International
Progress Report

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Äspö Hard Rock Laboratory

Status Report
January – June 2002

December 2002

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Äspö Hard Rock
Laboratory

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Summary

The Äspö Hard Rock Laboratory (HRL) constitutes an important part of SKB's work to design and construct a deep geological repository for spent nuclear fuel and to develop and test methods for characterisation of a suitable site. The Äspö HRL and the associated research, development, and demonstration tasks, managed by the Repository Technology Department within SKB, has so far attracted considerable international interest.

Natural Barriers

At the Äspö HRL experiments are performed at conditions that are expected to prevail at repository depth. The experiments are related to the rock, its properties, and in-situ environmental conditions. The goals are to increase the scientific knowledge of the safety margins of the deep repository and to provide data for performance and safety assessment and thereby clearly present the role of the geosphere for the barrier functions: isolation, retardation and dilution. Tests of models for groundwater flow, radionuclide migration and chemical/biological processes are one of the main purposes of the Äspö HRL. The programme includes projects with the aim to evaluate the usefulness and reliability of different models and to develop and test methods for determination of parameters required as input to the models.

Tracer Retention Understanding Experiments are carried out in the TRUE-projects with the aim to identify flow paths, retention of weakly and moderately sorbing tracers and the effect of matrix diffusion. The *TRUE Block Scale* (up to 100 m) completes the sequence of scales addressed within the TRUE-programme and the project will be reported in a series of four final reports, two of the reports were published during the spring. A first call for the 1st International TRUE Block Scale Seminar to be held at Äspö HRL in November 2002 has been made. The experiments within the TRUE Block Scale has come to its conclusion during the first half of 2002 and complementary field works and modelling within the TRUE-project are currently performed in two projects: TRUE Block Scale Continuation and TRUE-1 Continuation. The *TRUE Block Scale Continuation* project is a continuation of the tracer experiments. The time point for the completion of the experiment is still under consideration. In the *TRUE-1 Continuation* project a new interference tests have been initiated and breakthroughs of tracers have been observed. In addition, the radon concentration in groundwaters sampled from packed off sections at the TRUE-1 site at two occasions during last year has been analysed as part of the testing of a methodology to assess fracture aperture.

The **Long Term Diffusion Experiment** is performed to investigate diffusion of solutes, during 3-4 years, from natural fractures into matrix rock. The aim is to improve the understanding of sorption processes and obtain sorption data for some radionuclides on natural fracture surfaces. The rockwork at the site is concluded and installation of equipment and pre-tests are ongoing. The actual experiment can be initiated as soon as stable geochemical conditions are established in the circulation system. At present it can not be stated when the injection of tracers can take place.

Radionuclide Retention Experiment with CHEMLAB are carried out with the aim to confirm retention results of laboratory studies in-situ, where natural conditions prevail concerning e.g. contents of colloids, organic matter, and bacteria in the groundwater. The experiments are carried out in special borehole probes, CHEMLAB 1 and

CHEMLAB 2, designed for different kinds of in-situ experiments. At present *radiolysis experiments,* with the aim to investigate the influences of radiolysis on the migration of oxidised technetium in bentonite clay, and experiments on the *migration of actinides* (americium, neptunium and plutonium) in a natural rock fracture in a drill core are ongoing.

In the **Colloid Project** the concentration, stability, and mobility of colloids in the Äspö environment are studied. The natural *background concentration* of colloids in groundwaters from eight different boreholes has been measured and analysed and a report will be published. The planning of *borehole specific measurements* with the aim to determine the colloid generation properties of bentonite clay in contact with groundwater has been initiated. The planning of a *fracture specific measurement* with the aim to evaluate the transport capacity in a natural fracture for colloids and radionuclides is in progress. A colloid workshop was held in Stockholm on the 5th of March with participants from Sweden, Finland, and Germany.

The **Microbe Project** has been initiated in the Äspö HRL for studies of microbial activity in groundwater at in-situ conditions. Three microbial sites have been opened. The main site is at the 450 m level, a formation groundwater circulation system and a system for sensible measurement of hydrogen and other reducing gases are being set up. The second experimental site (located in a side vault at tunnel length 1127B) has a constructed, shallow pond where an unique population of sulphur oxidising bacteria has been established. The population of bacteria will be used to examine the distribution of stable isotopes in sulphate, sulphur and sulphide (sulphur metabolism). At the third site, two flow channels filled with gravel are fed with groundwater and artificial supports for biological iron oxide systems (BIOS) attachment and growth. The biological filtering effect and retention of radionuclides and trace element in the BIOS are studied.

Matrix Water Chemistry Experiment has been performed to understand the origin and age of matrix fluids in fissures and small-scale fractures and their possible influence on fluid chemistry in the bedrock. The gathering of scientific data has been conducted and the remaining work comprises mainly geochemical modelling and evaluation of groundwater to derive a range of groundwater compositions as suitable input for near-field model calculations. The activities during this period aim at final reporting of the whole project. A conclusion from the experiment is that the matrix fluids seem to be part of a relatively mobile water system. It should be noted, however, that studies of this type is very site specific since e.g. the rock fracturing is supposed to influence the results.

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 modelling work within Task 5 has been finalised and the ten modelling teams are working with the modelling reports. A workshop about Task 5 was held on June 13 at Äspö. Task 6 comprise two different length scales (single fracture and fracture network) and two different time scales (experimental and performance assessment). The modelling work within Task 6 is proceeding according to plans.

NUMMOD is a project with the aim to improve the concept and the numerical tool (DarcyTools) for modelling of flow and transport of solutes but also to update the regional and local scale groundwater flow models for the Äspö HRL.

PADAMOT is a new three-year EC-project, which started late 2001. An activity plan for the project has been produced and a first meeting was held in January. An example of an activity within the project is the samples of calcite fracture fillings that have been taken in a core (KLX01) from Laxemar nearby Äspö for analysis.

Disposal technology

The Äspö HRL makes it possible to demonstrate and perform full-scale tests of the function of different components of the repository system that are important for the performance and the long-term safety of a repository. It is also important to show that high quality can be achieved in design, construction, and operation of the repository. To fulfil these tasks several projects are performed.

Demonstration of Repository Technology has the aim of testing and demonstration of the deposition process is ongoing, e.g. in the Prototype Repository. The whole system of different machines and equipment needed in a deep repository will be identified and developed to a feasibility stage as part of the ongoing design studies of the deep repository.

In the **Prototype Repository** the integrated function of the repository components is demonstrated and full-scale reference of a KBS-3 repository for comparison with models and assumptions are provided. The inner section (with four canisters) is installed and measurement of THM-processes in buffer and backfill is in progress. The instrumentation in the tunnel, deposition holes, and in the boreholes in the outer section is in progress. According to present plan the two additional canisters and the tunnel backfill will be installed during autumn and the plug grouted at the end of the year.

Backfill and Plug Test is a test of different backfill materials and emplacement methods and a test of a full-scale plug. It is a test of the hydraulic and mechanical function of the backfill materials and their interaction with the near-field rock. It is also a test of the hydraulic and mechanical function of a plug. The water pressure in the wetting mats has been increased to 500 kPa and it has been shown that the hydraulic pressure in the tunnel can be maintained without a significant water leakage through the plug.

Canister Retrieval Test has the purpose of testing technology for retrieval of canisters after the buffer has become saturated. One canister with heaters and bentonite blocks were emplaced in a full size deposition hole. During 2000 the hole was sealed with a plug, heater turned on and artificial water supply to saturate the buffer started. Problems with short-circuit in the electrical system of the heaters occurred in the end of 2001. It has, however, been possible to provide the needed experimental conditions. Much of the work during the first six months this year has been devoted to fault localisation and testing for solving the problem.

The **Long Term Tests of Buffer Material** aim to validate models and hypotheses concerning physical properties in a bentonite buffer and of related processes. Five test parcels with different duration times were installed. In 2001 a 1-year parcel was extracted from the rock by overlapping core drilling. The main task during 2002 was devoted to the examination of the field-exposed material from this parcel. Tests and analyses of the bentonite material, copper corrosion, and diffusion properties have been made and will continue. The remaining four long-term test parcels are planned to run for at least five years.

The **Pillar Stability Experiment** has been initiated to demonstrate the capability to predict spalling in fractured rock mass and the effect of backfill on the propagation of micro cracks. The first phase of the project, a feasibility study and preliminary design of the experiment, was completed during 2001. The second phase includes the development of the final experimental design, exploratory core drilling in the extension of a new experiment tunnel to be constructed in Äspö HRL during 2003, as well as numerical modelling with different codes to predict the outcome of the experiment. The core drilling has started and is soon completed.

Low alkali cementitious products is a project, performed in co-operation with Posiva and NUMO, with the aim to investigate the use of low-alkali cementitious products in the deep repository. One of the objectives is to develop recipes for cementitious products to be used as grouting and mortar for anchoring of rock bolts. A recipe for low-alkali cement has been developed. However, a planned small field experiment in Äspö HRL has been postponed since the low-alkali cement developed did not work as grouting material.

KBS-3 method with horizontal deposition. Late 2001 SKB published an R&D program for KBS-3H. The program is divided into four parts: Feasibility study, Basic design, Construction and testing at the Äspö HRL, and Evaluation. The aim with this study is to investigate if the KBS-3H variant is technically feasible. The feasibility study was initiated during 2001 and the work is in progress.

Cleaning and sealing of investigation boreholes is a new project initiated in May, with the aims to identify and to demonstrate, in field experiments, the best available techniques for cleaning and sealing of investigation boreholes. The first phase of the project that comprises identification of available techniques, complementary laboratory experiments with potential sealing materials, and investigation of the status of two boreholes at Äspö that are planned to be used for the demonstration of cleaning techniques, will be concluded in 2002.

Task Force on Engineered Barrier Systems has its focus on the water saturation process in buffer, backfill and near-field rock. Since the water saturation process is also a part of the modelling work in the Prototype Repository, the work of the Task Force was consequently linked together with modelling work within the EC-project concerning the Prototype Repository.

Äspö Facility

The main goal for the operation of the facility is to provide a safe and environmentally correct facility for everybody working or visiting the Äspö HRL. This includes a number of projects such as preventative and remedy maintenance in order to withhold high availability in all systems as drainage, electrical power, ventilation, alarm and communications in the laboratory. To meet the need for additional office space to host the staff of the site investigation in Oskarshamn the available number of offices has been increase in temporary barracks and an additional extension of the Äspö facility is being designed.

The Hydro Monitoring System (HMS) which collects data on-line of groundwater head, salinity, electrical conductivity, Eh and pH has been performing well and the two programs for monitoring of groundwater head and flow and chemistry are running according to plans with minor maintenance activities.

The existing geological, geomechanical, geohydrological and hydrogeochemical models of Äspö will be updated in the GeoMod project. The work has started by assessing the existing data/models within each geoscientific discipline: geology, hydrogeology, rock mechanics and hydrogeochemistry.

International Co-operation

Eight organisations from seven countries are from January 2002 participating in the Äspö HRL.

SKB is through Repository Technology co-ordinating two EC contracts: Prototype Repository and Cluster Repository Project (CROP). SKB takes part in several EC-projects of which the representation is channelled through Repository Technology in five cases: FEBEX II, BENCHPAR, ECOCLAY II, SAFETI and PADAMOT. SKB will also be co-ordinator in the new project NET.EXCEL.

Contents

1 General

The Äspö Hard Rock Laboratory (HRL) constitutes an important part of SKB's work to design and construct a deep geological repository for spent nuclear fuel and to develop and test methods for 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. 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 Äspö HRL and the associated research, development, and demonstration tasks, managed by the Repository Technology Department within SKB, has so far attracted considerable international interest.

SKB's overall plans for research, development, and demonstration during the period 2002-2007 are presented in SKB's RD&D-Programme 2001 /SKB, 2001a/. The planned activities related to Äspö HRL are detailed on a yearly basis in the Äspö HRL Planning Report /Äspö HRL, 2002/. The role of the Planning Report is also to present the background and objectives of each experiment and activity. This report, the Status Report concentrates on the work in progress and refers to the Planning Report for more background information. The Annual Report will in detail present new findings and results.

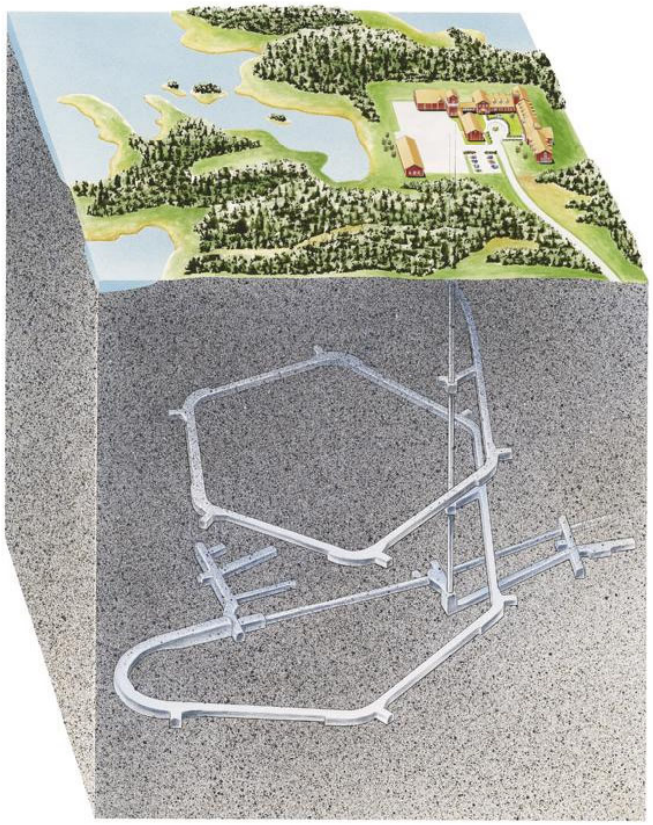

Figure 1-1 *Overview of the Äspö HRL facilities.*

2 Natural barriers

At the Äspö HRL experiments are performed at conditions that are expected to prevail at repository depth. The experiments are related to the rock, its properties, and in-situ environmental conditions. The goals are to increase the scientific knowledge of the safety margins of the deep repository and to provide data for performance and safety assessments and thereby clearly present the role of the geosphere for the barrier functions: isolation, retardation and dilution.

Tests of models for groundwater flow, radionuclide migration and chemical/biological processes are one of the main purposes of the Äspö HRL. The programme includes projects with the aim to evaluate the usefulness and reliability of different models and to develop and test methods for determination of parameters required as input to the models.

The main projects are Tracer Retention Understanding Experiments (TRUE), Long Term Diffusion Experiment, Radionuclide Retention Experiment, Microbial Project, Colloid Project, and Matrix Water Chemistry.

2.1 Tracer Retention Understanding Experiment

Tracer tests are carried out in the TRUE-projects. These are conducted at different scales; laboratory scale (< 0.5 m), detailed scale (~ 5 m) and block scale (up to 100 m) with the aim to identify flow paths, retention of weakly and moderately sorbing tracers and the effect of matrix diffusion. Experiments in the laboratory and detailed scales have been completed and reported /Winberg et al., 2000/. The tracer test stage of the TRUE Block Scale has come to its conclusion during the first half of 2002. Complementary field works and modelling are currently performed in two projects: TRUE-1 Continuation and TRUE Block Scale Continuation.

2.1.1 TRUE Block Scale

The block scale (up to 100 m) completes the sequence of scales addressed within the TRUE programme. Five boreholes have been drilled, characterised and completed with multi-packer systems. The results of the performed characterisation have resulted in a focus on a particular fracture network defined by five structures (#20, #13, #21, #22 and #23) for subsequent tracer tests performed in three phases (A-C). Phase A focused on identification of suitable injection and sink sections, Phase B demonstrated mass recovery and matrix diffusion, and Phase C comprised a series of injections with radioactive tracers.

Achievements during the time period (January - June 2002)

The TRUE Block Scale project will be reported in a series of four final reports (the present status of the reports is given within brackets, two of the reports were published during the spring):

- Characterisation and model development /Andersson et al., 2002a/.
- Tracer tests in the block scale /Andersson et al., 2002b/.
- Modelling of flow and transport (the work is finalised and a final concept of the report is prepared).

- Synthesis of flow, transport and retention in the block scale (extended synopsis is available and the report will be finalised during the second half of 2002).

The developed hydro-structural model (March 2000) of the TRUE Block Scale rock volume /Hermanson and Doe, 2000/ has provided a satisfactory geometrical basis for the modelling and evaluation work. The modelling of flow and transport has been finalised and a report will be published (see above). Examples of comparisons of model predictions and measured mass fluxes are given in Figure 2-1 for the sorbing tracers calcium and rhenium. Teams from Enresa, JNC, Nirex, Posiva, and SKB have done the modelling work. It was e.g. concluded that the retention observed of radioactive sorbing tracers cannot be explained by equilibrium surface sorption alone and all modelling groups assigned matrix diffusion as an important retention mechanism. Retention seems to be governed by parameter groups (flow field, immobile zone diffusion properties and sorption). No new retention phenomena/processes have been observed in the block scale compared to what has been seen in the detailed scale.

A first call for the 1st International TRUE Block Scale Seminar to be held at Äspö HRL in November 2002 has been made. The theme of the seminar is "Understanding of block scale radionuclide transport and retention in a network of structures/fractures".

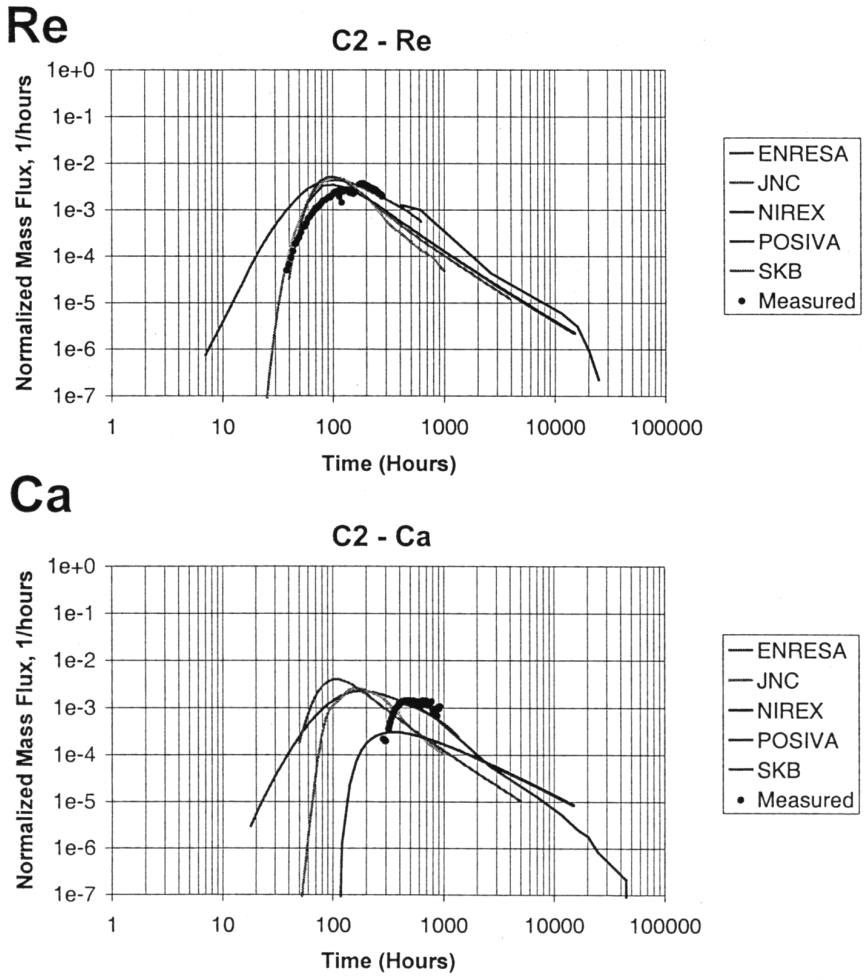

Figure 2-1 *Comparison between measured and calculated mass fluxes for calcium and rhenium.*

2.1.2 TRUE Block Scale Continuation

The TRUE Block Scale Continuation (BS 2) project has its main focus on results obtained at the existing TRUE Block Scale site. The project is divided into two separate phases:

BS 2a Continuation of the TRUE Block Scale (Phase C) pumping and sampling. Employment of developed enrichment techniques to lower detection limits. Complementary modelling work that includes evaluation of tails of breakthrough curves and simplified examples related to heterogeneity in flow and retention parameters. In addition, new hypotheses to be tested by in-situ experiments will be formulated.

BS 2b Additional in-situ tracer tests based on BS 2a analysis. Tests preceded by reassessment of the need to optimise/remediate the piezometer array. The specific objectives of BS 2b are to be formulated on the basis of the outcome of BS 2a.

Achievements during the time period (January - June 2002)

The tracer experiment is continuously being monitored and the data from the continued monitoring delivered by the end of March will be published. The modelling of the experiment is ongoing and will continue until October 2002. The time point for the completion of the experiment is still under consideration.

2.1.3 TRUE-1 Continuation

The TRUE-1 Continuation project is a continuation of the TRUE-1 experiments. According to present plans the TRUE-1 site will be injected with epoxy resin. In connection to this, the methodology of resin injection will be refined. Before conducting the impregnation some complementary cross-hole hydraulic interference tests combined with tracer dilution tests are foreseen. The special objectives of the complementary activities at the TRUE-1 site are to obtain insight into the internal structure of the investigated Feature A. The aim is also to resolve the pore space providing the retention noted in the performed experiments and to provide insight into the three-dimensionality of the rock block studied such as the role and effect of the fracture network connected to Feature A.

Achievements during the time period (January - June 2002)

The interference tests have been initiated and breakthroughs of tracers have been observed.

The radon concentration in groundwaters sampled from packed off sections at the TRUE-1 site at two occasions during last year have been analysed. The analysis of radon in the groundwater, together with measurements of the radon flux from geological material (fracture intercepts in drill cores, fracture-filling material), is part of the testing of a methodology to assess fracture aperture.

2.2 Long-Term Diffusion Experiment

The Long Term Diffusion Experiment (LTDE) is performed to investigate diffusion of solutes, during 3-4 years, from natural fractures into matrix rock. The aim is to improve the understanding of sorption processes and obtain sorption data for some radionuclides on natural fracture surfaces. A core stub with a natural fracture surface is isolated in the bottom of a large diameter telescoped borehole, see Figure 2-2 and Figure 2-3. A cocktail of non-sorbing and sorbing tracers are circulated in the test section for a period of 3-4 years after which the core stub is over-cored, and analysed for tracer content.

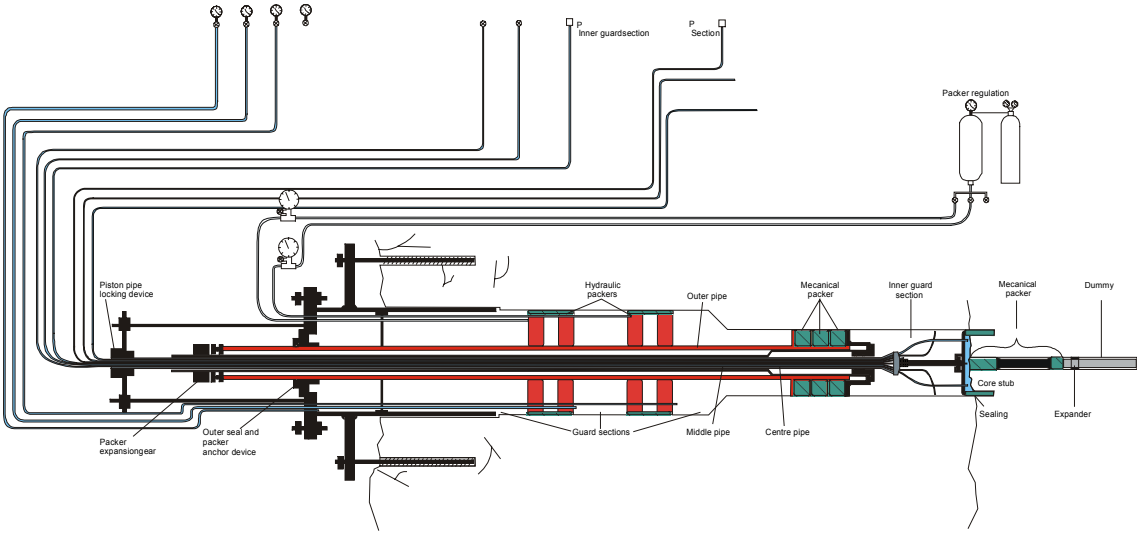

Figure 2-2 *Schematic drawing showing the modified down-hole equipment in the telescoped larger diameter LTDE borehole.*

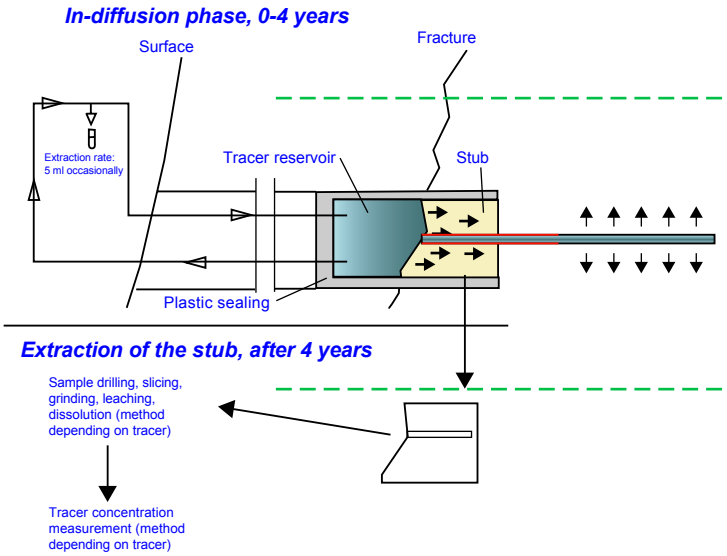

Figure 2-3 *Schematic of LTDE experimental concept including injection borehole in contact with a fracture surface, combined with excavation and penetration profile studies.*

Achievements during the time period (January - June 2002)

The rock work at the site is concluded and installation of equipment and pre-tests are ongoing. The installation of the borehole equipment was originally planed during the first half of this year but the delivery of the borehole equipment has been delayed. However, a new container has been installed at the experimental site and the manufacturing of the Plexiglas boxes are completed. It is foreseen that installation work in the container will be completed in the beginning of August. There has been a problem associated with a leaking casing (in the outer part of the borehole), but the casing has now been sealed.

The delay affects the start of the experiments, which can be initiated as soon as stable geochemical conditions are established in the circulation system. At present it can not be stated when the injection of tracers into the core stub can take place.

The descriptive geological model of the target area has been updated during the spring and summer.

Several groups associated to the Äspö Task Force for Modelling of Groundwater Flow and Transport of Solutes are doing predictive modelling of the experiments.

2.3 Radionuclide Retention Experiment

Radionuclide Retention Experiments are carried out with the aim to confirm results of laboratory studies in-situ, where natural conditions prevail concerning e.g. contents of colloids, organic matter, and bacteria in the groundwater. The experiments are carried out in special borehole probes, CHEMLAB 1 and CHEMLAB 2, designed for different kinds of in-situ experiments, see Figure 2-4. Experiments can be carried out at simulated near field conditions (bentonite) and in tiny rock fractures. The present focus is on the influence of radiolysis products on the migration of the redox-sensitive element technetium in bentonite (radiolysis experiments) and on the experiments with redox-sensitive actinides in a rock fracture (migration of actinides).

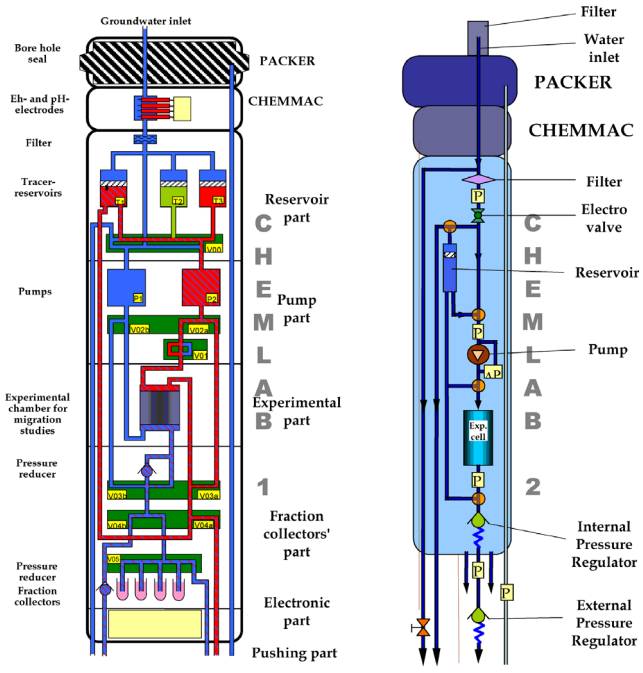

Figure 2-4 *Schematic illustration of CHEMLAB 1 and 2.*

Achievements during the time period (January - June 2002)

Radiolysis experiments

The radiolysis experiments, with the borehole probe CHEMLAB 1, are intended to investigate the influence of radiolysis on the migration of oxidised technetium in bentonite clay. In experiments performed with primary formed water radiolysis products (direct irradiation) reduced technetium tracer is placed on an irradiation source at the bottom of the test cell containing bentonite, Figure 2-5.

The radiation cell, used in these experiments was found to be leaking when used during long time periods. The cell has been modified but also been equipped with a stronger radiation source. The experiments were delayed due to the modification work, but were initiated in June 2002. The stronger radiation source means that the expected duration of the experiment has decreased (to 12 weeks).

Similar experiments with secondary formed water radiolysis products (indirect radiolysis) will be performed in a next step.

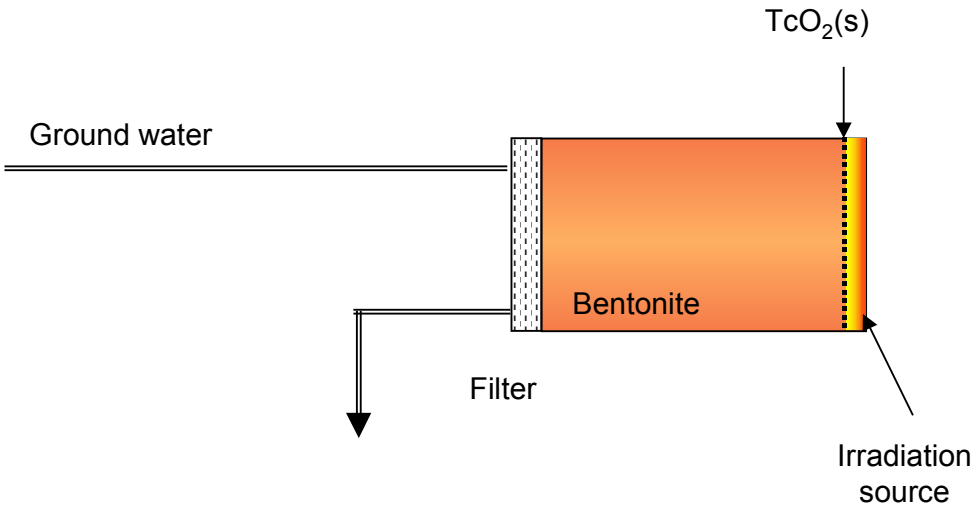

Figure 2-5 *Schematic experimental set-up. Direct radiolysis.*

Migration of actinides

Experiments on the migration of actinides (americium, neptunium and plutonium) in a natural rock fracture in a drill core are carried out in CHEMLAB 2. The rock samples are analysed with respect to the flow-path and to the actinides sorbed onto the solid material. Non-destructive and destructive techniques will be applied, such as x-ray computer tomography and cutting the samples after injection of fluorescent epoxy resin. The distribution of actinides along the flow-path is determined from the abraded material gained by cutting, as well as by coupled laser ablation ICP-MS techniques of the slices.

The first actinide experiment was stopped in advance due to failure in the electronic components in the CHEMLAB 2 probe. The failure was most probably due to blasting in the Prototype Repository tunnel about 50 m away from the experimental site. The probe was sent to France for service and will be available for new experiments during the fall of 2002.

The analysis and the evaluation of the earlier experiments, performed by FZK/INI, have required more time than expected. In addition, FZK/INI have had problems with the sealing of new drill cores and with the planning of the next experiment. New experiments will commence as soon as these problems are solved.

In addition, six drill cores with longitudinal fractures have been sent to FZK/INE for laboratory tests with actinides.

Due to the interruption of the first experiment, it was decided to extend the number of experiment from two or three to four. This is also in line with SKB's desire to include uranium and technetium, apart from americium, neptunium and plutonium, in the radionuclide cocktail. Extending the program to four experiments and the lengthy evaluation of the first experiment has led to a delay in the project with eight months.

2.4 Colloid Project

In the Colloid Project the concentration, stability, and mobility of colloids in the Äspö environment are studied. The project also comprises studies of the potential of colloids to enhance solute transport and the potential of bentonite clay as a source for colloid generation.

During year 2002 the background measurements of the natural colloid concentrations in the groundwaters at Äspö and the laboratory experiments are to be concluded and reported. Field experiments, to study bentonite clay as a source for colloid generation, will be initiated during this year.

Achievements during the time period (January - June 2002)

The laboratory experiments with the aim to investigate the role of the bentonite clay as a source for colloid generation at varying groundwater salinity (NaCl/CaCl) have been evaluated and a report will soon be published. Bentonite material was dispersed in test tubes filled with groundwaters with different salinity. The degree of sedimentation was studied. Examples of conclusions drawn are that the content of colloids is highest in groundwater with low salinity and the sedimentation rate increased in water with a high content of calcium. The occurrence of colloids influences the pH in the water.

The natural *background concentration* of colloids in groundwaters from eight different boreholes was measured, along the Äspö HRL-tunnel in October 2001. The colloid content was measured on-line from the boreholes by using a modified laser based equipment LIBD (Laser-Induced Breakdown-Detection) which has been developed by FZK/INE in Germany. The outcome of these measurements will be compared with standard type of measurements such as particle counting by using Laser Light Scattering (LLS) on pressurised groundwater samples. The groundwater in the different boreholes shows variability in salinity. The colloid concentration in the groundwater decrease with increasing salinity and a high content of dissolved organic carbon (DOC) in the water results in high colloid concentrations. In addition, a groundwater with a high salinity generally contains a low content of microbes. Aluminium, silica, and clay particles form the major parts of the colloids. The measurements have been evaluated and a report will be published.

The planning of the *borehole specific measurements* with the aim to determine the colloid generation properties of bentonite clay in contact with groundwater has been initiated. In addition, the work with the equipment to be used in the three boreholes along the Äspö tunnel that will be used for the borehole specific measurements has started. The colloid content will be measured by using both laser (LIBD/LLS) and conventional filtering.

A colloid workshop was held in Stockholm on the 5th of March with participants from Sweden, Finland, and Germany. The main topics for the workshop were the laboratory and the field experiments.

The planning of the fracture specific measurement with the aim to evaluate the transport capacity in a natural fracture for colloids and radionuclides is in progress and the development of the equipment is ongoing, e.g. the reactor for colloid generation.

In addition, to the fracture specific colloid experiments that will be performed at Äspö HRL, similar experiments are planned also at Olkiluoto in Finland. The salinity in the groundwaters at Olkiluoto is lower than the salinity in the groundwaters at Äspö.

2.5 Microbe Project

The Microbe Project has been initiated in the Äspö HRL for studies of the microbial activity in groundwater at in-situ conditions. Microbial effects on redox conditions, radionuclide migration, gas composition, and gas consumption will be in focus. Three Microbe sites have been opened in Äspö HRL.

Achievements during the time period (January - June 2002)

The main site is at the 450 m level and consists of three core drilled boreholes (KJ0050F01, KJ0052F01 and KJ0052F03) intersecting water conducting fractures at 12.7, 43.5 and 9.3 ms depth respectively. A formation groundwater circulation system and a system for sensible measurement of hydrogen and other reducing gases are being set up at the site. The packers and the circulation system as well as the container are nearly installed. The bio-film reactor was delivered and will be installed and tested. The system for gas analysis will also be completed in the near future. The gas mixture will yet have to be delivered. The development of bio-films (at 1 and 5 atm) in groundwater from one of the boreholes (KJ0052F03), was examined during the time period September 2001 to January 2002.

The second Microbe experimental site is located in a side vault (at tunnel length 1127B). A unique population of sulphur oxidising bacteria has been established in the constructed shallow pond (2000 x 1000 x 10 cm). The populations of bacteria will be used to examine the distribution of stable isotopes in sulphate, sulphur and sulphide (sulphur metabolism).

The third site (2200A m), at 296 m depth, is equipped with open flow channels fed with groundwater from a packed off borehole. Two flow channels filled with gravel, fed with groundwater from a packed off borehole and artificial supports for biological iron oxide systems (BIOS) attachment and growth, are now in operation. The BIOS may form a biological filter for radionuclides and trace element and the retention of these in the (BIOS) are studied. The BIOS-measurements have commenced and are made fortnightly.

2.6 Matrix Fluid Chemistry Experiment

The main objectives of the Matrix Fluid Chemistry Experiment are to understand the origin and age of matrix fluids in fissures and small-scale fractures and their possible influence on fluid chemistry in the bedrock. Matrix fluids are sampled from a borehole drilled into the rock matrix. Fluid inclusions in core samples have also been studied.

The gathering of scientific data has been conducted and reported and the activities during 2002 aim at final reporting of the whole project. A continuation of the project is under consideration.

Achievements during the time period (January - June 2002)

The experiment in the full-scale programme was designed to sample matrix fluids from predetermined, isolated borehole sections. The composition of the sampled fluids corresponds to the composition of the groundwater in surrounding transmissive fractures. There is little evidence that the salinity of the matrix groundwaters has been influenced by fluid inclusions. All this indicates that the matrix fluids are part of a relatively mobile water system. It should be noted, however, that studies of this type is very site specific since e.g. the rock fracturing is supposed to influence the results.

The remaining work comprises mainly geochemical modelling and the evaluation of groundwater to derive a range of groundwater compositions as suitable input for near-field model calculations. In addition, the final crush/leach tests are about to be finalised.

The project has so far been reported in Internal Technical Documents (ITD reports) and the following reports have been published and distributed:

- Smellie J, 2001. Matrix Fluid Chemistry Experiment. Mineralogy and Fluid Inclusion Studies. (ITD-02-03).

- Tullborg, E-L, 2001. Matrix Fluid Chemistry Experiment. Borehole KF 0051 A01: 4m-Results from chemical and SEM/EDS analyses and porosity/density measurements. (ITD-02-04).

Final reporting of the project will be presented in the third quarter of 2002.

2.7 Modelling of groundwater flow and transport of solutes

An important goal for the activities at Äspö HRL includes projects with the aim to evaluate the usefulness and reliability of different models and to develop and test methods for determination of parameters required as input to the models. Part of this work is performed in the Äspö Task Force on Modelling of Groundwater Flow and Transport of Solutes.

Further modelling work includes the development of codes (NUMMOD) for ground-water flow and transport of solutes that will be undertaken and applied to Äspö data and used in the Swedish site investigation programme.

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

The Äspö Task Force 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.

Much emphasis is put on building of confidence in the approaches and methods in use for modelling of groundwater flow and migration in order to demonstrate their use for performance and safety assessment.

Achievements during the time period (January - June 2002)

In the Task Force work has been made on the following tasks during the first half of 2002:

Task 4 The Tracer Retention and Understanding Experiment (TRUE), 1st stage.

Task 5 The coupling between hydrochemistry and hydrogeology.

Task 6 Performance Assessment Modelling Using Site Characterisation Data.

The modelling conducted within Task 4 is being evaluated and a final draft version of the report is foreseen in October.

The modelling work within Task 5 has been finalised and the ten modelling teams are working with the modelling reports. In addition, a Summary Report and a Reviewers Report are to be published. The work with these reports is ongoing. A workshop about Task 5 was held on June 13 at Äspö.

Task 6 comprise two different length scales (single fracture and fracture network) and two different time scales (experimental and performance assessment). The Task has been divided into five subtasks (A-E):

Subtask 6A Model and reproduce selected TRUE-1 tests with a performance assessment (PA) model and/or a stochastic continuum (SC) model. This task provides a common reference platform for all SC-type and PA-type modelling to be carried out as the project progresses. This ensures a common basis for future comparison.

Subtask 6B Model selected PA cases at the TRUE-1 site with new PA relevant (long term/base case) boundary conditions and temporal scales. This task serves as a 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.

Subtask 6C Develop semi-synthetic, fractured granite hydrostructural models. Two scales are supported (200 m block scale and 2000 m site-scale). The models are developed based on conditions at the TRUE Block Scale site. The structural model should also be complemented with a hydraulic parameterisation. The structural model will include sufficient elements of the TRUE Block Scale experiment to make it possible to reproduce a TRUE Block Scale tracer experiment as part of subtask 6D.

Subtask 6D Task 6D is similar to Task 6A, using the synthetic structural model and a 50 to 100 m scale TRUE-Block Scale tracer experiment. The flow and transport simulations will be carried out using both SC-type and PA-type models. This task provides a common reference platform for all SC-type and PA-type modelling in the considered scale and ensures a common basis for subtask 6E.

Subtask 6E Subtask 6E extends the subtask 6D transport calculations to a reference set of PA time scales and boundary conditions. In the first part of subtask 6E, a basic set of PA and SC assumptions and simplifications should be used. These can be extended to alternative assumptions as part of the sensitivity study part of subtask 6E.

The modelling work within Task 6 is proceeding according to plans and the final modelling results for subtasks 6A and 6B were presented and discussed at a Task Force Meeting in June 11-13, 2002. The work on a structural model (subtask 6C) is ongoing and will provide basis for subtasks 6D and 6E. Further specifications of Task 6 were discussed at a workshop at Thoresta Herrgård, March 14-15. The specifications of subtasks 6D and 6E are planned to be available during autumn 2002.

The 16th International Task Force meeting was held at Äspö near Oskarshamn on 11-13 June with participants from seven countries, excluding Sweden. This time, the participants were from Canada, England, Finland, France, Japan, USA and Switzerland. A summary of the work in Task 4 was given. Presentations were given by the reviewers of Task 5 followed by a workshop regarding Task 5. Eleven modelling groups presented modelling work within Task 6. In addition, other research work and modelling work related to groundwater flow and transport of solutes were presented. The delegates were contributing with discussions and review.

2.7.2 Numerical Modelling of Groundwater Flow (NUMMOD)

The general objective of NUMMOD is to improve the concept and the numerical tool (DarcyTools) for modelling of flow and transport of solutes but also to update the regional and local scale groundwater flow models for the Äspö HRL. The project is divided into Part 1 and Part 2.

Work performed in Part 1 of NUMMOD will be published in two reports:

- DarcyTools – Concepts, Method, Equations and Tests, version 1.0.
- DarcyTools – Software description and documentation, version 1.0.

The aim of the second part of NUMMOD is to develop a second version of DarcyTools, which will be used in the Swedish site investigation programme. The second version will e.g. be linked to SKB's three-dimensional Rock Visualisation System (RVS) and the user interface will be developed.

Achievements during the time period (January - June 2002)

The reporting of Part 1 has been finalised and two reports concerning DarcyTools are to be printed. In addition, the planning of Part 2 - NUMMOD 2 - is in progress.

2.8 PADAMOT

A new three-year EC-project named PADAMOT (Paleohydrogeological data analysis and model testing) started late 2001. The project is a continuation of the concluded EQUIP-project, which had as specific objective to trace the past hydrochemical conditions by investigating fracture-filling minerals (calcite).

During the Quaternary, global climate has alternated between glacial conditions and climate states warmer than the today. In northerly latitudes the potential for cold region processes to affect groundwater pathways, fluxes, residence times and hydrochemistry is significant, whilst for southern European localities the alternation between pluvial and arid conditions is equally important. PADAMOT will investigate the evolution of

minerals and groundwater through these climate changes. The project will use advanced analytical techniques and numerical modelling tools. This Paleohydrogeological approach investigates processes that are significant for repository safety studies on length and time scales that cannot be simulated by experiments. Interpretations will be used to constrain the range of scenarios for conceptual model development and time-variant modelling in performance assessments.

Achievements during the time period (January - June 2002)

An activity plan for the project has been produced and a first meeting was held at Heathrow on the 17th of January. A workshop on methods for Paleohydrology and its importance in performance assessment will be held in Brussels later this year. SKB participation in the project is channelled through Repository Technology.

Samples of calcite fracture fillings have been taken in a bore core (KLX01) from Laxemar nearby Äspö for analysis. Documentation, preparation and $^{18}O/^{13}C$ analyses of the samples have been made and so far 44 samples have been analysed. The possibilities to carry out tracer analysis using ICP-MS technique together with Earth Sciences Centre in Gothenburg are being discussed.

3 Disposal technology

The Äspö HRL makes it possible to demonstrate and perform full-scale tests of the function of different components of the repository system that are important for the performance and the long-term safety of a repository. It is also important to show that high quality can be achieved in design, construction, and operation of the repository. To fulfil these task several projects are performed, e.g. Demonstration of Repository Technology, Prototype Repository, Backfill and Plug Test, Canister Retrieval Test, Long Term Tests of Buffer Material, and Pillar Stability Experiment.

3.1 Demonstration of repository technology

The project of Demonstration of Repository Technology provides a full-scale example of canister deposition under radiation-shielded conditions and works with testing of canister handling in full size deposition holes. Testing and demonstration of the deposition process is ongoing, e.g. in the Prototype Repository. The whole system of different machines and equipment needed in a deep repository will be identified and developed to a feasibility stage as part of the ongoing design studies of the deep repository.

3.2 Prototype Repository

The Prototype Repository is located in the last part of the TBM tunnel at the 450 m level and will include six deposition holes in full scale, see Figure 3-1. 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 deep repository system, regarding geometry, materials, and rock environment. Instrumentation will be used to monitor processes and properties in the canister, buffer material, backfill, and the near-field rock. The installations in the inner section (Section I) with four deposition holes were completed and the plug, which seals off this inner section, was cast during 2001.

The Prototype Repository is co-funded by the European Commission for a 42 months period starting September 2000 with SKB as Co-ordinator and including seven participating organisations. The work reported below has been performed within the frame of the EC-project.

Achievements during the time period (January - June 2002)

An indicated malfunction of the heaters in the Canister Retrieval Test is judged to have an influence also on the Prototype Repository project as all four installed canisters are equipped with heaters and lead throughs in the canister lid of the same design. According to this a new design for the lead throughs in the lid will be developed and used in the two additional canisters. A fault localisation program was initiated, see Section 3.5.

The measurement of THM-processes in buffer and backfill in the inner section (Section I) is in progress. The measuring systems and transducers work well (with a few exceptions) and the wetting in deposition hole 1 (see Figure 3-1) has started, whereas very little wetting of the buffer has been observed so far in the other holes. There is, however, a probable intrusion of water into the slot between the canister and the buffer. Canisters 2 and 3 have reached a temperature of 90°C and the temperatures in the Canister 1 and 4 are lower, 70°C and 83°C respectively.

The instrumentation in the tunnel, deposition holes, and in the boreholes in the outer section (Section II) is in progress. According to present plan the two additional canisters and the tunnel backfill will be installed during autumn and the plug grouted at the end of the year. This means that the time schedule has been delayed according to the original plan.

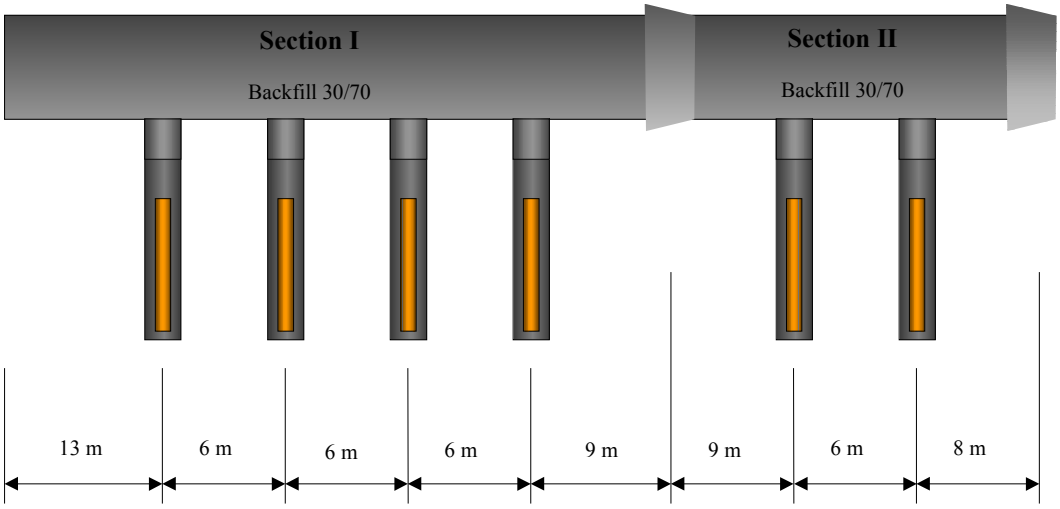

Figure 3-1 *Schematic view of the layout of the Prototype Repository. The deposition holes and canisters are numbered (1-6) from left to right in the figure. (not to scale)*

3.3 Backfill and Plug Test

The Backfill and Plug Test is a test of different backfill materials and emplacement methods and a test of a full-scale plug. It is a test of the hydraulic and mechanical function of the backfill materials and their interaction with the near-field rock. It is also a test of the hydraulic and mechanical function of a plug.

The experimental set-up (see Figure 3-2) was finished during 1999, the tunnel was backfilled and the plug to seal the drift put in place. The wetting of the backfill materials started in the end of 1999 and has continued. The water pressure in the applied wetting mats was increased during 2001 to enhance the water saturation of the backfill. The wetting of the backfill will continue until full saturation is obtained and testing of backfill properties will start thereafter.

Achievements during the time period (January - June 2002)

The water pressure in the wetting mats has been increased to 500 kPa and it has been shown that the hydraulic pressure in the tunnel can be maintained without a significant water leakage through the plug. The effect of increasing the pressure to 500 kPa on the water saturation has been predicted, and it is expected that the bentonite/crushed rock mixture (30/70) will be saturated at the end of 2002. If the wetting rate agrees with the predictions, flow testing of the backfill can start during 2003. A decision concerning the start of the flow tests will be taken at a project meeting in March 2003. This means that the flow tests will begin three months later than planned in the original time plan.

A problem arose in the one of the systems. The system has been repaired and is in operation but the stop has led to that some measurement data is lacking between December 2001 and May 2002.

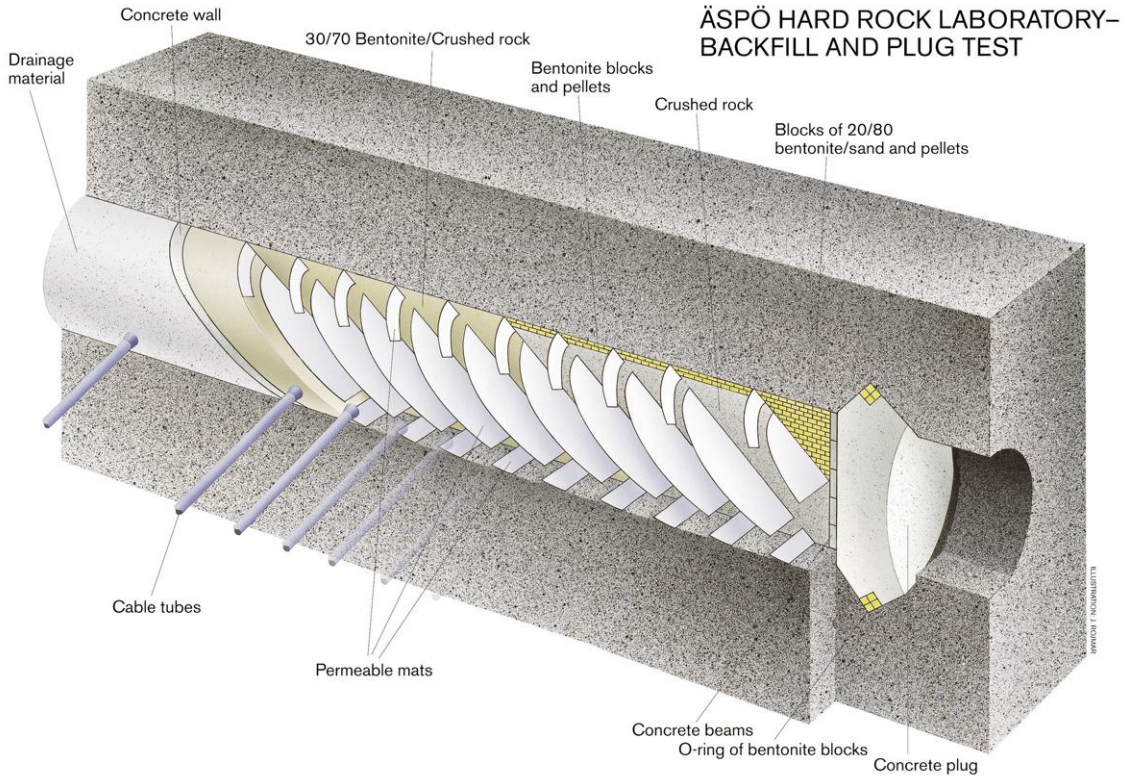

Figure 3-2 *Illustration of the experimental set-up of the Backfill and Plug Test.*

3.4 Canister Retrieval Test

In the Canister Retrieval Test two full-scale deposition holes have been drilled for the purpose of testing technology for retrieval of canisters after the buffer has become saturated. These holes have also 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 (see Figure 3-3) during 2000, the hole was sealed with a plug, heater turned on and artificial water supply to saturate the buffer begun.

Achievements during the time period (January - June 2002)

Problems with short-circuit in the electrical system of the heaters occurred in the end of 2001. However, it has been possible to provide the needed experimental conditions and so far the heating has continued without problem. The plan is to continue the artificial water supply and the heating until the bentonite buffer has been fully saturated.

A fault localisation program was initiated including test of the epoxy in plug, thermo-gravimetric test on conductors, a magnesium oxide study, resistance measurement on all installed canisters, and a full scale laboratory test on a canister. Consequently, much of the work during the first six months this year has been devoted to fault localisation and testing for solving the problem.

Due to the efforts spent on the fault localisation program the reporting of the first phase of the project has been delayed

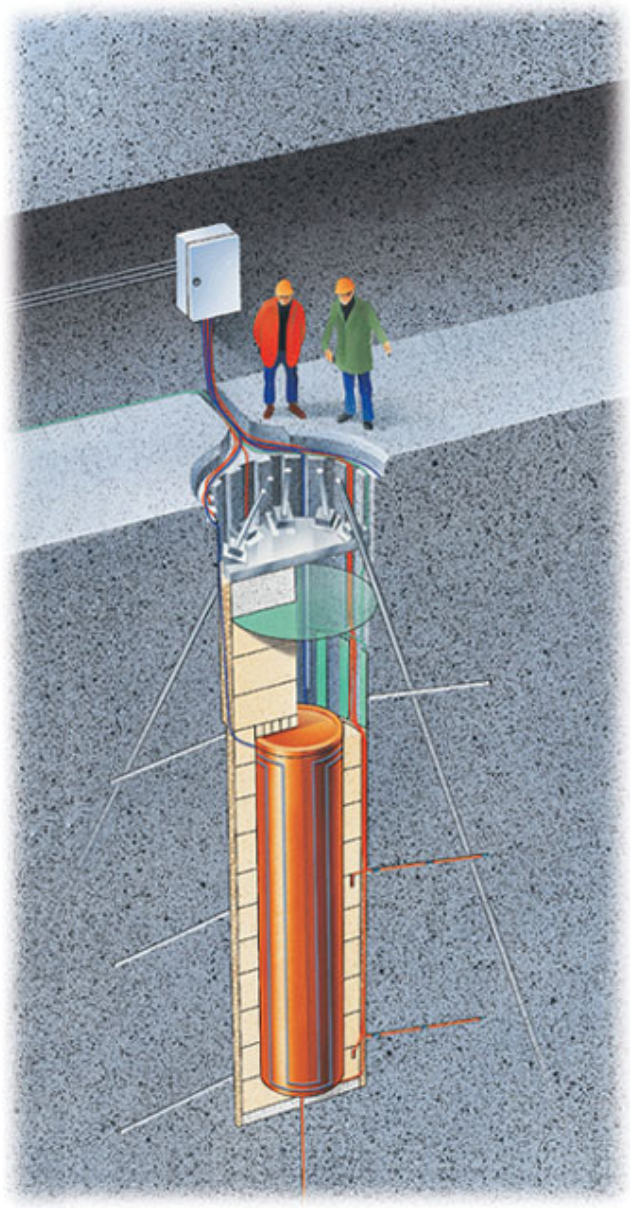

Figure 3-3 *Experimental set-up in Canister Retrieval Test.*

3.5 Long Term Test of Buffer Material

The Long Term Tests of Buffer Material aim to validate models and hypotheses concerning physical properties in a bentonite buffer and of related processes such as bentonite degradation, microbiology, copper corrosion and gas transport in buffer material under conditions similar to expected repository conditions. Five 300 mm diameter test holes have been drilled and instrumented. Five test parcels (see Figure 3-4) with different duration times were installed in 1999. In 2001 the 1-year parcel was extracted from the rock by overlapping core drilling. The remaining four long-term test parcels are planned to run for at least five years.

Achievements during the time period (January - June 2002)

The main task during 2002 is devoted to the examination of the field-exposed material from the 1-year parcel (A0). Tests and analyses of the bentonite material, copper corrosion, and diffusion properties have been made and will continue.

The analyses of the *bentonite material* comprise:

- Physical properties (hydraulic conductivity, swelling pressure and plasticity)
- Mineralogical stability (montmorillonite, accessory minerals)
- Chemical evolution (Eh, pH, corrosive agents).

Different teams are involved in the analyses. The bentonite mineralogy and physical properties are analysed at Clay Technology and the University in Lund where analyses with X-ray diffraction (XRD) are in progress. VTT in Helsinki work on the issues related to bentonite pore water chemistry. Characterisation of the original bentonite material used in the parcels will be made in parallel to the characterisation of the exposed bentonite material.

Studsvik is carrying out *copper corrosion* analyses of the parcel tube and well characterised copper coupons that were placed in the bentonite at installation of the test parcels.

Diffusion of tracers (^{60}Co, ^{134}Cs) in the exposed bentonite are performed at Royal Institute in Stockholm.

The work proceeds according to plan and the results obtained so far are informative and logical. The work on the 1-year parcel (A0) will be reported during the autumn of 2002 in a SKB Technical Report.

The four long-term parcels are running according to plans and water pressure, total pressure, temperature and moisture are continuously being measured.

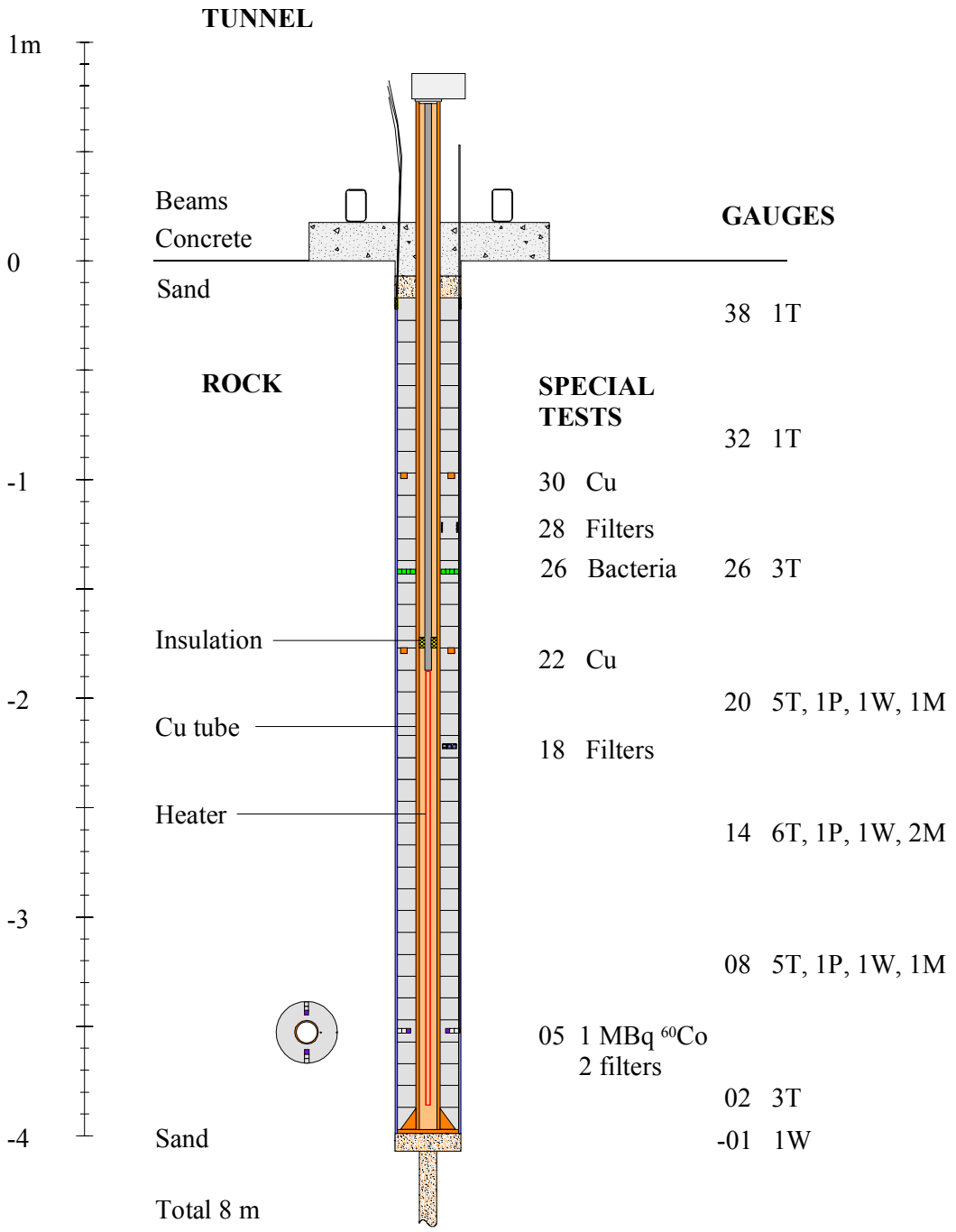

Figure 3-4 *Cross-section view of a standard condition parcel (S-type). The first figures in column denote block number and second figures denote the number of sensors. T denotes thermocouple, P total pressure sensor, W water pressure sensor, and M moisture sensor.*

3.6 Pillar Stability Experiment

A Pillar Stability Experiment has been initiated to complement an earlier study performed at URL in Canada. The major aims are to demonstrate the capability to predict spalling in fractured rock mass and the effect of backfill on the propagation of micro cracks. In addition the capabilities of two- and three-dimensional mechanical and thermal predictions will be compared.

Achievements during the time period (January - June 2002)

The project is divided into four phases. The first phase, a feasibility study and preliminary design of the experiment, was completed during 2001. A decision to continue with the second phase of the project has been taken. The outcome of this phase will be the final experimental design. The second phase also includes exploratory core drilling in the extension of the new experiment tunnel constructed in Äspö HRL and numerical modelling with different codes to predict the outcome of the experiment.

Core drilling has started and is soon completed. The construction of a short new tunnel is planned in 2003 to ensure that the experiment is carried out in a rock mass with a virgin stress field. In the new tunnel a vertical pillar will be constructed in the floor. The pillar will be designed in such a way that spalling will occur when the pillar is heated. To create the pillar two vertical holes will be drilled in the floor of the tunnel so that the distance between the holes is 1 m. Thermistors and Acoustic Emission will be used to monitor the experiment. Only these two kinds of monitoring together with visual inspection are necessary to assess the outcome of the experiment.

Estimation of vibrations at different distances from blasting at different magnitudes in a tunnel has been made. This was done to ensure that disturbances of other experiments during the blasting of the new tunnel can be avoided.

Regarding the modelling work, definitions of numerical modelling and characterisation are nearly concluded. It is decided that Posiva will participate in the project and contribute with Particle Flow Code (PFC) modelling.

3.7 Low-alkali cementitious products

A project, in co-operation with Posiva and NUMO, concerning the use of low-alkali cementitious products in the deep repository began in 2001. The objectives of the project are to develop recipes for cementitious products to be used as grouting and mortar for anchoring of rock bolts and to demonstrate the usage of these products in small field experiments in Äspö HRL.

Achievements during the time period (January - June 2002)

A recipe for low-alkali cement has been developed. However, the planned small field experiment in Äspö HRL has been postponed since the low-alkali cement developed did not work as grouting material.

3.8 KBS-3 method with horizontal deposition

Late 2001 SKB published an R&D program for KBS-3H /SKB, 2001b/, a variant of KBS-3 with horizontal deposition of the canisters, see Figure 3-5. The R&D program is divided into four parts: Feasibility study, Basic design, Construction and testing at the Äspö HRL, and Evaluation. The feasibility study was initiated during 2001 and will be concluded during 2002. It will be followed by a decision concerning the continuation of the project in accordance with the R&D program, which is carried through by SKB in co-operation with Posiva.

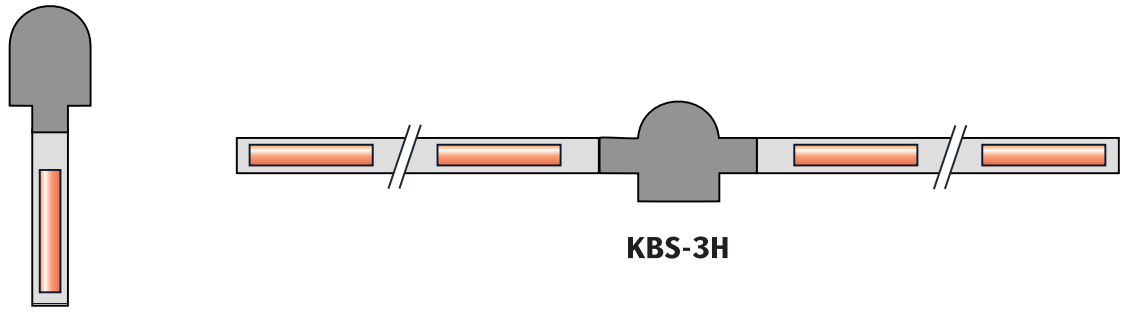

Figure 3-5 *Schematic illustrations of variants of the KBS-3 method.*

Achievements during the time period (January - June 2002)

The work within the feasibility study is in progress. The aim with this study is to investigate if the KBS-3H variant is technically feasible. This issue concerns e.g. the function and layout of a deposition container, the techniques for deposition and drilling of the long deposition holes. Furthermore, the differences between KBS-3H and KBS-3V in view of the long-term safety and cost aspects will be elucidated.

3.9 Cleaning and sealing of investigation boreholes

A new project, with the aims to identify and to demonstrate, in field experiments, the best available techniques for cleaning and sealing of investigation boreholes, was initiated in May.

The first phase of this project comprises identification of available techniques, complementary laboratory experiments with potential sealing materials, and investigation of the status of two boreholes at Äspö that are planned to be used for the demonstration of cleaning techniques, will be concluded in 2002.

Achievements during the time period (January - June 2002)

So far a project description and project plan has been written and a first project meeting was held on the 11th of June where a time plan was decided.

3.10 Task Force on Engineered Barrier Systems

A Task Force on Engineered Barrier Systems has been initiated. The preparatory workshop suggested that the prior focus should be on the water saturation process in buffer, backfill and near-field rock. Since the water saturation process is also a part of the modelling work in the Prototype Repository, the work of the Task Force was consequently linked together with modelling work within the EC-project concerning the Prototype Repository.

Achievements during the time period (January - June 2002)

Modelling work are going on within Work Package 3g (HM and THM modelling of the rock mass), Work Package 3h (THM modelling of buffer, backfill and interaction with near-field rock), and Work Package 3i (C modelling of buffer, backfill and groundwater).

4 Äspö facility

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

An important part of the Äspö facility is the administration, operation, and maintenance of instruments as well as development of investigation methods. Other tasks are a program for monitoring of groundwater head and flow and a program for monitoring of groundwater chemistry.

The aim of the GeoMod project is to update the existing geological, geomechanical, geohydrological and hydrogeochemical models over Äspö by integrating new data collected since 1995.

4.1 Facility operation

The main goal for the operation of the facility is to provide a safe and environmentally correct facility for everybody working or visiting the Äspö HRL. This includes preventative and remedy maintenance in order to withhold high availability in all systems as drainage, electrical power, ventilation, alarm and communications in the underground laboratory.

Achievements during the time period (January - June 2002)

A plant supervision system has been taken into operation. This has considerably increased the possibility to run the facility in a safe and economic way. The availability in the underground-related systems (ventilation, hoist, lightning, pumps etc.) has been 98%.

To meet the need for additional office space to host the staff of the site investigation a temporary barrack was built. The building accommodates 16 offices and two conference rooms. In addition, the design of an further extension of the Äspö facility has begun and 17 new offices will be available in the ventilation building in April 2003.

A new storage facility for underground equipment was taken into operation during the spring period. It is located adjacent to the ramp portal.

Road works has been performed during spring 2002 on the road through Ävrö village.

4.2 Hydro Monitoring System

The Hydro Monitoring System (HMS) collects data on-line of groundwater head, salinity, electrical conductivity of the water in some borehole sections, and Eh and pH in some other boreholes. The data are recorded by numerous transducers installed in boreholes on Äspö as well as in boreholes located in the tunnel. Similar system will be set up at candidate sites for the deep repository.

All data are transmitted to the main office at Äspö, by radio or modems. Weekly quality controls of preliminary groundwater head data are performed. Absolute calibration of data is performed three to four times annually. This work involves comparison with groundwater levels checked manually in percussion drilled boreholes and in core drilled boreholes, in connection with the calibration work.

Achievements during the time period (January - June 2002)

The system has been performing well. One main maintenance activity has taken place focusing on the replacement of the main computer.

4.3 Program for monitoring of groundwater head and flow

The monitoring of water levels started in 1987 while the computerised HMS was introduced in 1992. The number of boreholes included in the network has gradually increased. The tunnel excavation started in October 1990 and the first pressure measurements from tunnel drilled boreholes were included in the HMS in March 1992.

To date the monitoring network comprise boreholes of which many are equipped with hydraulically inflatable packers, measuring the pressure by means of transducers. The measured data are relayed to a central computer situated at Äspö village through cables and radio-wave transmitters. Once a year the data are transferred to SKB's site characterisation database, SICADA. Manual levelling is also obtained from the surface boreholes on a regular basis. Water seeping through the tunnel walls is diverted to trenches and further to 21 weirs where the flow is measured. The scope of maintaining such a monitoring network has scientific as well as legal grounds.

Achievements during the time period (January - June 2002)

The monitoring points from the previous year have been maintained and no additional point are planned during 2002. The system will continue to support the experiments undertaken and meet the requirements stipulated by the water rights court.

4.4 Program for monitoring of groundwater chemistry

During the Construction Phase of the Äspö HRL, different types of water samples were collected and analysed with the purpose of monitoring the groundwater chemistry and its evolution as the construction proceeded. At the beginning of the Operational Phase, sampling was replaced by a groundwater chemistry monitoring programme, aiming at a sufficient cover of the hydrochemical conditions with respect to time and space within the Äspö HRL. This program 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.

Achievements during the time period (January - June 2002)

No water samples were taken during this time period since the annual water sampling campaign is scheduled to take place in September - October 2002.

4.5 Geo-scientific modelling

Based on pre-investigations geological, geomechanical, geohydrological and hydrogeochemical models were made over Äspö HRL. During the Construction Phase the models were successively updated based on characterisation data obtained from 1986 until 1995. This work resulted in the Äspö96 models /Rhén et al., 1997/.

In the GeoMod project existing geological, geomechanical, geohydrological and hydrogeochemical models of Äspö will be updated by integration of data collected since 1995, as well as by integrating the different geoscientific models compiled separately before. A major part of the new data has been collected during the operational phase for the different experiments. The new data have been produced in the lower part of the Äspö HRL. The modelling is contained within a common virtual cube with 1 km side length extending from +50 m to -1000 m above sea level in elevation.

Achievements during the time period (January - June 2002)

The work has started by assessing the existing data/models within each geoscientific discipline; geology, hydrogeology, rock mechanics and hydrogeochemistry. Sampling of selected data has been done in order to appraise the data and check its quality and to fill the gap between well characterised rock volumes. The starting point was to utilise results from the different projects conducted at Äspö.

5 International co-operation

Eight organisations from seven countries are from January 2002 participating in the Äspö HRL. The co-operation is based on separate agreements between SKB and the organisations in question, see Table 5-1. The international partners and SKB form the Äspö International Joint Committee (IJC). IJC is responsible for the co-ordination of the work arising from the international participation. The committee meets once every year. The last meeting was on May 27th. In conjunction with each IJC meetings a Technical Evaluation Forum (TEF) is held. TEF consists of scientific experts appointed by each organisation.

Table 5-1 Existing agreements between SKB and the organisations participating in Äspö HRL.

Organisation	Country	Period of agreement
Andra	France	2002-07-01 – 2004-06-30
BMWi	Germany	1999-01-01 – 2002-12-31
Enresa	Spain	2001-01-01 – 2004-12-31
JNC and Criepi [1)]	Japan	1999-03-02 – 2002-12-31
Nagra	Switzerland	1998-01-01 – 2002-12-31
Posiva	Finland	2001-01-01 – 2005-12-31
USDOE/Sandia	USA	1999-12-01 – 2002-09-30

[1)] The participation by JNC and CRIEPI is regulated by one agreement and one delegate in the International Joint Committee represents the two companies

Most of the organisations are interested in groundwater flow, radionuclide transport and rock characterisation. Several organisations are participating in the experimental work as well as in the Äspö Task Force on modelling of groundwater flow and transport of solutes. A Task Force on Engineered Barrier Systems has also been initiated. It will concentrate on the water saturation process in buffer, backfill and rock. Since the water saturation process is also a part of the modelling work in the Prototype Repository, the work of the Task Force has been linked together with the modelling work within an EC-project concerning the Prototype Repository. Table 5-2 shows the scope of each organisation's participation under the agreements.

Table 5-2 International participation in Äspö HRL.

Organisation	Participation
Agence Nationale pour la Gestion des Déchets Radioactifs, ANDRA, France.	Tracer Retention Understanding Experiments (TRUE Block Scale) Task Force on Modelling of Groundwater Flow and Transport of Solutes Prototype Repository Temperature Buffert Test – A test in the second hole in the Canister Retrieval Tunnel consisting of a bentonite column with heaters inside for creation of a line heat source
Bundesministerium für Wirtschaft und Technologie, BMWi, Germany	Radionuclide Retention Project (Acitinide experiments) Colloid Project Microbe Project Task Force on Modelling of Groundwater Flow and Transport of Solutes Prototype Repository
Empresa Nacional de Residuos Radiactivos, ENRESA, Spain	Tracer Retention Understanding Experiments (TRUE Block Scale) Task Force on Modelling of Groundwater Flow and Transport of Solutes Backfill and Plug Test Prototype Repository
Japan Nuclear Cycle Development Institute, JNC, Japan. The Central Research Institute of the Electronic Power Industry, CRIEPI, Japan	Tracer Retention Understanding Experiments (TRUE Block Scale Continuation) Task Force on Modelling of Groundwater Flow and Transport of Solutes Prototype Repository Task Force on Modelling of Groundwater Flow and Transport of Solutes Prototype Repository Voluntary project on groundwater dating – Validation of groundwater dating methods and evaluation of stability in groundwater environments after tunnelling.
Nationale Genossenschaft für die Lagerung Radioaktiver Abfälle, NAGRA, Switzerland	Task Force on Modelling of Groundwater Flow and Transport of Solutes
Posiva, Finland.	Tracer Retention Understanding Experiments (TRUE Block Scale) Colloid Project Task Force on Modelling of Groundwater Flow and Transport of Solutes Prototype Repository Long Term Test of Buffer Material Pillar Stability Experiment
USDOE Carlsbad Field Office/Sandia National Laboratories, USA	Task Force on Modelling of Groundwater Flow and Transport of Solutes

EC-projects

SKB is through Repository Technology co-ordinating two EC contracts: Prototype Repository and Cluster Repository Project (CROP). SKB takes part in several EC-projects of which the representation is channelled through Repository Technology in five cases: FEBEX II, BENCHPAR, ECOCLAY II, SAFETI and PADAMOT. SKB will also be co-ordinator in the new project NET.EXCEL.

Prototype Repository - Full scale testing of the KBS-3 concept for high-level radioactive waste (2000-09-01 – 2004-02-29)

Co-ordinator: Swedish Nuclear Fuel and Waste Management Co, Sweden

Participating countries: Finland, Germany, Japan, Spain, Sweden and United Kingdom

CROP - Cluster repository project, a basis for evaluating and developing concepts of final repositories for high level radioactive waste (2001-02-01 – 2004-01-31)

Co-ordinator: Swedish Nuclear Fuel and Waste Management Co, Sweden

Participating countries: Belgium, Canada, Finland, France, Germany, Spain, Sweden, Switzerland and USA

FEBEX II - Full-scale engineered barriers experiment in crystalline host rock phase II (1999-07-01 – 2003-12-31)

Co-ordinator: Empresa Nacional de Residuos Radiactivos, Spain

Participating countries**:** Belgium, Czech Republic, Finland, France, Germany, Spain, Sweden, and Switzerland

BENCHPAR - Benchmark tests and guidance on coupled processes for performance assessment of nuclear repositories **(**2000-10-01 – 2003-09-30)

Co-ordinator: Royal Institute of Technology (Dep. of Civil and Environmental Engineering), Sweden

Participating countries: Finland, France, Spain, Sweden and United Kingdom

ECOCLAY II - Effects of cement on clay barrier performance, phase II (2000-10-01 – 2003-09-30)

Co-ordinator: National Radioactive Waste Management Agency of France

Participating countries: Belgium, Finland, France, Germany, Spain, Sweden, Switzerland and United Kingdom

SAFETI - Seismic validation of 3-D thermo-mechanical models for the prediction of the rock damage around radioactive spent fuel waste (2001-09-01 – 2004-09-01)

Co-ordinator: The University of Liverpool (Dep of Earth Sciences), United Kingdom

Participating countries: France, Sweden and United Kingdom

PADAMOT - Paleohydrogeological data analysis and model testing (2001-11-01 – 2004-11-01)

Co-ordinator: Nirex Ltd, United Kingdom

Participating countries: Czech Republic, Spain, Sweden and United Kingdom

6 Documentation

During the period January-June 2002, the following reports has been published and distributed.

6.1 Äspö International Progress Reports

Svensson U, 2001. Prototype Repository. Groundwater flow pressure and salinity distributions around the Prototype Repository. Continuum model No 1.
IPR-01-40

Pusch R, 2001. Prototype Repository. Instrumentation of buffer and backfill in section I.
IPR-01-60

Äspö Hard Rock Laboratory. Status Report July - September 2001.
IPR-01-61

Puigdomenech I, Sandén T, 2001. Prototype Repository. Instrumentation for gas and water sampling in buffer and backfill (D7). Tunnel section I.
IPR-01-62

Tillmann R, 2001. Prototype Repository. Geological monitoring on buffer, backfill and rock (D9).
IPR-01-63

Forsmark T, Rhén I, 2001. Prototype Repository. Summary report of investigations before the operation phase (D27).
IPR-01-65

Pusch R, 2001. Prototype Repository. Selection of THMCB models (D33).
IPR-01-66

Gentzschein B, 1997. TRUE Block Scale experiment. Detailed flow logging of core boreholes KA2511A, KI0025F and KA3510A using a double packer system.
IPR-01-69

Hermansson J, Follin S, Wei L, 1997. TRUE Block Scale experiment. Input data for discrete feature network modelling of the TRUE Block Scale site. Part I - Structural anayslis of fracture tracers in boreholes KA2563A and KA3510A and in the TBM tunnel.
IPR-01-70

Follin S, Hermansson J, 1996. A discrete fracture network model of the Äspö TBM tunnel rock mass.
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Pusch R, Ramqvist G, 2001. Evaluation of the interaction of the buffer/rock interaction in the Stripa BMT project.
IPR-01-72

Äspö Hard Rock Laboratory. Status Report October-December 2001.
IPR-01-73

Klee G, Rummel F, Weber U, 2002. Rock stress measurements in Oskarshamn. Hydraulic fracturing and core testing in borehole KOV01.
IPR-02-01

Klee G, Rummel F, 2002. Rock stress measurements at the Äspö HRL. Hydraulic fracturing in boreholes KA2599G01 and KF0093A01.
IPR-02-02

Goudarzi R, Röshoff K, Feng Q, 2001. Sensor data report (Period: 000126-011101). Canister Retrieval Test. Report No: 3.
IPR-02-04

Bárcena I, García-Siñeriz L J, 2002. System for canisters displacement tracking.
IPR-02-06

Goudarzi R, Gunnarsson D, Johannesson L-E, Börgesson L, 2001. Sensors data Report (Period 990601-020101) Backfill and Plug Test, Report No:4.
IPR-02-10

Kulatilake P, Park J, Um J-G, 2002. Estimation of rock mass strength and deformation in three dimensions for four 30 m cubes located at a depth region of 380-500 m at Äspö HRL.
IPR-02-11

Kulatilake P, Um J-G, 2002. Fracture network models in three dimensions for four 30 m cubes located at a depth region of 380-500 m at Äspö HRL.
IPR-02-12

Hermansson J, Follin S, Nilsson P, Nyberg G, Winberg A, 1996. TRUE Block Scale Updating of the Structural-Hydraulic model and compilation of scooping data set.
IPR-02-13

Winberg A, Hermansson J, 1996. TRUE Block Scale Experiment allocation of experimental volume.
IPR-02-14

Maersk Hansen L, Hermansson J, 2002. Local model of geological structures close to the TASF-tunnel.
IPR-02-15

Gunnarsson D, 1997. Egenskaper hos kontaktzon mellan betong och bentonit i pluggar. (in Swedish)
IPR-02-21

6.2 Technical Documents and International Technical Documents

14 Technical Documents

6 International Technical Documents

7 References

Andersson P, Byegård J, Dershowitz B, Doe T, Hermanson J, Meier P, Tullborg E-L, Winberg A, 2002a. Final report of the TRUE Block Scale projekt 1. Characterisation and model development.
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Rhén I, Gustafson G, Stanfors R, Wikberg P, 1997. Äspö HRL - Geoscientific evaluation 1997/5. Models based on site characterization 1986-1995
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SKB 2001a. RD&D-Programme 2001. Programme for research, development and demonstration of methods for the management and disposal of nuclear waste.
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SKB 2001b. Forsknings-, utvecklings- och demonstrationsprogram för ett KBS-3-förvar med horisontell deponering.
SKB R-01-55. Svensk Kärnbränslehantering AB

Winberg A, Andersson P, Hermansson J, Byegård J, Cvetkovic V, Birgersson L, 2000. Final Report of the First TRUE Stage.
SKB TR-00-07. Svensk Kärnbränslehantering AB

Äspö Hard Rock Laboratory, 2002. Planning Report for 2002.
IPR-02-25. Svensk Kärnbränslehantering AB