvements on the equipment are planned to be performed and tested. Several components of the KBS-3H design have been tested and are being tested both at the -220 m level at Äspö and above ground.

The shotcrete plug test was carried out during 2006. The first tests with the Megapacker were carried out late 2007. Preparations have also been made to test the compartment plug by excavating the rock notch with a sawing technique in the 15 m long deposition hole.

Two designs are considered for the KBS-3H canisters: the Basic Design and the DAWE (drainage, artificial watering and air evacuation) design. To verify the ability to remove the saturation pipes tests on pulling out water pipes through bentonite are on-going in the Bentonite Laboratory.

Scope of work for 2008

The test and demonstration of the deposition equipment will continue in the 95 m long deposition hole at the -220 m level during the first half of 2008

The Megapacker tests will continue to verify the method and the function of the equipment. The test consists of three grouting sessions for the remaining fracture zones in the 95 m long deposition hole. The tests will be conducted in the first half of 2008.

A compartment plug will be manufactured, installed and tested in the 15 m long deposition hole during 2008. This test will most likely be installed in the second quarter of 2008, and the test will be in operation for two to three months.

The pipe removal tests for the DAWE alternative will continue during the year in the Bentonite Laboratory. The first test will be completed in February 2008. After that, the result will be analysed and a second test installed, possibly after minor changes in the test equipment. The third test will not be in operation until the second half of 2008.

Planning for different full-scale tests of the KBS-3H concept at the -220 m level and also for a KBS-3H prototype repository demonstration test at -400 to -420 m level will start during 2008.

4.9 Large Scale Gas Injection Test

Large-scale gas injection test (Lasgit) 420 m below ground at Äspö HRL. A scientist from the British Geological Survey (BGS) works next to the large steel lid anchored over the deposition hole.

Current knowledge pertaining to the movement of gas in a compacted bentonite buffer is based on small-scale laboratory studies. These diagnostic tests are designed to address specific issues relating to gas migration and its long-term effect on the hydro-mechanical performance of the buffer clay.

Laboratory studies have been used to develop process models to assess the likely implications of gas flow in a hard-rock repository system. While significant improvements in our understanding of the gas-buffer system have taken place, a number of important uncertainties remain. Central to these is the issue of scale and its effect on the mechanisms and process governing gas flow in compact bentonite.

The question of scale-dependency in both hydration and gas phases of the test history are key issues in the development and validation of process models aimed at repository performance assessment. To address these issues, a Large Scale Gas Injection Test (Lasgit) has been initiated.

Its objectives are:

- Perform and interpret a large scale gas injection test based on the KBS-3V design concept.
- Examine issues relating to up-scaling and its effect on gas migration and buffer performance.
- Provide information on the process of hydration and gas migration.
- Provide high-quality test data to test/validate modelling approaches.

In February 2005 the deposition hole was closed and the hydration of the buffer initiated. During 2007 preliminary hydraulic and gas transport tests were performed. These will be repeated as the buffer matures in order to examine the temporal evolution of these properties. When the buffer is fully-saturated a comprehensive series of gas injection tests will be undertaken to examine the mechanisms governing gas flow in KBS-3 bentonite.

Present status

At the request of project stakeholders a preliminary gas injection test was planned for 2007 with a view to verifying the operation and data reduction methodologies outlined in the original concept report and to provide qualitative data on hydraulic and gas transport parameters for a bentonite buffer during the hydration process.

With this in mind, activities during 2007 have focused on: (i) the continued hydration of the bentonite buffer, (ii) completion of leak-testing of key experimental systems in anticipation of gas testing,(iii) initial hydraulic test for the determination of baseline hydraulic properties, (iv) preliminary gas injection test to verify experimental operation and to define interim gas transport parameters and (v) repeat hydraulic test to examine evolution of hydraulic properties following a gas injection event. Background tasks have focussed on the reprocessing of legacy data and the conversion of Phase 1 hydration data for archiving by SKB.

Given the current hydration state of the buffer, it was decided that preliminary mass transport measurements would be undertaken in one of the 100 mm filters positioned in the lower canister array. On 25th May 2007, the lower filter arrays (FL901 to FL904) were isolated from all neighbouring test circuits and the pressures allowed to decay to provide information on the spatial distribution of local porewater pressures in the vicinity of each filter. On 21st June a constant head test was initiated using FL903, with the pressure on that filter raised to 4.3 MPa. During this hydraulic testing the remaining filters in the lower level remained isolated from the artificial hydration system and their pressure allowed to evolve in order to provide temporal data on local porewater pressures within the buffer clay. At the same time, artificial hydration continued through all remaining canister filters and hydration mats. Pressure on FL903 was maintained at 4.3 MPa until 19th July, when it was reduced to 560 kPa and then held at that level until 7th August.

Preliminary modelling of the hydraulic test has been carried out using a 2D axisymmetric variably saturated finite element porewater flow model. The initial saturation conditions for the hydraulic test cannot be determined *a-priori*, so it was necessary to try to model the whole hydration phase history in order to set these initial conditions. Using this approach, fits were obtained to the initial pressure decay data for the four filters that were isolated using values for hydraulic conductivity ranging from 9×10^{-14} to 1.6×10^{-13} ms^{-1} and specific storage values ranging from 5.5×10^{-5} to 4.4×10^{-4} m^{-1}. The constant pressure test on filter FL903 was fitted with a hydraulic conductivity of 7.5×10^{-14} ms^{-1} and a specific storage of 2.5×10^{-5} m^{-1}. Modelling to define the initial conditions also shows that significant zones around each of the canister filters remain unsaturated.

On 7th August gas injection into FL903 was begun. Analysis of the data suggest that gas starts to flow into the buffer at a pressure of about 775 kPa, which is much lower than the expected gas entry pressure for intact bentonite. It therefore seems likely that gas is flowing between the bentonite and the canister and possibly between bentonite blocks.

Following the onset of a second phase of gas pressurisation the observed pressure starts to deviate from the predicted ideal gas compression curve immediately, indicating that the pathway has re-opened without any delay. The gas flow rate into the buffer during this second phase rises gradually with time until, when the gas pressure is marginally greater than the local total stress, the flux into the bentonite rapidly increases. This is accompanied by small increases in total stress and porewater pressure within the system.

Following the cessation of injection the flux declines rapidly at first but then enters an extended period of very small flows. This is reflected in the pressure response which drops rapidly initially but then decays very slowly towards an asymptotic capillary threshold pressure, which is estimated to be about 4,990 kPa.

The test has been in successful operation for in excess of 1,000 days. Initial results from the preliminary gas tests performed to date, vindicate both the philosophy behind the experimental programme as well as the set-up and system design.

Scope of work for 2008

Experiment activities during 2008 will primarily focus on the second phase of hydration. It is anticipated that this component of the project will run for initially one year to provide adequate time for the buffer to continue its hydration and to potentially yield significantly different transport parameters, when interim hydraulic and gas testing is undertaken in early 2009. As before, these tests will be designed to minimise the effect of reintroducing gas. This cyclic approach to Lasgit testing will be continued while the buffer hydrates, yielding important interim data on the temporal evolution of the transport parameters. It is anticipated that the complexity of these subsequent test programmes will increase, reflecting the continued evolution of the buffer, and thereby generate additional data and process understanding.

4.10 Sealing of Tunnel at Great Depth

Grouting tests in Äspö HRL

Although the repository facility will be located in rock mass of good quality with mostly relatively low fracturing, sealing by means of rock grouting will be necessary. Ordinary grouts based on cement cannot penetrate very fine fractures and due to long term safety reasons a sealing agent that produces a leachate with a pH below 11 is preferred.

Silica sol, which consists of nano-sized particles of silica in water, has shown to be a promising grout, and in the sealing project at Äspö HRL, the use of silica sol is tested at great depth.

Depending on the encountered rock mass conditions low-pH cementitious grouts will also be used and evaluated.

Present status

The main goals of the project are to confirm that silica sol is a useful grout at the water pressures prevailing at repository level and to confirm that it is possible at this water pressure to seal to the preliminary tightness requirement for a deposition tunnel. To achieve this, an approximately 100 m long tunnel will be constructed at the Äspö HRL.

Investigations for the selection of site were carried out during the spring and summer of 2007. The major site requirements were the direction, intensity and size of fractures along the potential tunnel, a high groundwater pressure and a high-enough possibility to keep away from heavily water conducting zones. At an early stage a tunnel position extending from the TASI-tunnel at the -450 m level was selected as a first alternative. The selection was based on geo-hydrological modelling of the site and its surroundings, predictions of the singular fractures based on the results from examination of rock cores and geo-hydrological measurements.

In parallel with site investigation preliminary designs, drafting for new equipment and procurement for the constructional works were carried out. In September a contract with the contractor for rock works was signed. A silica sol pump with a control device specially designed for the use of silica sol at great depths has been specified and manufactured within the project. Initial testing of the behaviour of silica sol and cement-based low-pH grout has been carried out in order to verify theories for grout spread and erosion. Contract works started in November with a first short grouting fan followed by rock excavation.

Scope of work for 2008

The execution will be step-wise and is planned to include ordinary grouting fans, grouting with grout holes inside the contour, tests with post-grouting and tests of the sealing of drips. The extent of grouting will depend on the properties of the rock mass encountered, and on the results achieved in previous steps. Depending on the encountered rock mass conditions low-pH cementitious grouts will be used and evaluated. The project will implement and evaluate grouting characterisation methods and grout spread models as developed by Royal Institute of Technology and Chalmers University of Technology. A major part of the work is scheduled for 2008 with final reporting in 2009.

4.11 In Situ Corrosion Testing of Miniature Canisters

Operation of the five miniature canisters

Miniature canister with support cage

This project (MiniCan) is designed to provide information about how the environment inside a copper canister containing a cast iron insert would evolve if failure of the outer copper shell were to occur. The development of the subsequent corrosion in the gap between the copper shell and the cast iron insert would affect the rate of radionuclide release from the canister. The information obtained from the experiments will be valuable in providing a better understanding of the corrosion processes inside a failed canister.

Miniature canisters with a diameter of 14.5 cm and containing 1 mm diameter defects in the outer copper shell have been set up in five boreholes with a diameter of 30 cm and a length of 5 m at the Äspö HRL.

The canisters are mounted in support cages, four of which contain bentonite (three low density bentonite, one compact bentonite), and are exposed to natural reducing groundwater. Together with corrosion test coupons which are also in the boreholes, the canisters will be monitored for several years. The corrosion will take place under realistic oxygen-free repository conditions that are very difficult to reproduce and maintain for long periods of time in the laboratory.

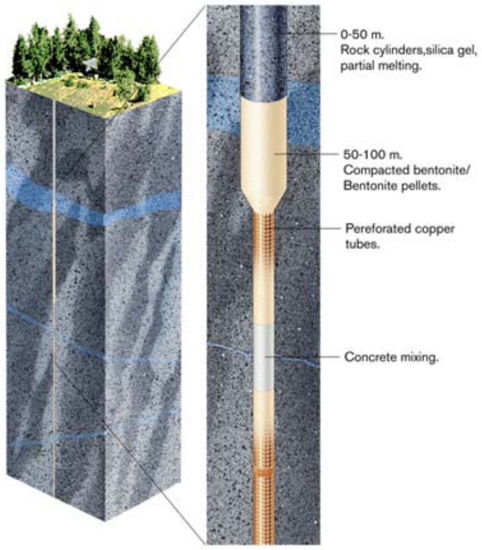
Present status

All five experiments are in operation and corrosion data are being collected as planned. This includes measurements of corrosion potential, corrosion rate and redox potential, using a range of electrochemical techniques. Regular water analyses and microbial analyses of the local environment have been obtained. Strain gauges are used to monitor for any dimensional changes on two of the model canisters. A number of additional corrosion coupons are in place in the boreholes. Data are transferred regularly to the UK for analysis through the internet link. A report on the first year’s operations is in progress.

Scope of work for 2008

During 2008, monitoring of the experiments will continue in the same way. No major changes to the experimental arrangements are envisaged although some changes may be made to the measurement parameters. Data analysis will continue, together with regular water sampling and analysis.

4.12 Cleaning and Sealing of Investigation Boreholes



The purpose of the programme is to develop technologies for borehole sealing including materials, installation techniques and equipment to meet the required long-term safety aspects.
After the completion of the Phase 3 of the project, it was found necessary that more testing of materials and equipment, as well as full-scale demonstration are needed. These should be carried out to assess the technical feasibility and long-term performance of the different concepts.
Therefore, the development of a strategy for sealing the boreholes is important, especially at repository level and this work is included in the programme, Phase 4, for the next four-year period.

Present status

Reports of the four sub-projects from Phase 3 have been approved and printed as International Progress Reports. The sub-projects comprises of:

Sub-project 1	Design and modelling of the performance of borehole plugs /Pusch and Ramqvist 2006a/
Sub-project 2	Plugging of 5 m boreholes at Äspö /Pusch and Ramqvist 2006b/
Sub-project 3	Plugging of borehole OL-KR24 at Olkiluoto and reference boreholes at Äspö /Pusch and Ramqvist 2007a/
Sub-project 4	Sealing of 200 mm boreholes at Äspö /Pusch and Ramqvist 2007b/

Preparatory planning for Phase 4 on the “Joint Work Programme on Borehole Sealing” has been initiated. An agreement on the co-operation between Posiva and SKB has been signed of both parties comprising the period 2007-2010.

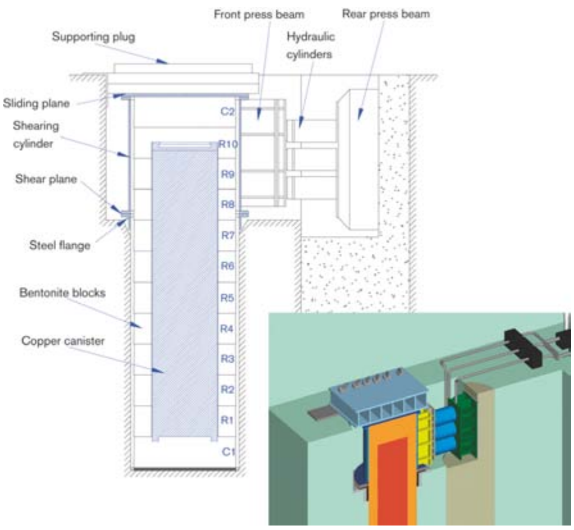
Scope of work for 2008

After the completion of the Phase 3 it was found that more testing of materials and equipment, as well as, full-scale demonstrations are needed.

The Phase 4 programme consists of the following tasks/issues.

- Conceptual plugging plan for boreholes - The borehole to be sealed and plugged will be divided into categories. Principal conceptual designs for each category will be developed.
- Detailed design for implementation - For the selected boreholes detailed designs will be drafted. These comprise among other things estimates on needs and techniques for stabilisation, as well as, acceptance criteria, definition of accurate requirements for plugging procedure, specification for plugs and their detailed designs.

4.13 Rock Shear Experiment



The Rock Shear Experiment (Rose) aims at observing the forces that act on a KBS-3 canister if a displacement of 100 mm would take place in a horizontal fracture that crosses a deposition hole. Such a displacement may be caused by an earthquake and the test set-up need to provide a shearing motion along the fracture that is equal to the worst expected shearing motion in real life.

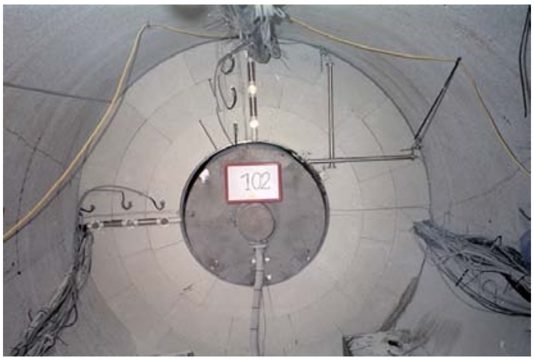
Present status

A pre-study of design and feasibility of an in situ test is completed and reported /Börgesson et al. 2006/. The main conclusion is that the test is feasible.

Scope of work for 2008

A rock shear experiment in full scale in the Äspö HRL is a possibility, however not yet decided on. Presently, the main interest in the area of rock shear effects is laboratory testing and as a first step, a series of laboratory tests will be performed in order to verify the optimal parameters for further work within the scope.

4.14 Task Force on Engineered Barrier Systems



The Task Force on Engineered Barrier Systems (EBS) is a natural continuation of the modelling work in the Prototype Repository Project, where also modelling work on other experiments concerning both field and laboratory tests is conducted. The Äspö HRL International Joint Committee has decided that in the first phase of this Task Force (period 2004-2008), work should concentrate on:

Task 1 THM modelling of processes during water transfer in buffer, backfill and near-field rock. Only crystalline rock is considered initially, although other rock types could be incorporated later.

Task 2 Gas transport in saturated buffer.

The objectives of the Tasks are to: (a) verify the capability to model THM and gas migration processes in unsaturated as well as saturated bentonite buffer, (b) refine codes that provide more accurate predictions in relation to the experimental data and (c) develop the codes to 3D standard (long-term objective).

Participating organisations besides SKB are at present Andra (France), BMWi (Germany), CRIEPI (Japan), Nagra (Switzerland), Posiva (Finland), NWMO (Canada) and RAWRA (Czech Republic). All together 12-14 modelling teams are participating in the work.

Since the Task Force does not include geochemistry, a decision has been taken by IJC to also start a parallel Task Force that deals with geochemical processes in engineered barriers. The two Task Forces have a common secretariat , but separate chairmen.

Present status

THM/Gas

For Task 1.1 the three benchmark tests regarding laboratory tests have been modelled by the teams. Two tasks concern the Spanish reference buffer material (Febex bentonite) and the other task concerns the Swedish reference buffer material MX-80. These tests have been modelled and reported. For Task 1.2 the modelling concerns large scale in situ tests. The modelling of the Buffer/Container Experiment and the Isothermal Test (carried out by AECL; Task 1.2.1) has been done during 2008. The other task (Task 1.2.2) that concerns modelling of the Canister retrieval Test at Äspö HRL has been prepared and a task description has been delivered to the participating teams and organisations.

For Task 2 (Gas) additional modelling of the two benchmark tests has been done by Clay Technology during 2007.

Geochemistry

Molecular dynamics modelling have been made by Clay Technology for SKB during 2007. The work has focused on ion diffusion in the montmorillonite/water system, and the results were presented at the Lille conference, and a paper is submitted for publication.

Ion diffusion is central in geochemical modelling, and in bentonite this is a complex matter due to the montmorillonite structure. A literature study of diffusion experiments has been made, which shows that several conceptual models of bentonite micro structure have been used in order to interpret the results. Reinterpretation of some results is now on-going with the aim to present a more coherent view of the structure and of the principles for diffusion in bentonite.

Redistribution of calcium minerals in the LOT experiment at Äspö will serve as a bench mark modelling task. Three groups representing SKB, Nagra and Posiva presented the first results at the task force meeting in Stockholm in November 2007.

Scope of work for 2008

THM/Gas

For 2008 the following work is planned:

- Finalisation and reporting of benchmark 1.2.1 (AECL experiments).
- Modelling of the Canister Retrieval Test and reporting of the results for benchmark 1.2.2.
- General evaluation of the modelling results and auditing of the capability of different codes used by the modelling teams.
- Reporting of the gas modelling and continued discussion of the mechanisms that control gas breakthrough.

Geochemistry

For 2008 the following work is planned:

- Continuation of theoretical and laboratory work concerning diffusion and ion exchange in bentonite.
- Introduce the “ion concentration discontinuity model” into the Phreeqc code.
- Modelling of the A2 parcel in the Long Term Test of Buffer Material; identification of processes and calculations.
- Continuation of molecular modelling (MD) concerning ion distribution in montmorillonite.

Publication of articles concerning mixed calcium/sodium montmorillonite, comparison of Poisson-Boltzmann generated ion distribution with those obtained from MD simulations, and water density variation in montmorillonite interlayer space.

5 Äspö facility

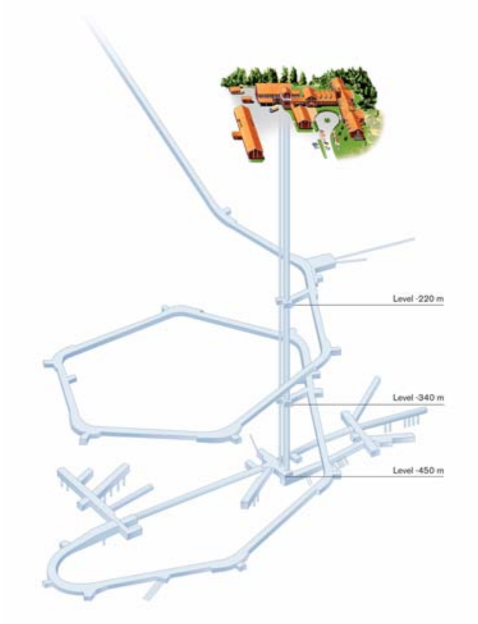
5.1 General

The organisational unit at Äspö Hard Rock Laboratory is responsible for the operation of the Äspö facility and the co-ordination, experimental service and administrative support of the research performed in the facility. Activities related to information and visitor services are also of great importance not only to give prominence to Äspö HRL but also to build confidence for SKB's overall commission. The Äspö HRL unit is organised in four operative groups and a secretariat:

- Project and Experimental service (TDP) is responsible for the co-ordination of projects undertaken at the Äspö HRL, for providing services (administration, planning, design, installations, measurements, monitoring systems etc.) to the experiments.
- Repository Technology and Geoscience (TDS) is responsible for the development and management of the geo-scientific models of the rock at Äspö and the test and development of repository technology at Äspö HRL to be used in the final repository.
- Facility Operation (TDD) is responsible for operation and maintenance of the Äspö HRL offices, workshops and underground facilities and for development, operation and maintenance of supervision systems.
- Public relations and Visitor Services (TDI) is responsible for presenting information about SKB and its facilities with main focus on the Äspö HRL. The HRL and SKB's other research facilities are open to visitors throughout the year.

Each major research and development task carried out in Äspö HRL is organised as a project that is led by a Project Manager who reports to the client organisation. Each Project Manager is assisted by an on-site co-ordinator with responsibility for co-ordination and execution of project tasks at the Äspö HRL. The staff at the site office provides technical and administrative service to the projects and maintains the database and expertise on results obtained at the Äspö HRL.

5.2 Äspö Hard Rock Laboratory



The main goal for the operation is to provide a safe and environmentally correct facility for everybody working or visiting Äspö Hard Rock Laboratory.

This includes preventative and remedy maintenance in order to withhold high availability in all systems as drainage, electrical power, ventilation, alarm and communications.

Present status

There have been no unplanned stops in the operation of the facility during 2007. The number of activities is increasing, which creates a demand for more space and new premises. A new storage tent, for machines and bentonite, has been built and a new storage building for new machines and other equipment has been completed.

A road-improvement plan has been developed in order to reduce the risk of accidents on the road to Äspö HRL. The first improvement will be construction of crash-barriers at certain places.

Scope of work for 2008

During 2008 SKB's own personnel will take over the maintenance of the facility. The maintenance agreement with Oskarshamn NPP, OKG, has been cancelled from December 31, 2007. This means that extra personnel is needed. The extension of the reserve-electricity system, which will ensure the functioning of safety during power-cuts, will continue during 2008. The operation-surveillance system Alfa will be improved so that it will be able to cope with future demands and so that new systems such as the maintenance system and the object surveillance system can be integrated.

An archive will be built at Äspö HRL during 2008. The premises will have the status of a National Archive, which means that there are special requirements regarding the indoor-environment and fire-safety.

A sewage pipe will be built from Äspö HRL to the treatment works at OKG, which will reduce the number of transports. The parking space will be extended with the waste rock which will be created by the excavation of the tunnel for the project Sealing of Tunnel at Great Depth and the mine-elevators cage will be renovated and painted during the summer of 2008.

5.3 Bentonite Laboratory

Stacking of test blocks in full scale

Before building a final repository, where the operating conditions include the deposition of one canister per day, further studies of the behaviour of the buffer and backfill under different installation conditions are required.

SKB has built a Bentonite Laboratory at Äspö designed for studies of buffer and backfill materials. The laboratory, a hall with dimensions 15×30 m, includes two stations where the emplacement of buffer material at full scale can be tested under different conditions. The hall will also be used for testing of different types of backfill material and the further development of techniques for the backfilling of deposition tunnels.

Present status

During the year, the Bentonite Laboratory has been completed and is now in full operation. Examples of activities performed in the laboratory are given below.

To prevent influence from leaking water on the buffer in the deposition hole during the backfilling activities there is a need for a buffer protection, that later will be removed. In the laboratory a solution for buffer protection has been developed and tested.

Different methods and techniques for installation of pellets and blocks in deposition tunnels have been tested. The tests have been concentrated on different materials and the influence from leaking water. The pellets installation tests have been performed in half scale and full scale size. In the Bentonite Laboratory there is a “tunnel” in half scale where the roof can be dismounted to see the filling after installation and also a full scale tunnel of wood. The tests on block installation have been performed with beddings of different materials and design. It can be concluded from the tests that the properties of the bedding determine the result of the installation.

Stacking tests of blocks have been performed in full scale. The tests show that it is necessary with a well functioning and adaptable equipment to stack the bentonite blocks in a certain flow and accuracy. The requested equipment will be unique for the project and will be developed during the coming years.

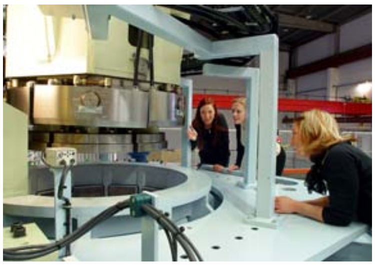
Scope of work for 2008

In the beginning of 2008 there will be a new bentonite mixer installed with the aim to have the mixer in operation during the first quarter.

The tests on pellets and block installations for deposition tunnels will continue during 2008. Of special interest is the function of the system for different water inflows e.g. effects of piping and erosion. Tests in half scale are on-going and will continue during the spring.

The machine group will during the first six months of 2008 perform tests of the installation tool for the buffer in the deposition hole. In addition, tests for the backfilling of the bevelled part of the deposition hole must be initiated. A test series is also planned, with regards to piping and erosion in the buffer and pellets installed in the deposition hole.

5.4 Public Relations and Visitor Services



SKB operates three facilities in the Oskarshamn municipality: Äspö HRL, Central interim storage facility for spent nuclear fuel (Clab) and Canister Laboratory.

The main goal for the Public Relations and Visitor Services Group is to create public acceptance for SKB, which is done in co-operation with other departments at SKB. The goal will be achieved by presenting information about SKB, the Äspö HRL, and the SKB siting programme on surface and underground.

The team is also responsible for visitor services at Clab and gives support to Canister Laboratory. In addition to the main goal, the information group takes care of and organises visits for about 1,500 foreign guests every year.

The information group has a special booking team at Äspö HRL which books and administrates all visitors. The booking team is also at OKG's service according to agreement.

Present status

During the year 2007 the facilities in Oskarshamn (Äspö HRL, Clab and Canister Laboratory) and the site investigation activities in Oskarshamn were visited by 15,124 persons. The visitors represented the general public, municipalities where SKB perform site investigations, teachers, students, politicians, journalists and visitors from foreign countries. The total number of visitors to all SKB facilities and site investigation activities in Oskarshamn and Forsmark was 25,669.

Planned special events for 2008

During the summer and on some Saturdays during the year, tours for the general public are planned. Several bus-tours a day take visitors to the laboratory, where they are given information about on-going research. The summer project will start at the end of June and finish up in August.

Target groups with high priority, mainly from the surrounding municipalities, will be invited to special events. Three occasions are planned to take place on Saturdays during the spring. If the result turns out positive, the same approach will be used during the autumn. The reason for choosing Saturdays is due to limitations in the tunnel during blasting periods.

A series of lectures with special connection to the research and development of techniques conducted at the Äspö facility started in 2007 and is to be continued during 2008.

Other special events which are planned are:

- *April 3,* The Environmental Day – in connection with the environmental week arranged in Oskarshamn on March 31 –April 5.
- *September 12-13,* The Geology Day – activities for schools and general public.
- *September 19 (preliminary date)* - Researchers Night – a European Union initiative.
- *December,* Äspö Running Competition – a yearly event.

6 Environmental research

6.1 General

Äspö Environmental Research Foundation was founded 1996 on the initiative of local and regional interested parties. The aim was to make the underground laboratory at Äspö and its resources available for national and international environmental research. SKB's economic engagement in the foundation was concluded in 2003 and the activities thereafter concentrated to the Äspö Research School.

6.2 Äspö Research School

Surface water sampling point at Laxemar catchments area

Kalmar University's Research School in Environmental Science at Äspö HRL, called Äspö Research School, started in October, 2002. This School is the result of an agreement between SKB and Kalmar University. It combines two important regional resources, i.e. Äspö HRL and Kalmar University's Environmental Science Section.

The activity within the school will lead to:
(a) development of new scientific knowledge,
(b) increase of geo and environmental scientific competence in the region and (c) utilisation of the Äspö HRL for various kinds of research.

Present status

The Äspö Research school has over the first years of research activities focused on chemical processes in the surface environment. This includes studies on the leaching dynamics of black shales (a bedrock type rich in sulphur and metals), biogeochemical patterns in forest ecosystems, hydrochemical patterns in surface and ground water, the behaviour in boreal waters of uranium and niobium, and as a complement hydrogeochemical investigations in a contrasting climate zone. Most of these studies will be included in Ph.D. theses. A Ph.D.-course in bedrock-water-biosphere has recently been completed at Äspö. In November a Ph.D. thesis focusing on hydrochemistry in Oskarshamn and Forsmark was defended at Kalmar University /Rönnback 2007/.

Scope of work for 2008

Two Ph.D. students will defend their theses during 2008: Christian Brun who is studying trace metal behaviour during litter decomposition and trace metal distribution in boreal forested ecosystems, and Ulf Lavergren who is studying the behaviour of sulphur and trace metals in black shale environments. New research will also be initiated. This will focus on two issues: Hydrogeochemistry of the lanthanides, which consists a group of metals with similar behaviour to several radionuclides, and distribution and reactions of major ions in bedrock groundwater. Both these studies will include samples and data from Äspö HRL and the Site Investigations in Oskarshamn and Forsmark.

7 International co-operation

7.1 General

Eight organisations from seven countries will in addition to SKB participate in the co-operation at Äspö HRL during 2008. Six of them; Andra, BMWi, CRIEPI, JAEA, NWMO and Posiva together with SKB form the Äspö International Joint Committee (IJC), which is responsible for the co-ordination of the experimental work arising from the international participation. The committee meets once every year. In conjunction with each IJC meeting a Technical Evaluation Forum (TEF) is held. The TEF consists of scientific experts appointed by each participating organisation. For each experiment the Äspö HRL management establishes a peer review panel consisting of three to four Swedish or international experts in fields relevant to the experiment.

Most of the organisations participating in the Äspö HRL co-operation are interested in groundwater flow, radionuclide transport, rock characterisation and THMC modelling. Several of the organisations are participating in the two Äspö Task Forces on (a) Modelling of Groundwater Flow and Transport of Solutes and (b) THMC modelling of Engineered Barrier Systems. These specific technical groups, so called Task Forces, are another form of organising the international work. The Task Force on Modelling of Groundwater Flow and Transport of Solutes, which is a forum for co-operation in the area of conceptual and numerical modelling of fractured rock, has been working since 1992. The Task Force on Engineered Barrier Systems, a forum for code development on THMC processes taking place in a bentonite buffer and gas migration through a buffer, was activated during 2004 and will be increasingly active and a prioritised area of work in the coming years. The participation of each organisation is given in Table 7-1 and an overview of prioritised activities during 2008 is given in Sections 7.2 to 7.9.

SKB also takes part in work within the IAEA framework. Äspö HRL is part of the IAEA Network of Centres of Excellence for training in and demonstration of waste disposal technologies in underground research facilities.

Table 7-1 International participation in the Äspö HRL projects during 2008.

Projects in the Äspö HRL during 2008	Andra	BMWi	CRIEPI	JAEA	NWMO	Posiva	Nagra	RAWRA
Natural barriers								
Tracer Retention Understanding Experiments				X		X		
Long Term Sorption Diffusion Experiment					X			
Colloid Dipole Project						X		
Microbe Project		X						
Radionuclide Retention Project		X						
Task Force on Modelling of Groundwater Flow and Transport of Solutes			X	X	X	X		
Engineered barriers								
Prototype Repository	X	X		X		X		
Alternative Buffer Materials	X	X		X		X	X	X
Long Term Test of Buffer Materials					X	X	X	
Temperature Buffer Test	X	X						
KBS-3 Method with Horizontal Emplacement						X		
Large Scale Gas Injection Test	X	X			X	X		
Task Force on Engineered Barrier Systems	X	X	X		X	X	X	X

Participating organisations:
Agence nationale pour la gestion des déchets radioactifs, Andra, France
Bundesministerium für Wirtschaft und Technologie, BMWi, Germany
Central Research Institute of the Electronic Power Industry, CRIEPI, Japan
Japan Atomic Energy Agency, JAEA, Japan
Nuclear Waste Management Organisation, NWMO, Canada
Posiva Oy, Finland
Nationale Genossenschaft für die Lagerung Radioaktiver Abfälle, Nagra, Switzerland
Radioactive Waste Repository Authority, Rawra, Czech Republic

7.2 Andra

L'Agence Nationale pour la Gestion des Déchets Radioactifs (Andra) is fruitfully co-operating in the Äspö HRL for more than a decade.

The first actions were devoted to enhancing the understanding of flow and transport of solutes in fractured rock. On this topic, the True Block Scale Continuation is now ending with valuable results and the Task 7 of the Task Force on Modelling of Groundwater Flow is also almost achieved.

Prioritised activities during 2008

For many years, Andra has been active in the Meuse / Haute-Marne Underground Research Laboratory implemented in a sedimentary Callovo-Oxfordian clay layer located in the east of France. A radioactive waste Act passed mid 2006 opens the way for developing a deep geological repository in such clay-rock. Thus, Andra's long-lasting co-operation with SKB is no more related to crystalline host-rock properties but to swelling clays and understanding of the engineered barrier system.

The co-operation covers common development of the Temperature Buffer Test, TBT, with tentatively a gas migration test occurring in 2008, participation in Lasgit where gas injection tests have already started and will be pursued in 2008, and interest in both the Long Term Test of Buffer Material and the Alternative Buffer Materials projects.

Also to be mentioned is Andra's participation in the Task Force on Engineered Barrier Sytems with the Spanish UPC-CIMNE modelling team involved in the THM tasks and the Swiss company Colenco in gas transport tasks.

7.3 BMWi

The first co-operation agreement between Bundesministerium für Wirtschaft und Technologie (BMWi) and SKB was signed in 1995. The agreement was extended in 2003 for a period of six years. Several research institutes are performing the work on behalf of and funded by BMWi: the Federal Institute for Geosciences and Natural Resources (BGR), DBE Technology GmbH, Forschungszentrum Karlsruhe GmbH Institut für Nukleare Entsorgung (FZK-INE), Forschungszentrum Dresden-Rossendorf (FZD), Gesellschaft für Anlagen- und Reaktorsicherheit mbH (GRS), and Bauhaus Universität Weimar. The purpose of the co-operation with the Äspö HRL programme is to improve the knowledge on the engineered barrier system and on potential host rocks for radioactive waste repositories in Germany. The topics of special interest are:

- Behaviour of the bentonite buffer.
- Characterisation of fracture zones in the rock mass and disturbed zones surrounding underground openings.
- Geochemical investigations of the migration behaviour especially of actinides under near-field and far-field conditions.
- Geochemical modelling of individual processes controlling migration.
- Thermodynamic databases for radionuclides relevant for long-term safety.
- Behaviour of colloids and microbes and their respective interaction with radionuclides.
- Groundwater flow and transport of solutes.

Prioritised activities during 2008

Prototype Repository

Measurements of the electric resistivity distribution are performed in the backfill, the buffer, and the rock between two of the deposition boreholes. Since there is a direct correlation between solution content and electric resistivity, these measurements can be used to monitor the water uptake of the backfill and the buffer and potential desaturation of the rock.

Tomographic dipole-dipole measurements using electrode arrays installed in the backfill of the Sections I and II and in the buffer at the top of deposition hole #5, as well as Wenner measurements along three electrode chains placed in boreholes located between the deposition holes #5 and #6 are automatically performed on a daily basis and evaluated quarterly. The recording unit for these arrays is controlled remotely from Braunschweig/Germany via a telephone connection. Evaluation comprises determination of the resistivity distribution around the electrode arrays by inverse modelling using the code SensInv2D. From laboratory measurement results obtained during an earlier phase of the project, the resistivity distributions can be interpreted in terms of solution content of the backfill, the buffer, and the rock, respectively.

To increase the confidence in the results of the inversions of the apparent resistivities measured in situ, a laboratory experiment has been performed in which controlled progressing water uptake in drift backfill was simulated and monitored by geoelectric measurements. The backfill material was, however, considerably drier than the material installed in situ. Therefore, a second experiment with relevant initial water content is currently prepared and will be performed in early 2008. Comparison between the known state of water uptake and the results of the measurements will allow better assessment of the inversion accuracy.

The daily measurements of the electric resistivity distribution will be continued until shutdown and dismantling of Section II of the Prototype Repository. Data evaluation will be performed in Braunschweig and contributions to SKB’s sensor data reports will be provided on a half-year basis.

Alternative Buffer Materials

BGR is participating in this project in the framework of its national R&D activities on argillaceous materials (host rock and buffer). The work is focused at the mineralogical and physical characterisation of bentonite materials. In 2008 BRG will continue to perform the laboratory investigations of the bentonite in situ samples.

Temperature Buffer Test

Main focus of the work performed by DBE Technology will be put on the back analysis of the measured data obtained from the Temperature Buffer Test. A huge amount of data is available providing information on temperature evolution, pressure and pore pressure development as well as suction and humidity progress. The numerical back analysis of the observed slow movement of injected water going from the outer sand filter into the bentonite will be continued in order to improve the understanding of the on-going processes. The measurement activities and the data acquisition respectively will be stopped until mid of 2008 since there is only one remaining sensor sparsely providing data which doesn’t justify the effort. A summarising report of the work performed up to June 2008 is planned for the second half of the year.

Lasgit

The work being conducted by BGR as part of the Lasgit project focuses both on the investigation of processes and interactions that occur in the experiment and the behaviour and nature of the engineered barriers system and the excavation damaged zone (EDZ). Surface packer test - also with Helium as gas tracer - have been performed to determine the permeability of the gallery wall.

Test evaluation and modelling exercises are executed by using the finite-element code RockFlow (THMC-code). The work in 2008 will focus on the modelling of processes in the engineered barriers system. Measured data from Lasgit will be used as reference. Different approaches for modelling gas migration will be tested.

Task Force on Engineered Barrier Systems

The Task Force on Engineered Barrier Systems has the objective to verify the ability to model THMC and gas migration processes in the buffer, to identify possible gaps in the conceptual models and to refine and to improve codes (coupling and 3D-capability). GRS, BGR, and Bauhaus University Weimar are participating in the Task Force.

The work is divided into two Tasks, Task 1 *THM processes in buffer materials* and Task 2 *Gas migration in buffer materials*. The tasks comprise of two phases each of which is based on benchmark exercises. In between, the codes are to be audited. In the first phase the codes are tested against well-controlled laboratory experiments, in the second, longer phase against field experiments. The results of the experiments are given together with the benchmark description and emphasis is laid on an open discussion of problems and solutions during modelling. BGR uses the codes GeoSys/Rockflow (Tasks 1 and 2) and GRS uses Viper (Vapour diffusion/Task 1). After GRS has successfully applied Code Viper to a non-isothermal laboratory test in the framework of phase 1 of Task 1 it will be used in phase 2 to model the non-isothermal water uptake of bentonite in the Canister Retrieval Test. Before the actual modelling some theoretical work has to be done, though. The code must be adapted to deal with radial symmetry, the problem whether condensation is possible and how it is being taken care of in the code must be tackled and attention has to be devoted to the formulation of the boundary conditions since liquid water flow is not considered in the model. First results are planned to be presented at the Task Force meeting in spring 2008.

BGR successfully completed the first phase of Task 1. The work in 2008 will focus on the modelling of the field experiments. It is planned to improve the modelling with respect to the flow processes by stepping from the Richards approach for unsaturated flow to multiphase flow. The code development to couple multiphase flow with deformation processes will be continued. The code development will govern the continuation of BGR’s work in modelling gas migration.

The work package of the Laboratory of Soil Mechanics at Bauhaus University Weimar is related to a system identification approach for coupled multi-field problems. The planned activities comprise the identification of THMC models by applying an inverse approach using genetic algorithms. Further, a THMC column experiment is planned that may serve for a possible benchmark test. Temperature effects on the hydraulic-mechanical behaviour of expansive clays and the permeability of expansive clays will be an issue of future investigations.

Microbe Projects

The project conducted by FZD/IRC aims at improving the understanding of the behaviour of colloids and microbes and their respective interaction with radionuclides. It investigates the indirect interaction mechanism of a mobilisation of actinides by released bioligands from relevant Äspö bacteria in the aquifer system. It focuses on: (i) isolation and characterisation of microbial ligands produced from a subsurface strain of *Pseudomonas fluorescence* isolated at Äspö, (ii) interaction of U(VI), Np(V), and Cm(III) with the microbial ligands including compounds simulating the functionality of the microbial ligands and the surface of the bacteria and (iii) spectroscopic characterisation of the formed actinide complexes/compounds. The formation constants determined will be used directly in speciation and transport models.

Activities planned are:

- Complexation studies of Np(V) with model compounds (a) simulating the functionality of the bioligands (e.g., salicylhydroxamic acid, desferrioxamine, 2,3-dihydroxynaphthalene) and (b) simulating the surface of the bacteria (e.g., peptidoglycan and lipopolysaccharide) using spectroscopic methods.
- Complexation studies of Np(V) with the bioligands isolated from *P. fluorescence* (CCUG 32456 A) using spectroscopic techniques.
- Investigations of the interaction of Cm(III) with peptidoglycan-lipopolysaccharide mixtures using fluorescence spectroscopy.
- Continuation of the structural investigations of the formed aqueous U(VI) complexes with the isolated natural pyoverdin-type siderophores and model systems by X-ray absorption spectroscopy.
- The results describing the speciation of several actinides (e.g., U(VI), Np(V), Cm(III)) with pyoverdin-type siderophores isolated from the Äspö bacterium *P.fluorescence* (CCUG 32456 A) in comparison to relevant model compounds will be summarised in a final report.

7.4 CRIEPI

Central Research Institute of Electric Power Industry (CRIEPI) signed a contract with SKB for the Äspö HRL Project in 1991 and renewed it in 1995, 1999, 2003 and 2007. The main objectives of CRIEPI's participation have been to demonstrate the usefulness of its numerical codes, develop its site investigation methods and improve the understanding of the mechanisms of radionuclide retention in fractured rock and the interaction between engineered barriers and surrounding rock. Since 1991, CRIEPI has participated in the exchange of information concerning research and technology for geological disposal of high-level radioactive wastes with other organisations within the Äspö HRL co-operation. In addition, CRIEPI has performed several voluntary works e.g. groundwater dating, fault dating, measurement of velocity and direction of groundwater flow and study on impact of microbes on radionuclide retention. CRIEPI has participated in the Task Force on Modelling of Groundwater Flow and Transport of Solutes and also in the Task Force on Engineered Barrier Systems since 2004.

Prioritised activities during 2008

During 2008, CRIEPI will participate in both the Task Forces as well as exchange information about research, disposal technologies and methodologies for site investigations with SKB and the other participating organisations.

As to the Task Force on Modelling of Groundwater Flow and Transport of Solutes, CRIEPI will compile a report on modelling results for sub-task 7A, reduction of performance assessment uncertainty through site scale modelling of long-term pumping in borehole KR24 at Olkiluoto, Finland. CRIEPI will also perform modelling work for sub-task 7B, block scale modelling of interference tests in boreholes KR14 and KR18 at Olkiluoto.

As for the Task Force on Engineered Barrier Systems, CRIEPI will conduct computational work for Benchmark 2 (large scale field tests). The tests to be modelled are the Buffer/Container Experiment (BCE) and the Isothermal Test (ITT) conducted in Canada, and the Canister Retrieval Test (CRT) conducted in Äspö HRL. In addition, the numerical results for the modelling of Benchmark 2 will be reported.

7.5 JAEA

The JAEA participation in the Äspö HRL is regulated by the trilateral project agreement between JAEA, CRIEPI and SKB which was signed in 2006. JAEA is currently constructing underground research laboratories in fractured granite at Mizunami and in a sedimentary formation at Horonobe. The aims are to establish comprehensive techniques for investigating the geological environment and to develop a range of engineering techniques for deep underground applications. The results obtained from these laboratories will contribute to ensure the reliability of repository technology and to establish a safety assessment methodology. JAEA also continues to be active in the research at Äspö HRL, which is directly applicable to the Japanese programme.

The objectives of JAEA’s participation in Äspö HRL during 2008 will be to:

- Develop technologies applicable for site characterisation.
- Improve understanding of flow and transport in fractured rock.
- Improve understanding of behaviour of engineered barriers and surrounding host rock.
- Improve techniques for safety assessment by integration of site characterisation information.
- Improve understanding of underground research laboratory experiments and priorities.

These objectives are designed to support high level waste repository siting, regulations and safety assessments in Japan.

Prioritised activities during 2008

JAEA will actively participate in the Task Force on Modelling of Groundwater Flow and Transport of Solutes (Task 7) to evaluate the value of flow measurement during a long-term pumping test in terms of constructing hydrogeological model relevant to PA.

7.6 NWMO

In 2007, Ontario Power Generation (OPG) assigned the SKB / OPG Äspö Project Agreement to the Nuclear Waste Management Organization (NWMO). The prime objective of NWMO’s participation at Äspö HRL is to enhance the Canadian technology base for a deep geological repository through international co-operation projects. The committed work on Äspö HRL projects to be carried out in 2008 is described below. Canada is also participating with SKB in work related to planning, e.g., the backfill (Baclo) project and the Rock Shear Experiment (Rose).

Prioritised activities during 2008

Canada is providing supporting laboratory experiments with respect to the Long Term Sorption Diffusion Experiment (LTDE-SD) and the Colloid Dipole Project. Support for the LTDE-SD experiment is continuing in 2008 and will consist of post-test analyses using a previously developed Motif model to estimate in situ diffusion coefficients, and where appropriate, sorbing coefficients for the suite of non-sorbing and variably-sorbing tracers used. The focus of the colloid work in 2008 will be to undertake a series of laboratory experiments in the 1 m scale Quarried Block test facility at Atomic Energy of Canada Limited (AECL) to improve the understanding of processes that could affect the long-term stability of bentonite in contact with a fracture containing deionized water.

Canada joined the Lasgit project in 2004. The Canadian modelling group is Intera Engineering and the reference code is Tough2 with modified permeability and capillary pressure functions. In 2007, modelling work focussed on comparisons with laboratory gas migration experiments (BGS) and on initial modelling of the preliminary gas injection phase (including exploring key test parameters to guide future test planning). In 2008, modelling of the gas injection tests will continue.

Canada is participating in the Task Force on Engineered Barrier Systems, with respect to the THM modelling task. The modelling team is from AECL and the reference code is Code_Bright. In late 2006, a dataset based on the in situ Canadian Buffer/Container Experiment and the parallel Isothermal Test was provided to the Task Force for use as the THM model for Benchmark 2 during 2007. For 2008, it is anticipated that the modelling task will be based on the results from an Äspö HRL experiment.

Canada is also participating in the Task Force on Modelling of Groundwater Flow and Transport of Solutes, with respect to Task 7. The modelling team is from the Université Laval and the reference code is Frac3DVS. In 2008, project activities will include completing the reporting for sub-task 7A involving simulations of the large-scale pump test KR24 at the Onkalo site in Finland, as well as modelling for sub-task 7B, which is focused on a series of detailed hydraulic tests completed at a smaller, local scale in the fractured crystalline bedrock.

In 2006, Canadian support to the Long Term Test of Buffer Material (LOT) and Canister Retrieval Test (CRT) were provided by AECL’s microbial analyses on various LOT and CRT buffer (bentonite) specimens. No additional samples were available in 2007 for analysis. However, further microbial analyses by AECL are planned in 2008 on samples from the LOT parcel expected to be retrieved in early 2008. This microbial work is complementary to the Canadian laboratory tests, which are exploring microbial behaviour under a range of salinity, density and temperature conditions in bentonite.

7.7 Posiva

Posiva’s co-operation with SKB continues with the new co-operation agreement signed in the autumn of 2006. The focus of the co-operation will be on encapsulation and repository technology and on bedrock investigations. Posiva also contributes to several of the research projects within Natural barriers. The implementation and construction of the underground rock characterisation facility Onkalo at Olkiluoto in Finland give possibilities to co-operate within the research and development of underground construction technology.

The organisation is participating in the following projects:

- Prototype Repository
- KBS-3 Method with Horizontal Emplacement
- Large Scale Gas Injection Test
- Sealing of Tunnel at Great Depth
- Long Term Test of Buffer Materials
- Cleaning and Sealing of Investigation boreholes
- True Block Scale Continuation
- Task Force on Modelling of Groundwater Flow and Transport of Solutes
- Task Force on Engineered Barrier Systems

Posiva's co-operation is divided between Äspö HRL and more generic work that can lead to demonstrations in Äspö HRL. The work planned to be performed within the different projects during 2008 is described below.

Prioritised activities during 2008

Sealing of Tunnel at Great Depth

SKB has initiated a project to develop the practical grouting issues in deep conditions. Posiva has been concentrated on development of low pH grouting cement to the fractures around 100 µm and SKB has been concentrated on methods for sealing narrow fractures, which cannot be penetrated with cementitious materials. Co-operation is based on the information exchange between projects and experiences gathered during construction of a tunnel. Posivas contribution is to participate in the reference group of the project.

Cleaning and Sealing of Investigation Boreholes

Phase 3 of the joint SKB and Posiva programme was finalised during 2007. After assessing the results, the continuation of the project, Phase 4, will be determined and topics defined.

KBS-3 Method with Horizontal Emplacement

SKB and Posiva are engaged in an R&D programme over the period of 2002-2007 with the overall aim to investigate whether the KBS-3H concept can be regarded as a viable alternative to the KBS-3V concept. The demonstration phase is on-going since 2004 and includes test boring at Äspö HRL, planning of the construction of the emplacement equipment, and safety evaluations. The programme will end with an evaluation of the potential of the concept. The project is jointly executed by SKB and Posiva and has a common steering group. Next stage is probably a complementary study stage, during 2008-2009, where the target is to solve a number of pre-designed issues by desk studies and to conduct component tests in the field and select the most appropriate design. Also full-scale system tests in a representative environment will be planned.

Long Term Test of Buffer Materials

Posiva`s task in this project is to study the pore water chemistry in the bentonite. The task is carried out at VTT. The aim of the work is to obtain data on the chemical conditions, which develop in the bentonite considering the effect of temperature, additives and rock features. The study gives information about the chemical processes occurring in the bentonite, but also supports the other planned studies of the chemical conditions. During 2008 the reliability of the research methods on the cation exchange capacity (CEC) of bentonite will be studied. Posiva will also participate in the studies of the next retrieved parcel when the samples are available.

Alternative Buffer Materials

Posiva will contribute to the project with similar types of experimental studies as already done in the project Long Term test of Buffer material. The clay materials of interest in the studies made by Posiva are MX-80, Deponit, Asha and Friedland Clay. During 2008 the work comprises studies with the reference materials. The aim of those studies is to get information of the materials before they have been used in the experiment and to test the research methods, which will be used when the packages have been retrieved.

Task Force on Engineered Barrier Systems

During 2008 the THM behaviour of the water saturation phase of the Canister Retrieval Test will be simulated. The simulated results will be compared to the measured values. These simulations will be done by Marintel Ky and after that, the next phase of the work will be decided.

Task Force on Modelling of Groundwater Flow and Transport of Solutes

From Finland Posiva together with Finnish Research Centre (VTT) and Pöyry Environment participate. The target of the work for following years is numerical modelling of multi-borehole interference experiment in Olkiluoto, borehole KR14 to KR18 (was carried out in spring 2002). The objectives are to quantify the reduction of the uncertainty in the properties of the background fracture network and to assess the Posiva Flow-logging (PFL) data when analysing the background rock (rock mass). The analysis of Posiva Flow Log data aims at reducing the uncertainty in performance analyses.

Bentonite Laboratory

Part of the testing in Posiva-SKB joint work programme for backfilling and sealing of deposition tunnels will be implemented in the Bentonite Laboratory. Posiva participates to the planning and design and utilise the results in reporting of the backfilling concept.

7.8 Nagra

Nationale Genossenschaft für die Lagerung Radioaktiver Abfälle, Nagra, has the task to provide scientific and technical basis for the safe disposal of radioactive waste in Switzerland. Nagra has had agreements with SKB for participation in Äspö HRL since 1994 to include mutual co-operation and participation in Äspö HRL and Grimsel Test Site projects. The last agreement expired 2003 and Nagra has now left the central and active core of participants.

However, during 2008, Nagra is taking part in the Task Force on Engineered Barriers Systems and the parallel task force that deals with geochemical processes in engineered barriers, and chemical modelling of bentonite. Nagra also participate in the Alternative Buffer Materials project and the Long Term Test of Buffer Material experiment. For these projects, Nagra's activities focus on analysis of samples and performance of laboratory tests in Switzerland.

7.9 RAWRA

Radioactive Waste Repository Authority, RAWRA, was established in 1997 and has the mission to ensure the safe disposal of existing and future radioactive waste in the Czech Republic and to guarantee fulfilment of the requirements for the protection of humans and the environment from the adverse impacts of such waste. RAWRA became a participant in the Task Force on Engineered Barrier Systems in 2005 and participates also in the Alternative Buffer Materials project.

Prioritised activities during 2008

In 2008, there will be checked and finished models developed as a part of the results from the work in the Task Force on Engineered Barrier Systems. Primarily the gas transport model will be checked by parallel calculations using different computer codes. Water and heat transport models have been practically verified and will be used to carry out the modelling of water and heat flows for the benchmark tests and/or mock-up experiments.

8 References

Andersson C J, 2007. Äspö Hard Rock Laboratory. Äspö Pillar Stability Experiment, Final report. Rock mass response to coupled mechanical thermal loading. SKB TR-07-01, Svensk Kärnbränslehantering AB.

Andersson P, Byegård J, Billaux D, Cvetkovic V, Dershowitz W, Doe T, Hermanson J, Poteri A, Tullborg E-L, Winberg A, 2007. TRUE Block Scale Continuation Project. Final Report. SKB TR-06-42, Svensk Kärnbränslehantering AB.

Börgesson L, Sandén T, Johannesson L-E, 2006. ROSE, Rock Shear Experiment. A feasibility study. SKB IPR-06-13, Svensk Kärnbränslehantering AB.

Essén S A, Johnsson A, Bylund D, Pedersen K, Lundström U S, 2007. Siderophore production by Pseudomonas stutzeri under aerobic and anaerobic conditions. Appl Environ Microbiol 73, 5857-5864.

Goudarzi R, Åkesson M, Hökmark H, 2007. Äspö Hard Rock Laboratory. Temperature Buffer Test. Sensors data report (period 030326-070101) Report No:9. SKB IPR-07-07, Svensk Kärnbränslehantering AB.

Hökmark H, Ledesma A, Lassabatere T, Fälth B, Börgesson L, Robinet J C, Sellali N, Sémête P, 2007. Modelling heat and moisture transport in the ANDRA/SKB temperature buffer test. Physics and Chemistry of the Earth, 32, p. 753-766.

Magnor B, Hardenby C, Kemppainen K, Eng A, 2007. Rock Characterisation System - RoCS. Final report - feasibility study, phase l. State-of-the-art in 3D surveying technology. SKB IPR-06-07, Svensk Kärnbränslehantering AB.

Moll H, Johnsson A, Schäfer M, Pedersen K, Budzikiewicz K, Bernhard G, 2007. Curium(III) complexation with pyoverdins secreted by a groundwater strain of Pseudomonas fluorescens. Biometals (Published Online First: 101007/s10534-007-9111-x).

Neretnieks I, 1982. ”Leach Rates of High Level Waste And Spent Fuel. –Limiting Rates as Determined by Backfill And Bedrock Conditions” In: Lutze, W. (Ed.), Scientific Basis for Nuclear Waste Management V, Materials Research Society Symposium Proceedings 11, North-Holland, New York, Amsterdam, Oxford, 1982, pp. 559– 568.

Nielsen M E, Pedersen K, Fisk M, Istok J, 2006. Microbial nitrate respiration of lactate at in situ conditions in groundwater from a granitic aquifer situated 450 m underground. Geobiology 4, 43-52.

Nyberg G, Jönsson S, Wass E, 2007. Äspö Hard Rock Laboratory. Hydro Monitoring Program. Report for 2006. SKB IPR-07-10, Svensk Kärnbränslehantering AB.

Pedersen K, 2001. Diversity and activity of microorganisms in deep igneous rock aquifers of the Fennoscandian Shield. In Subsurface microbiology and biogeochemistry. Edited by Fredrickson J.K. and Fletcher M. Wiley-Liss Inc., New York. pp 97-139.

Pedersen K, 2002. Microbial processes in the disposal of high level radioactive waste 500 m underground in Fennoscandian shield rocks. In Interactions of microorganisms with radionuclides. Edited by Keith-Roach M.J. and Livens F.R. Elsevier, Amsterdam. pp 279-311.

Pusch R, Ramqvist G, 2006a. Cleaning and sealing of borehole. Report of Sub-project 1 on design and modelling of the performance of borehole plugs. SKB IPR-06-28, Svensk Kärnbränslehantering AB.

Pusch R, Ramqvist G, 2006b. Cleaning and sealing of borehole. Report of Sub-project 2 on plugging of 5 m boreholes at Äspö. SKB IPR-06-29, Svensk Kärnbränslehantering AB.

Pusch R, Ramqvist G, 2007a. Cleaning and sealing of borehole. Report of Sub-project 3 on plugging of borehole OL-KR24 at Olkiluoto and reference borholes at Äspö. SKB IPR-06-30, Svensk Kärnbränslehantering AB.

Pusch R, Ramqvist G, 2007b. Cleaning and sealing of borehole. Report of Sub-project 4 on sealing of 200 mm diameter holes. SKB IPR-06-31, Svensk Kärnbränslehantering AB.

Rönnback P, 2007. Major and trace elements in surface and ground waters in two near-coastal granitoidic settings in eastern Sweden. Ph.D. theses at Kalmar University 2007.

SKB, 2007. Fud-program 2007. Program för forskning, utveckling och demonstration av metoder för hantering och slutförvaring av kärnavfall. Svensk Kärnbränslehantering AB. (In Swedish)

Smellie J A T, Waberg H N, Frape S K, 2003. Matrix fluid chemistry experiment. Final report. June 1998-March 2003. SKB R-03-18, Svensk Kärnbränslehantering AB.

Winberg A, Andersson P, Hermanson J, Byegård J, Cvetkovic V, Birgersson L, 2000. Äspö Hard Rock Laboratory. Final report of the first stage of the tracer retention understanding experiments. SKB TR-00-07, Svensk Kärnbränslehantering AB.

Winberg A, Andersson P, Byegård J, Poteri A, Cvetkovic V, Dershowitz W, Doe T, Hermanson J, Gómez-Hernández J, Hautojärvi A, Billaux D, Tullborg E-L, Holton D, Meier P, Medina A, 2003. Final report of the TRUE Block Scale project. 4. Synthesis of flow, transport and retention in the block scale. SKB TR-02-16, Svensk Kärnbränslehantering AB.

Åkesson M, 2006a. Temperature Buffer Test. Evaluation modelling - Field test. SKB IPR 06-10, Svensk Kärnbränslehantering AB.

Åkesson M, 2006b. Temperature Buffer Test. Evaluation modelling - Mock-up test. SKB IPR-06-11, Svensk Kärnbränslehantering AB.