International Progress Report

IPR-00-03

Äspö Hard Rock Laboratory

Status Report

October – December 1999

January 2000

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Summary

Investigations and experiments

The barrier function of the host rock

The Tracer Retention Understanding (TRUE) aim at further developing understanding of radionuclide migration and retention processes and evaluation of different approaches to modelling such processes. The TRUE-1 tests are performed over distances of about 5 m in a fracture at approximately 400 m depth. The tracer experiments were completed in the end of 1998. A number of laboratory studies to support the interpretation of the breakthrough curves have been completed. The final report of the TRUE-1 project now exists as a final draft. It will be released as a SKB Technical Report after internal approval.

The Long-Term Diffusion Experiment is intended as a complement to the *in-situ* dynamic experiments and the laboratory experiments performed within the TRUE Programme. The objectives are to study diffusion into the rock matrix and to obtain data on sorption processes and properties. The experimental concept is based on a large diameter borehole, which exposes a fracture surface. This fracture is packed off with a cap, similar to what was used in the REX experiment. A suitable target fracture has been identified at the 410 m level. The drilling of the test borehole will begin in January 2000.

The TRUE Block Scale project aims at studying the tracer transport in a fracture network over distances up to 50 m. The main activities during the period has been evaluation of the performed site characterisation in borehole KI0025F03, ia. the performed programme with short-time crosshole pressure interference tests and flow and pressure build-up tests. The new borehole KI0025F03 has been instrumented with a multi-packer system. Subsequently the first of the experimental phases during the Tracer Test Stage, Phase A, have been performed. In addition, the developed stochastic continuum, discrete fracture network and channel network models have been updated using the reconciled March'99 structural model and available hydraulic and tracer test data, including the results of the performed Pre-tests. These models will be used to predict selected parts of the Phase A tracer tests.

The detailed scale redox experiment (REX) studies the behaviour of oxygen that will become trapped in the tunnels when the repository is closed. The data collected is being interpreted in order to obtain a mechanistic model for the O_2 consumption rates. The drillcores used in the replica and field experiments have been examined for mineralogical changes and biofilm formation. Final project reports are being written.

The CHEMLAB probe has been constructed and manufactured for validation experiments in situ at undisturbed natural conditions. The CHEMLAB 2 probe system has been delivered to Äspö. This probe will be used for tests of redox sensitive nuclides and experiments with actinides. Preparations for the radiolysis experiments have been completed.

The Matrix Fluid Chemistry experiments has the aim to determine the origin and age of matrix fluids and to establish to what extent the composition of matrix fluid has been influenced by diffusion processes. The analytical data are now complete from the 3 crush/leaches (i.e. different size fractions) carried out by University of Waterloo and the single leach carried out by the University of Bern on the same drillcore material. There was good agreement between the first crush/leach of Waterloo and the Bern sample; both samples represented approximately similar size fractions. Sampling of water from one of the borehole sections was undertaken in December 1999. The section had then been allowed to collect water for 18 months. Some 160 mL of water were collected under an inert N_2 atmosphere. This was out of a total borehole section volume of 210 mL, of which 35 mL was considered inaccessible because of the geometry of the borehole. The sample is presently being analysed, but preliminary data suggest a nearby fracture origin for the water, via diffusion into the sampling section, rather than matrix derived.

The Task Force is a forum for the organisations supporting the Äspö Hard Rock Laboratory Project to interact in the area of conceptual and numerical modelling of groundwater flow and solute transport in fractured rock. The report on the deconvolution of the breakthrough curves for Task 4E (Modelling of tracer tests with sorbing tracers in one fracture, STT1 and STT-1b) has been on review and the report has been printed. Task 5 concerns comparison and integration of hydrology and chemistry through modelling of Äspö tunnel drainage impact on hydraulic and chemical parameters. All modelling groups have delivered their predictions for Task 5 and a description of the chemical reactions to be included in their individual modelling procedures.

Technology and function of important parts of the repository system

The Prototype Repository experiment is located in the last part of the TBM tunnel at the 450 m level and will include 6 deposition holes in full scale. 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. Physical activities in the Prototype Repository tunnel has been limited to mapping of the bored deposition holes and measurement of in-flowing water both into the tunnel and into each deposition hole with specific attention to the spots were the water enters. The instrument plan for the buffer and backfill has been finalised and reported in Swedish. An English version is scheduled early next year. Planning of lead-through and how these can be made watertight as well as gastight has been going on. The number of cables is large and may cause practical problems during installation. A preliminary modelling of the buffer saturation process has been conducted including a sensitivity analysis of the importance of different parameters.

The supporting project “Test of Deposition Process” has not continued as planned due to malfunction of the small deposition machine and late delivery of the crane.

The overall time plan of the Prototype Repository project has been changed. The start of installation of bentonite blocks is now scheduled for January 2001.

The Backfill and Plug Test comprises full scale testing of backfill materials, filling methods, and plugging. The backfilling of the test drift started at the end of 1998 and was completed in July 1999. The arrangement for filling and pressurising the permeable mats has been installed. Every second mat in the sections with bentonite/crushed rock has been filled with water with the salt content 1.6% and pressurised with 100-150 kPa. The water saturation of the backfill is expected to continue for about one year.

The retrieval test is aiming at demonstrating the readiness for recovering of emplaced canisters also after the time when the bentonite has swollen. Two holes will be equipped with canisters, buffer and instrumentation. The plan on instrumentation of the buffer has been completed and the purchase process for these instruments has been initiated. The work on the design of the plugs on top of the holes has concentrated on a combined concrete/steel plug placed in the hole below the floor level. This plug will be anchored to the rock by means of up to a dozen cable bolts, which can resist a swelling pressure from the bentonite of up to 10 MPa (design pressure is 5 MPa). The results from the acoustic emission measurement and changes in rock stresses around the holes during drilling have been evaluated and presented in draft reports. The velocity of ultrasonic waves changes in the rock at approx. 20-30 mm from the borehole walls, indicating a drop in the rock elastic modulus.

The Long Term Tests of Buffer Material aim to validate models and hypotheses concerning long term processes in buffer material. The assemblage and placement of the four long-term test parcels and the extra one-year parcel are completed. All parcels were equipped with instruments, bacteria, copper coupons and with radioactive tracers according to plans. The instruments are found to work properly with the exception of two optical sensors. Laboratory characterisation of the bentonite test material has been made.

International Cooperation

Nine organisations from eight countries are currently (December 1999) participating in the Äspö Hard Rock Laboratory.

During the last quarter of 1999 Posiva has participated in the fieldwork of the Äspö HRL mainly within the Hydrochemical Stability project. The Posiva groundwater sampling method has been tested in the borehole KLX02. In addition to the testing of the equipment the aim of the project was to get samples for characterising the hydrochemistry of the deep saline groundwater.

Facility Operation

The ”five year inspection” of the underground facility has been completed. The inspection identified a few areas were intense reinforcement is necessary.

The net surrounding the hoist shaft on the different landings has been changed to material in stainless steel to avoid corrosion.

The reliability of the electrical supply to the facility will be improved when an extra power cable directly from the nuclear power plant to Äspö is connected. The cable will be in operation within a few months.

Data Management and Quality systems

A new database server, Sun Microsystem ULTRA Enterprise 450, has been installed and configured to be used as a dedicated SICADA server.

A new software connection between HMS (Hydro Monitoring System) and SICADA has been implemented.

RVS version 2.1 has been delivered. This new version embodies about 30 new or improved existing functions.

Groundwater head and chemistry monitoring

The HMS program has been running providing real time data acquisition in support of the various projects undertaken in the Äspö Hard Rock Laboratory.

The HMS detected responses in groundwater head induced by an earthquake of magnitude 7.2 with its epicenter in Turkey. A compilation of data was compiled to this effect.

The results from the groundwater sampling campaigns in April and in October will be presented in Technical Documents in February-March. The next sampling occasion is scheduled to take place w016 and 017.

Information activities

During the fourth quarter of 1999, 2870 visitors visited the Äspö HRL. The groups have represented the general public, communities where SKB performs feasibility studies, teachers, students, politicians, journalists and visitors from foreign countries. The total number of visitors during 1999 was 12211.

The entrance building for ”Urberg 500” was completed during the third quarter of 1999 and has been taken into use during the fourth quarter of 1999. The visitors get a presentation of SKB and the Hard Rock Laboratory in the entrance building before going down in the tunnel by bus. The tour finishes in the exhibition hall on Äspö.

Contents

1 General

The scientific investigations within SKB's research programme are part of the work conducted to develop and test methods for identification and characterisation of suitable repository sites and for design of a deep repository. This requires extensive field studies of the active processes and properties of the geological barrier and the interaction between different engineered barriers and host rock. The Äspö Hard Rock Laboratory provides an opportunity for research, development and demonstration of these issues in a realistic setting. The role of the Äspö Hard Rock Laboratory within the SKB Research Development & Demonstration programme are:

- to increase scientific understanding of the safety margins of the deep repository,
- to test and verify technology that provide cost reductions and simplifies the repository concept without compromising safety,
- to demonstrate technology that will be used in the deep repository,
- to provide experience and training of staff, and
- to inform about technology and methods to be used in the deep repository.

A set of Stage Goals have been defined for the work at the Äspö HRL. The Stage Goals were redefined in the SKB Research Development and Demonstration (RD&D) Programme 95, which was submitted to the Swedish Authorities in September 1995. An updated program RD&D Programme 1998 was submitted in September 1998. This programme is the basis for the planning and execution of the current work.

The Stage Goals for the Operating Phase of the Äspö HRL are as follows:

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 function of the host rock**

   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 and after closure.

4 Demonstrate technology for and function of important parts of the repository system

test, investigate and demonstrate on a full scale different components of importance for the long-term safety of a deep repository system and to show that high quality can be achieved in design, construction, and operation of system components.

2 Methodology for detailed characterisation of rock underground

General

A programme for detailed characterisation will be devised before detailed characterisation is initiated on a selected site and construction of the surface and underground portions of the deep repository is commenced. In conjunction with the driving of the Äspö tunnel, several different investigation methods have been tried and the usefulness of these methods for detailed characterisation for a deep repository is being evaluated. Preliminary experience from Äspö shows that there is a need for refinement of these methods to enhance the quality of collected data, boost efficiency and improve reliability in a demanding underground environment. Furthermore, the detailed characterisation programme needs to be designed so that good co-ordination is obtained between rock investigations and construction activities.

The objectives are:

- to try out existing and new methods to clarify their usefulness for detailed characterisation. The methods to be tested are chosen on the basis of their potential use within the detailed characterisation programme,
- to refine important methods in a detailed characterisation programme to enhance data quality, efficiency and reliability.

Detailed characterisation will facilitate refinement of site models originally based on data from the ground surface and surface boreholes. The refined models will provide the basis for updating the layout of the repository and adapting it to local conditions. Due to the heterogeneity of the rock, the layout of the repository needs to be adapted to the gradually refined model of rock conditions. This approach has a long tradition in underground construction and it should be used also for a deep repository. During 1999 an updating of the geoscientific models of Äspö HRL will be performed.

2.1 Updating of the geoscientific models of Äspö HRL

Background

Some basic research that is not project-related is conducted at the Äspö HRL. This work is aimed at providing support for the research, development and demonstration projects by conducting and comparing measurements of common interest for all projects. According to SKB's planning, the suitability of geological formations for deep disposal of spent nuclear fuel will be evaluated with the aid of geoscientific models of the site in question, including:

- geological model,
- geohydrological model,

- groundwater chemical model,
- geomechanical model,
- heat transport model,
- radionuclide transport model.

These models are compiled in conjunction with a site investigation and present an aggregate of existing knowledge on a site.

On Äspö, geoscientific information has been systematically collected during the pre-investigation and construction phases. Data continues to be collected from the various tests and projects that are being conducted. The information that has been gathered up to now and including completion of the main tunnel down to a level of 450 metres has been used to devise site-specific models of the conditions on Äspö. The models contain dimensionality, material properties, method for specification of properties in the whole model, boundary conditions, numerical or mathematical tools, and what parameters the model depicts (Olsson et al., 1994). Structure and content are described in greater detail in Rhén et al. (1997). The purpose of constructing these models has primarily been to verify our ability to foresee the properties of a rock mass on the basis of information from completed site investigations.

The existing geological, geohydrological and groundwater chemical models of Äspö will gradually be revised, particularly in the light of the new information that is constantly obtained from the projects described later. A test plan for this modelling exercise, which is given the name GeoMode, will be presented early 1999. The rock mass to be modelled cover the last tunnel spiral from the level of 340 m down to 460 m.

A heat transport model and a radionuclide transport model will also be developed but outside the GeoMode project.

Objectives

The aim of the project is to develop tools for constructing geological, geomechanical, geohydrological and groundwater chemical models as a basis for the different experiments to be conducted at Äspö HRL. The specific objectives are to:

- describe the rock volume in the last tunnel spiral
- define the initial and boundary conditions of importance to the different experiments
- integrate the knowledge for the different disciplines
- develop and refine tools for the model construction

The main goal is to construct an integrated model by June 2001. The individual geological, geomechanical, geohydrological and groundwater chemical models should be presented in June 2000. Necessary tools for input and visualisation of data, e.g. RVS and SICADA, should be further developed until September 2000.

Results

A definition of the boundary conditions for the different subjects has been performed. A screening of data for the different subjects has also be performed. The first visualisation mainly in chemistry has started up.

Planned work

Complementary input of data will follow and visualisation will be performed in June 2000.

3 Test of models for description of the barrier function of the host rock

General

The Natural Barriers in the deep geological repository for radioactive wastes are the bedrock, its properties and the on-going processes in the rock. The function of the natural barriers as part of the integrated disposal system can be presented as isolation, retention and dilution. The common goal of the experiments within Natural Barriers is to increase the scientific knowledge of the safety margins of the deep repository and to provide data for performance and safety assessment calculations. The strategy for the on-going experiments on the natural barriers is to concentrate the efforts on those experiments which results are needed for the planning of the future candidate site investigations. These are planned to start in 2002. For this focus there is also a need to involve experts of the different geoscientific disciplines into the on-going experiments in order to make them familiar with the work and quality procedures at Äspö.

Isolation is the prime function of the repository. It is obtained through the joint function of the engineered and the natural barriers. For deep geological disposal, the flow of water to the canister/waste containment is largely determining the magnitude at which the corrosion and the dissolution of the waste form can take place. For a good isolation it is thus necessary to minimise the groundwater flow to the waste containment. Additional conditions that affect the isolation are the chemistry of the groundwater and the mechanical stability of the rock.

Conceptual and numerical groundwater flow models have been developed through the entire Äspö project up to now. During 1999, focus is on the sporadic high permeable features (HPF:s) which normally are not detected by remote sensing tools, e.g. borehole radar and other geophysical tools. The consequences to repository lay-out and implementation into numerical models will be assessed.

Hydrochemical stability and potential variability is assessed within several ongoing projects. These aim at explaining possible chemical conditions in a repository host rock based on assumption of different climate conditions in the future. Of special importance are redox conditions and microbial activity, which will be reported within the REX project during 1999.

The retention of radionuclides dissolved in groundwater is the second most important barrier function of the repository. Retention will be provided by any system and process which interacts with the nuclides dissolved in the groundwater when eventually the water has come in contact with the waste form and dissolved radionuclides. Retention is provided by the physical and chemical processes that occur in the near-field and far-field. Some elements are strongly retarded while others are escaping with the flowing groundwater. The major emphasis in the safety assessment calculations has therefore been put on the weakly retarded nuclides even if they are not dominating the hazard of the waste.

Tracer tests are carried out within experiments in the TRUE-projects. These are conducted at different scales with the aim of identifying detailed scale (5m) and block scale (50m) flow paths, retention of weakly and moderately sorbing tracers and the effect of matrix diffusion. During 1999 the goals are to complete the first detailed scale experiment (TRUE-1), complete the characterisation for the block scale experiment (TRUE-Block Scale) and initiate the matrix diffusion experiment (LTDE). Modelling of the experiments is done by several groups associated to the Äspö Task Force for modelling of groundwater flow and transport of solutes.

CHEMLAB experiments are conducted with the moderately and highly sorbing nuclides. Experiments are carried out in simulated near field conditions (bentonite) and in tiny rock fractures. During 1999 diffusion experiments will be completed and experiments including effects of radiolysis will start. A second CHEMLAB unit will be used for experiments with redox sensitive nuclides and transuranics also starting during 1999.

A particular transport phenomenon could be caused by gas which may carry nuclides from depth to surface. This two phase flow phenomenon is investigated in an on-going experiment conducted by GRS and BGR. During 1999 the outcome of this experiment will be modelled in cooperation with the GRS/BGR team.

3.1 Tracer Retention Understanding Experiments

Background

The safety of a KBS-3 type repository relies heavily on the engineered barrier system that contains the waste. In the case that the engineered barrier fails, the geosphere provides the remaining waste containment. Realistic estimates and predictions of transport times through the geosphere and release rates to the biosphere are thus critical for any safety assessment. Of particular interest in this regard is the rock adjacent to the canister holes and storage tunnels.

The plans for tracer experiments outlined in the SKB RD&D Programme 92 comprised experiments in the Detailed and Block Scales. The experiments in the Detailed Scale consisted of three; Pore Volume Characterisation (PVC), Multiple-Well Tracer Experiment (MWTE), and the Matrix Diffusion Experiment (MDE). During 1994 detailed Test Plans were prepared for MWTE and MDE. Following review and evaluation the SKB HRL Project management decided to integrate the Detailed and Block Scale experiments within a common framework. This framework is described in a "Program for Tracer Retention Understanding Experiments" (TRUE) (Bäckblom and Olsson, 1994). The basic idea is that tracer experiments will be performed in cycles with an approximate duration of 2 years. At the end of each tracer test cycle, results and experiences gained will be evaluated and the overall program for TRUE revised accordingly.

The general objectives of the TRUE experiments (Bäckblom and Olsson, 1994) are;

- Develop the understanding of radionuclide migration and retention in fractured rock.
- Evaluate to what extent concepts used in models are based on realistic descriptions of rock and if adequate data can be collected in site characterisation.
- Evaluate the usefulness and feasibility of different approaches to model radionuclide migration and retention.

3.1.1 TRUE-1

Final reporting

During the period review and editing of the Final Report of the First TRUE Stage has been performed. This has included both internal and external peer review of the final version of the report. The report is expected to be released during the first quarter 2000.

An international seminar focused on the results of the first stage will held in September this year in conjunction with the 5th GEOTRAP meeting, scheduled for the second week of September. The venue for the two meetings will be the Äspö Hard Rock Laboratory.

The results of the performed TRUE-1 analysis and evaluation work is planned to be reported in a series of four papers aimed at international scientific journals, see below.

Complementary analysis

A) Sorption, diffusion and porosity of rim zone material

The Feature A specific rock slab (KXTT1) that have been used for through-diffusion experiment (Byegård et al. 1998) has been delivered to the University of Helsinki where the sample will be sliced and analysed using autoradiography in order to obtain information of the heterogeneity of the sorption/diffusion. The samples will thereafter be analysed by γ-spectrometry in order to study the penetration profile of the γ-radioactive tracers remaining in the sample (i.e., Na-22, Cs-137, Ba-133). The results will be presented at the Task Force Meeting in Carlsbad 8-11 February 2000.

Samples from the Feature A intercept in KXTT2 have been sawed, with the intention of isolating samples consisting of "pure" altered Äspö diorite and "pure" mylonite, respectively. The attempt was successful for the altered Äspö diorite; an 8 mm thick 2x2cm sample was obtained. However, the attempt to saw a pure mylonite sample of the same size resulted in a crack, parallel to the Feature A fracture, resulting in two samples; one ~5mm thick and one ~3mm thick. These three samples have been cast in plastic discs and are to be used in through-diffusion experiment (HTO as tracer). The results of these experiments are to be presented at the Task Force Meeting in Carlsbad 8-11 February 2000.

The porosity of the KXTT2 sample (described above) has been analysed by the water saturation method. Analysis has been performed both for the intact sample and for all the ten different samples obtained after the sawing of the sample. The intention being to see if the sawing process induces micro-cracks and micro-fractures which increase the porosity of the sample.

The results indicate that the porosity measured for the different sawed samples are not significantly higher than the porosity measured for the "intact" sample. The only sample that shows a slightly increased porosity is the T2H sample which has a porosity of ~1% compared to ~0.5% for the intact whole sample. A small fracture can be observed in this sample, corresponding to the crack resulting in the separation of the two mylonite samples, see above. An interpretation is that the noted somewhat increased porosity is caused by the small fracture.

B) Alternative interpretation of in situ experiments

Modelling of STT-1 and STT-1b have been performed in cooperation with Roy Haggerty, Oregon state University, and a manuscript draft has been produced. The paper is intended to be published in Journal of Contaminant Hydrology. The paper is presently subject to internal review. The work was presented as an oral presentation at the AGU-meeting by Roy Haggerty. The paper constitute one component in the PhD thesis of Henrik Johansson, CTH.

C) Inclusion of heterogeneity in evaluation of diffusion results

In an attempt to include heterogeneity in diffusion, interpretation of laboratory diffusion data from test using Äspö diorite has been performed. In the modelling, the independently ^{14}C-labelled PMMA measured porosity distribution (Byegård et al, 1998) has been used. Breakthrough curves in through-diffusion experiments as well as penetration profiles in the matrix have been evaluated using the porosity distributions. In the calculations only two parameters, the pore diffusivity (D_p) and the sorption distribution coefficient (K_d) have been varied in order to fit the experimental data to the proposed model. For the penetration profile of more strongly sorbing tracers, i.e., Cs^+ and Ba^{2+}, a significantly better explanation of the data is obtained using a heterogeneity model compared to using a uniform porosity distribution model. The data from the through-diffusion experiments give a better explanation of the shape at the beginning of the breakthrough curve. The results and interpretation of the modelling was presented at the MRS Fall Meeting in Boston 29 Nov- 2 Dec 1999 and a paper that will be included in the conference proceedings are included in this status report.

3.1.2 Long term Diffusion Experiment (LTDE)

Background

The Long-Term Diffusion Experiment is intended as a complement to the *in-situ* dynamic experiments and the laboratory experiments performed within the TRUE Programme.

The objectives of the planned experiment is to ;

- To investigate diffusion into matrix rock from a natural fracture in situ under natural rock stress conditions and hydraulic pressure and groundwater chemical conditions .
- To obtain data on sorption properties and processes of some radionuclides on natural fracture surfaces.

- To compare laboratory derived diffusion constants and sorption coefficients for the investigated rock fracture system with the sorption behaviour observed in situ at natural conditions, and to evaluate if laboratory scale sorption results are representative also for larger scales.

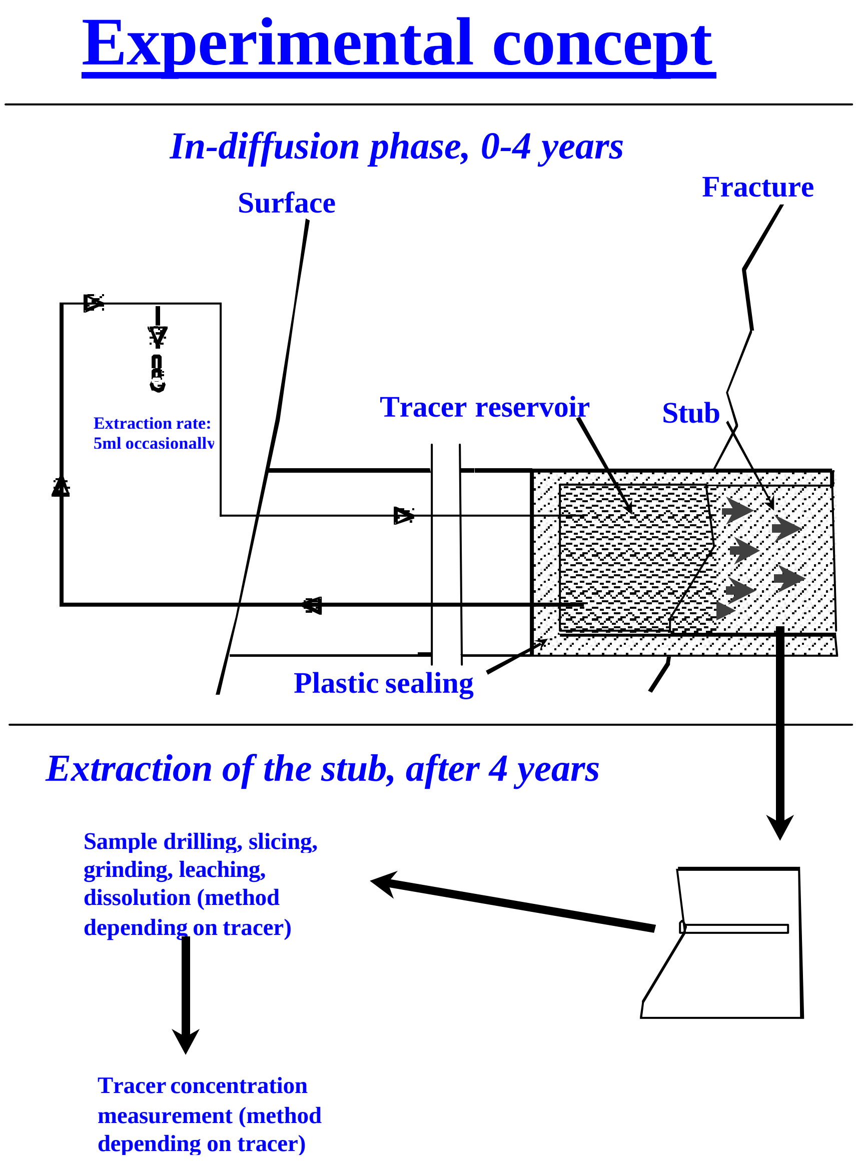


Figure 3-1 *Schematic of LTDE experimental concept including injection borehole in contact with a fracture surface, combined with excavation and penetration profile studies*

The updated test plan presents an experimental concept centred on establishment of an experimental (large diameter) borehole which exposes a fracture surface. This fracture surface is packed off with a cap, similar to the one used in the REX experiment, cf. Figure 3-1. The intention is to establish an experimental chamber in which a tracer solution is circulated over a period of four years. Performed scoping calculations using available diffusivity data indicates that axial diffusion will range from mm:s for the strongly sorbing tracers to dm:s for the weakly sorbing tracers considered. Apart from tracers used in the TRUE-1 experiment, also PA-relevant tracers (^{99}Tc, ^{237}Np and ^{241}Am) are being proposed. The principal feat of the experiment is to establish axial diffusion from a natural fracture, through the rim zone of fracture mineralisation and alteration, into the unaltered rock matrix, without any advective component (towards the tunnel). This is resolved using a multi-packer system which effectively shields off the gradient. In addition, an intricate pressure regulation system is devised which will effectively allow the pressure in the experiment chamber to adapt to the ambient conditions without causing pressure differences, and hence no advetive transport. The reference pressure is obtained from a packed-off pilot borehole in the immediate vicinity of the large diameter experimental borehole. The former borehole has also been used to identify the target fracture to be investigated.

The characterisation of the large diameter borehole includes ia. measurements with various electrical geophysical logs (resistivity). The idea being to enable coupling between the electrical resistivity and diffusivity. In addition the core will be analysed using mineralogical, petrophysical and geochemical methods.

Results

During the period a formal decision has been taken by SKB to run LTDE as laid out in the developed test plan for the project.

A suitable target fracture has been identified in borehole KA3065A02 at a depth of 9.81 m. This structure constitutes a chlorite splay (141/81) to a main fault, the latter on which slicken lines on the surface are evident. It shows mylonitic character in diorite/greenstone with an increasing alteration towards the fault centre. The total inflow at this zone is about 16 l/min. The target structure constitutes the lower fringe of the zone and is followed by a long > 0.5 m long intact piece of Äspö diorite.

During the period work has proceeded on two main fronts. First, the construction of downhole borehole and sampling and monitoring equipment has been initiated. Second, a tentative geometry for the planned telescoped (300mm/200mm) large diameter borehole, KA3065A03, has been derived using a RVS model of the target rock volume.

Samples of the proposed material used for the downhole equipment (PEEK and polyurethane) have been sent to CTH-Nuclear Chemistry in Gothenburg in order to test characteristics and possible influence on the experiment. As a result CTH have confirmed usage of the tested materials for the sealing, cf. Figure 3-1. A mock-up borehole has been manufactured of a steel tube trying to imitate the inner part of the borehole involving the core stub. A first prototype of the sealing rubber (shore 60-90 deg) has been manufactured and tested. The rubber withstands a differential pressure of about 0.5 Mpa. A new sealing rubber (shore 45-70 deg) is going to be delivered week 00-02. The new rubber is expected to withstand about 0.8 MPa in the mock-up borehole. The final construction, manufacturing and testing are going to be done when the actual geometry of the stub in the LTDE borehole is known.

The plan is to target the target feature some 0.3 away from the intercept in the existing pilot borehole (KA3065A02).Prior to conduction the actual drilling of the LTDE experimental hole, a trial drilling with the selected 196.5 mm core barrel selected for the final part of the borehole check that the surfaces will be smooth enough to enable satisfactory sealing. In addition the ability to drill short uptakes and break the core at selected depth will be tested.

The drilling of the telescoped experimental borehole will be done with a strong element of interactive site characterisation (borehole imaging) and structural modelling using the RVS system. After each uptake, borehole TV imaging will be performed and compared with the corresponding image from the pilot borehole some 0.3 m away, and the structural and geological extrapolations made on the basis of the developed model. The structural and geological model will be updated successively and the projected depth to the target structure will be adjusted accordingly. The drilling of the LTDE borehole constitute a first attempt at Äspö to interactively and on-site steer the drilling using site characterisation and structural and geological modelling.

3.1.3 Second TRUE Stage (TRUE-2)

Background

A tentative planning document for the Second TRUE Stage was presented at the combined LTDE/TRUE-2 Review Meeting, March 8-9. The overall goal of TRUE-2 is to address diffusion, and particularly diffusion from a fracture into the matrix, in a dynamic in-situ experiment. In order to realise this goal there is a need to establish an experimental situation with a low hydraulic gradient such that pumping at low flow rates can be employed without loosing tracer mass.

During the Spring of 2000, a test plan for TRUE-2 will be produced. In addition the prospects of locating the TRUE-2 experiment on the basis of the SELECT-2 pilot drilling and characterisation will be evaluated. It may be necessary to drill additional pilot boreholes to facilitate the location of the experiment.

3.1.4 TRUE Block Scale

Background

Work on the TRUE Block Scale Project started in mid 1996. This subproject of TRUE broadens the perspective from an address of a singular feature in TRUE-1, to flow and transport processes in a network of fractures and a spatial scale between 10 and 50m. The specific objectives of the TRUE Block Scale Project are to;

1) increase understanding and the ability to predict tracer transport in a fracture network,

2) assess the importance of tracer retention mechanisms (diffusion and sorption) in a fracture network,

3) assess the link between flow and transport data as a means for predicting transport phenomena,

A set of desired experimental conditions have been defined and a flexible iterative characterisation strategy has been adopted. The project is divided into a five basic stages;

- Scoping Stage
- Preliminary Characterisation Stage
- Detailed Characterisation Stage

- Tracer Test Stage
- Evaluation (and reporting) Stage

The total duration of the project is approximately 4.5 years with a scheduled finish at the end of the year 2000. The project was originally organised as a multi-partite project involving ANDRA, NIREX, POSIVA, and SKB. During 1997, also ENRESA and PNC have joined the project.

During 1997, a series of two boreholes, KI0025F and KI0023B, have been drilled using the triple-tube method from the I-tunnel at L=3/510 m in the access tunnel. These boreholes, 75 mm in diameter, are gently inclined (I=20 degrees) and complement the existing 56 mm boreholes, KA2511A and KA2563A, the latter drilled as a pilot borehole as part of the TRUE Block Scale Scoping Stage. The latter boreholes have been drilled with a higher inclination from a higher elevation in the laboratory. The boreholes have been characterised using different geological, geophysical and hydrogeological methods. Based on the collected data the structural model of the block has been updated sequentially.

During 1998 the Preliminary Characterisation Stage was concluded with elaborate cross-hole interference tests which involved all available boreholes in the investigated rock block. The primary aim of the tests was to investigate the hydraulic connectivity with the block, and specifically the existence, relative role of north-easterly and subhorizontal structures. In addition the tests involved performance of tracer dilution tests in selected test sections, whereby not only the drawdown due to an applied disturbance was obtained, but also the change in flow rate through the selected sections. One of the pumpings was driven long enough to study breakthrough of tracer.

The cross-hole interference data together with 3D seismic data were used together with data from KI0023B to produce the September 1998 structural model update.

During the Fall 1998 another borehole, denoted KI0025F02, was drilled as part of the Detailed Characterisation Stage from the I-tunnel, between KI0023B and KI0025F, was characterised and completed. In this hole the POSIVA flow log was used for the first time in the project. In addition a series of short time cross-hole interference tests and associated tracer dilution tests were performed.

The status of the project per November 1998 was presented at the 2nd TRUE Block Scale Review Seminar held Nov 17, in Stockholm. At this meeting, apart from presenting a conceptual model of groundwater flow, the project group also presented their tentative strategy for upcoming future tracer tests.

During the Spring of 1999 an intensive planning effort has been conducted which has resulted in definition of the important issues of the planned future tracer tests. A set of hypotheses related to the issues of conductive geometry, heterogeneity and retention have been put forward in a Tracer Test Programme. Further design calculations related to the effects of fracture intersections have been performed. In addition, a series of Pre-tests, in essence a series of three interference tests with associated tracer dilution tests have been performed. As a final field activity a multi-injection tracer test was performed which demonstrated breakthrough from four out of four injection sections, two of which showed high recovery in pathways involving multiple structures (>1)). The Tracer Test Programme also defines a tentative strategy for the future tracer tests which will be conducted in three consecutive phases, A through C. The first Phase, A, is a test of alternative sink sections, combined with complementary tracer dilution tests. Phase B will focus on the selected sink section, tests over both short and longer distances. Initiation of tests with weakly sorbing tests over longer distances and He may be foreseen towards the end of Phase B. The final phase, C, is fully devoted to tests with sorbing tracers.

A new 76 mm borehole, KI0025F03, was drilled in early August 1999 with the primary purpose of providing additional injection points for tracer, short flow paths for sorbing tracers and as a means of verifying the reconciled March'99 model. The projected locations of interpreted structures have largely been verified by observed structures and inflows in the borehole, as well as observed pressure responses in neighbouring packed-off boreholes.

After performed characterisation the borehole was packed off in 9 sections. Five sections are equipped to allow injection/abstraction of water and tracer. Two sections will be equipped with steel tubing to allow injection of He without risking diffusion through the lines.

Overview of activities during the period

The main activities during the period has been evaluation of the performed site characterisation in borehole KI0025F03, ia. the performed programme with short-time crosshole pressure interference tests and flow and pressure build-up tests. The new borehole KI0025F03 has been instrumented with a multi-packer system. Subsequently the first of the experimental phases during the Tracer Test Stage, Phase A, have been performed. In addition, the developed stochastic continuum, discrete fracture network and channel network models have been updated using the reconciled March'99 structural model and available hydraulic and tracer test data, including the results of the performed Pre-tests. These models will be used to predict selected parts of the Phase A tracer tests.

Site characterisation

Flow and pressure build-up test were performed in thirteen 2 m sections in KI0025F03. The tests were performed as constant rate withdrawal tests wit a 30 m flow period followed by a 45 minute long recovery period. The draw down in the sink section generally was about 2 MPa (200 metre water column). During the tests the pressure responses in the neighbouring boreholes. The pressure responses were interpreted quantitatively and plotted in diagnostic pressure response diagrams and in time distance diagrams. The observed responses were also compiled in a response matrix. The qualitative interpretation shows that the responses in general are consistent with the reconciled March'99 structural model. The dominating flow regimes are (pseudo-)radial which in some cases transform to leaky (pseudo-) spherical flow by the end of the tests.

Tracer tests

The principle objectives of the Phase A tests are to provide the basis for selection of the best main sink to be used in the subsequent experimental phases. In addition, the database of tracer dilution data is complemented using sink sections in the new borehole. Subsequently two tracer tests have been performed. One using the previously used sink in KI0023B:P6 (Structure #21) and injection points in the new borehole, and one test in KI0025F03::03 (Structure #20) with injection in 5 sections in adjacent holes. The database with tracer dilution test data at ambient and pumped conditions amount to a total of 70 sections after performing tests A1-A3. The results in terms of pressure responses and flow data have been distributed to the modelling teams.

The results from the tracer tests, A4 and A5, are presently being evaluated.

Analysis of conductive background fractures

The purpose of this study is to provide a quantitative basis for modelling of background fracturing in the immediate vicinity of Features #13, #20, #21, and #22 (TTS region) which are the focus of the Tracer Test Stage (TTS) of the TRUE Block Scale experiment. Based on this analysis, we have derived statistics for conductive background fracturing in the studied rock volume.

The analysis is based on a correlation of Posiva flow log features with fractures identified in borehole (BIPS) logs in boreholes KI0025F02, KI0025F03, KA2563A, and KA2511A. Analyses were carried out on files (a) adjusted to remove numbered deterministic structures, and (b) Terzaghi corrected for orientation biases. The following analyses were carried out on the derived borehole data set:

Intensity Analysis: Posiva flow log feature intensity P_{10} varies from 0.16 to 0.21 m^{-1}, with an average of 0.19 m^{-1}. This is a relatively small level of variation, and therefore a value of 0.19 m^{-1} should be appropriate for all modelling of the TTS region. This corresponds two a volumetric intensity P_{32} of 0.29 m^2/m^3.

Orientation Distribution Analysis: Posiva features define two sets with approximately equal intensities. The two sets can be described by Fisher distributions with Mean Pole Trend and Plunge of (211°,0.6°) and (250°,54°), respectively, with Fisher Dispersion κ of 9.35 and 3.8, respectively.

Transmissivity Analysis: Statistical Analysis of Posiva features indicate a lognormal distribution with $\log_{10}$ mean and standard deviation of (–8.95, 0.93) $\log_{10}$ m^2/s

Size Analysis: No new size data was analysed, such that the recommended radius distribution remain a lognormal distribution, mean of 6 m and standard deviation of 2 m.

Spatial Structure: Extensive fractal, geostatistical, and distributional analyses were carried out to evaluate alternative spatial models. However, no compelling result was identified to justify the use of models other than the commonly used Baecher model.

Modelling Phase A

The tests will be subject to prediction using the updated stochastic continuum, discrete fracture network and channel network models.

Stochastic Continuum

The new structural model has been implemented. A hydraulic conductivity data base is built for each fracture plane and for the background. For the matrix conductivity the flow logging data on 5 m intervals are used. For the fracture plane conductivities the compiled data set with transmissivities for the main fracture planes are used. These data are used as pointwise conditioning information. The conductivities used in the model are the obtained transmissivities from the data divided by the grid block size of the numerical model.

The simulated hydraulic conductivity for a grid cell is only conditioned to hydraulic conductivity data taken in the fracture plane to which the cell belongs. The hydraulic conductivity variogram model is not estimated from the data but is adopted according to expert knowledge because too few data are available to estimate variogram models for all fracture planes. The hydraulic conductivity databases and the variograms are the main input information to the condition/calibration process.

The 3D hydraulic conductivity fields are inversely conditioned to hydraulic head data by sequential self calibration. First, the conductivity field is conditioned to steady state hydraulic head data from July 1999. Second, the field is conditioned to a series of selected transient interference tests.

The prescribed heads on the boundaries are also calibrated using the steady state head data, since the hydraulic head has changed over the period of experimentation. The inverse conditioning is carried out for two different scenarios related to fracture intersection zones (FIZ) (1) Treating the FIZ as a separate zone. The grid cells belonging to the FIZ are in this case perturbed separately from the rest of the fracture planes. (2) Treating the FIZ as belonging to multiple fracture planes. Perturbations at grid cells belonging to a FIZ are in this case influenced by perturbations calculated in the fracture planes of which the grid cells form part.

Four simulations for the two scenarios have been performed so far. Each of them is conditioned to the most recent structural model, hydraulic conductivity data, steady state head data and five short term interference tests. The reproduction of the measured hydraulic head is better than in previous calculation results. The correspondence is better for the scenario in which the FIZ are treated separately. The updated conductivities show an important spatial variance inside the fracture planes with important differences in average conductivities between planes representing individual deterministic structures.

Discrete feature network

A basic local DFN model of the TRUE Block site has been constructed based on the so-called March'99 model. This includes a parameterised structural model (primarily based on transmissivity measurements arising from the pre-testing of the key structures) of the basic reconciled geometrical model. A development has been completed to enable the DFN code NAPSAC to include small-scale variability, potentially down to a 5cm scale, to be included in an efficient way. Figure 3-2 shows the March '99 model with variability on a 10-20m scale. It has been demonstrated that it is possible to perform detailed scale calculations. Work is progressing on calibration approaches and the integration of data on various length-scales, which will eventually result in prediction of the Phase A tests.

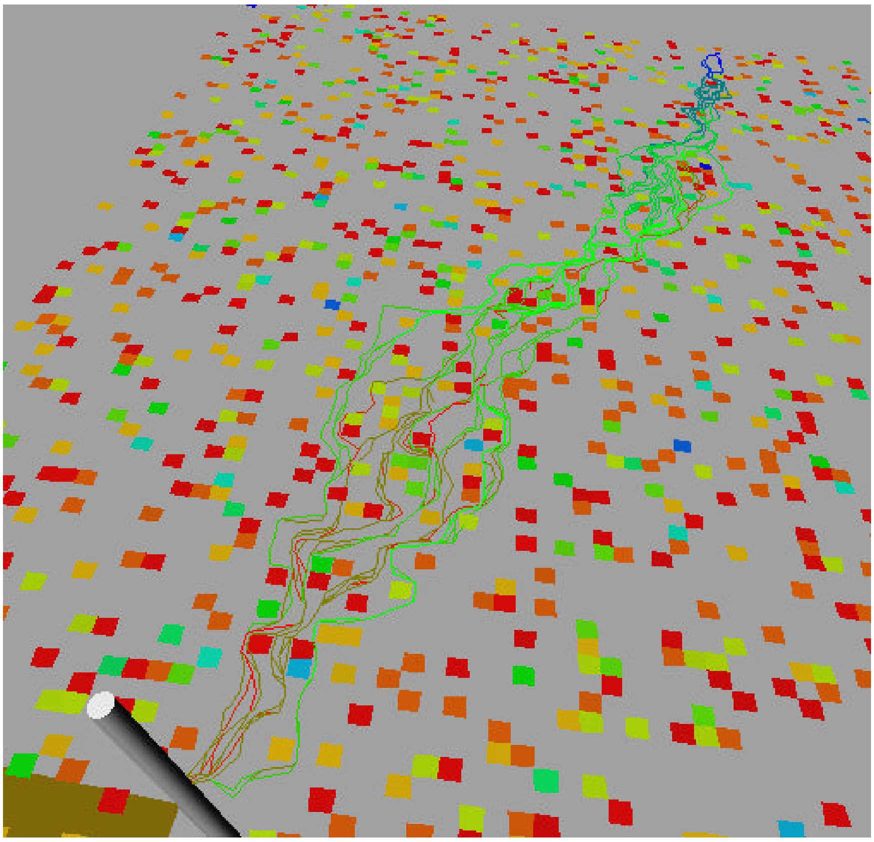


Figure 3-2 *NAPSAC/DFN - Pathlines of particles* **(***coloured .according to time) released from a point in the feature and being received by the abstraction borehole. The flow channels (higher T>1E-8) have been removed (in the visualisation) to more easily visualise the flow in the channels. The small-scale variability is on a 10 cm length scale.*

PAWorks Channel Network Model

During the fourth quarter of 1999 and the first quarter of 2000, JNC/Golder are in the process of updating their PAWorks Channel Network model for use in prediction of the "Phase A" tracer tests. The following updates were initiated during the fourth quarter of 1999:

- CN Model Features: Borehole KI0025F03 was added to CN Model
- Virtual Packers: Virtual Packer locations based on Doe (1999) were implemented into the model 8this to account for planar interpretation of structures based on individual intercepts)
- Background Fracturing: The background fracturing in the model was updated using values determined, see above.
- Boundary Conditions: Boundary conditions were implemented for PT-1 through PT-4 and A-1 through A-3 interference and tracer test simulations.
- Simulations using these updated models will be carried out during the first quarter of 2000.

Planned work

1st quarter 2000

TRUE-2

- Tentative location of experimental site for TRUE-2
- Test of new double packer and new injection scheme at the TRUE-1 site

LTDE

- Drilling
- Site characterisation

TRUE Block Scale

Tracer Test Stage

- Performance of Phase B tracer tests
- Performance of model predictions of Phase A tests using SC, DFN and CN models

3.2 The REX-experiment

Background

A block scale redox experiment was carried out in a fracture zone at 70 m depth in the entrance tunnel to Äspö. In spite of massive surface water input, the fracture zone remained persistently anoxic. The main conclusion from that study was that the increased inflow of relatively organic-rich shallow groundwater instead of adding dissolved oxygen, it added organic compounds that acted as reductants in the deeper parts of the fracture zone. These conclusions are specific to this particular fracture zone, experimental conditions and the time scale (3 years) of the experiment, but are probably also relevant for other conductive fracture zones.

The detailed scale redox experiment (REX) is planned to focus the question of oxygen that is trapped in the tunnels when the repository is closed. Questions regarding the role of oxygen in this context are:

- Will oxygen penetrate into the rock matrix during construction and operation?
- If yes, how much of the rock will be oxidised and how long time will it take before oxygen is consumed?

- What happens to the oxygen in the backfill/buffer: how much is consumed by the rock, and how much by the buffer?

The REX project focuses on the first two of these questions, especially the second one. The third question is not included in the experiment.

The objectives of the experiment are:

- How does oxygen trapped in the closed repository react with the rock minerals in the tunnel and deposition holes and in the water conducting fractures?
- What is the capacity of the rock matrix to consume oxygen?
- How long time will it take for the oxygen to be consumed and how far into the rock matrix and water conducting fractures will the oxygen penetrate?

The emphasis of the project was on a field experiment involving motionless groundwater in contact with a fracture surface. To this aim a ≈20 cm borehole was drilled in the Äspö tunnel at 2861 m. Field data (hydrochemical and bacteriological) were used to establish the boundary conditions for the experiments.

The field study was supported by laboratory experiments to determine O_2 reaction rates and mechanisms, both for inorganic and microbially mediated processes. These laboratory investigations were performed with minerals, microbes and groundwaters from Äspö. A replica experiment was performed in France with the other half of the fracture surface obtained in the drilling procedure.

New results

Both replica experiment at CEA Cadarache, and the *in-situ* experiment at Äspö have been completed. A series of O_2 injection pulses have been performed. The results show that concentrations of O_2 in the range 1 to 8 mg L^{-1} are consumed in the experiments within a few days, both for the field and replica experiments.

The data collected is being interpreted in order to obtain a mechanistic model for the O_2 consumption rates. The drillcores used in the replica and field experiments have been examined for mineralogical changes and biofilm formation. Final project reports are being written.

3.3 Radionuclide retention

Background

The retention of radionuclides in the rock is the most effective protection mechanism if the engineering barriers have failed and the radionuclides have been released from the waste form. The retention is mainly caused by the chemical character of the radionuclides themselves, the chemical composition of the groundwater, and to some extent also by the conditions of the water conducting fractures and the groundwater flow.

Laboratory studies on solubility and migration of the long lived nuclides of e.g. Tc, Np, and Pu indicate that these elements are so strongly sorbed on the fracture surfaces and into the rock matrix that they will not be transported to the biosphere until they have decayed. In many of these retention processes the sorption could well be irreversible and thus the migration of the nuclides will stop as soon as the source term is ending.

Laboratory studies under natural conditions are extremely difficult to conduct. Even though the experiences from different scientists are uniform it is of great value to demonstrate the results of the laboratory studies in situ, where the natural contents of colloids, of organic matter, of bacteria etc. are present in the experiments. Laboratory investigations have difficulties to simulate these conditions and are therefore dubious as validation exercises. A borehole laboratory, CHEMLAB, has been developed, in which the experiments can be controlled similar to ordinary lab experiments, but with the advantage of keeping the in situ conditions of the groundwater. Figure 3-3 shows the different sections of the CHEMLAB 1 probe.

Objectives

The objectives of the Radionuclide Retention (CHEMLAB) experiments are:

- To validate the radionuclide retention data which have been measured in laboratories by data from in situ experiments in the rock
- To demonstrate that the laboratory data are reliable and correct also at the conditions prevailing in the rock
- To decrease the uncertainty in the retention properties of the relevant radionuclides

Figure 3-3 *Photograph of the CHEMLAB probe sections. The entire length of the probe is 14 metres. The different sections are coated with steel tubes which are tightly connected to each other.*

Experimental concept

CHEMLAB is a borehole laboratory built in a probe, in which migration experiments will be carried out under ambient conditions regarding pressure and temperature and with the use of the formation groundwater from the surrounding rock.

The full suite of planned experiments are:

- Diffusion of radionuclides in bentonite clay
- Migration of redox sensitive radionuclides and actinides
- Radionuclide solubility
- Desorption of radionuclides from the rock
- Migration from buffer to rock
- Radiolysis
- Batch sorption experiments
- Spent fuel leaching

New Results

- Accepted delivery of the CHEMLB 2 probe system.
- Preparations for the radiolysis experiments have been completed

Planned work

- Start the radiolyses experiments
- Prepare a license application for the actinide experiments
- Prepare the Quality Plan for the actinide experiment

3.4 Fracture Classification and Characterisation (FCC)

Background

Groundwater flow and nuclide transport is taking place in water conducting paths that are transmissive due to their genesis. Therefore eventually parameter values used in the numerical transport calculations should reflect the type of water conducting feature.

Fracture characterisation and classification aim at suggesting suitable types of fractures for tracer tests and at giving parameter values for modelling of relevant flow paths for nuclide migration.

Objectives

The objectives of the study are:

– to develop a methodology for characterisation of fractures with respect to rock type, tectonic evolution, infillings and wallrock alteration,

and by means of this characterisation be able:

– to develop a methodology for classification of different features/fractures (fracture sets) in terms of their importance for radionuclide mass transfer.

Outcome of the project has continuously been fed into the TRUE tracer test programme.

New results

No work has been made during the last three month.

Planned work

Complete the final report.

3.5 Hydrochemistry modelling/Hydrochemical stability

Background

The chemical properties of groundwater affect the canister and buffer stability and the dissolution and transport of radionuclides. It is therefore important to know the possible changes and evolution of the groundwater chemistry during the life span of the repository. Important questions concern the understanding of the processes which influence and control the salinity, and the occurrence, character and stability of both saline and non-saline groundwaters.

At present this project is carried out within the framework of the Äspö agreement between SKB and Posiva. It also covers the technical parts of the participation in the EC EQUIP project and the modelling Task #5 within the framework of the Äspö Task Force for modelling of groundwater flow and transport of solutes.

Objectives

The objectives of this project are:

- To clarify the general hydrochemical stability (= groundwater chemistry of importance for canister and bentonite durability and radionuclide solubility and migration)
- To describe the possible scenarios for hydrochemical evolution at Äspö over the next 100.000 years, separated into time intervals of 0-100, 100-1000, 1000-10000 and 10.000-100.000 years.
- To develop a methodology to describe the hydrochemical evolution at candidate repository sites, e.g. Olkiluoto.

Model concepts

Geochemical interpretation of groundwater-rock interaction along flow paths makes use of the results from groundwater chemical investigations, i.e. chemical constituents, isotopes and master variables pH and Eh in combination with the existing mineralogy, petrology and thermodynamic data. Useful tools for these calculations are reaction path codes like NETPATH and equilibrium-mass balance codes like EQ 3/6. These codes are frequently used in hydrochemical studies. A newly developed code M3 assumes a complete and complex mixing of the water in the investigated system. The principal assumptions behind this concept is that the varying hydraulic conditions of the past have caused the complex mixing pattern presently observed at Äspö. Mass balance calculations are then made to explain the difference between the ideal mixing and the observations.

The modelling strategy is based on:

– Process identification for Finnish and Swedish sites.

– Geochemical mixing for Äspö and Olkiluoto.

– Site intercomparison with PCA. Comparison between the M3 and NETPATH techniques for Olkiluoto.

– Hydrologic modelling for Äspö and Olkiluoto. Inclusion of the results from Task #5.

New Results

Task #5: All modelling groups have delivered their predictions and a description of the chemical reactions to be included in their individual modelling procedures.

EQUIP: The draft of the final report has been sent to the EU project co-ordinator.

Modelling: Calculations of the flow dynamics response to variation in groundwater and sea level fluctuations and effects on the boundary between groundwater of extremely saline brine at a postulated depth of 1000 m.

KLX02: Completed groundwater sampling from four deep sections in the borehole, using the Posiva PAVE sampling unit.

Planned work

- Presentation of the final modelling results of TASK#5 at the 13th Task Force Meeting in February
- Report the results of KLX02 sampling and analyses.
- Draft the report for the Hydrochemical Stability project.

3.6 Matrix Fluid Chemistry

Background

Groundwater sampled from the Äspö site has been collected from water-conducting fracture zones with hydraulic conductivities greater than K= 10^{-9} ms^{-1}. The chemistry of these groundwaters probably results from mixing along fairly rapid conductive flow paths, being mainly determined by the hydraulic gradient, rather than by chemical water/rock interaction. In contrast, little is known about groundwater compositions from low conductive parts (K< 10^{-10} ms^{-1}) of the bedrock (i.e. matrix fluids), which are determined mainly by the mineralogical composition of the rock and the result of water/rock reactions. As rock of low hydraulic activity constitutes the major volume of the bedrock mass in any granite body, matrix fluids are suspected to contribute significantly to the salinity of deep formation groundwaters. It is considered expedient therefore to sample and quantify such fluids and to understand their chemistry and origin.

Knowledge of matrix fluids and groundwaters from rocks of low hydraulic conductivity will complement the hydrogeochemical studies already conducted at Äspö. It can also provide a more realistic chemical input to near-field performance and safety assessment calculations, since deposition of spent fuel will be restricted to rock volumes of similar hydraulic character.

Objectives

The main objectives of the task are:

- to determine the origin and age of the matrix fluids,
- to establish whether present or past diffusion processes have influenced the composition of the matrix fluids, either by dilution or increased concentration,
- to derive a range of groundwater compositions as suitable input for near-field model calculations, and
- to establish the influence of fissures and small-scale fractures on fluid chemistry in the bedrock.

Experimental concept

The experiment has been designed to sample matrix fluids from predetermined, isolated borehole sections. The borehole was selected on the basis of: a) rock type, b) mineral and geochemical homogeneity, c) major rock foliation, d) depth in the tunnel, e) presence and absence of fractures, and f) existing groundwater data from other completed and on-going experiments at Äspö. Special equipment has been designed to sample the matrix fluids ensuring: a) an anaerobic environment, b) minimal contamination from the installation, c) minimal dead space in the sample section, d) the possibility to control the hydraulic head differential between the sampling section and the surrounding bedrock, e) in-line monitoring of electrical conductivity and drilling water content, f) the collection of fluids (and gases) under pressure, and g) convenient sample holder to facilitate rapid transport to the laboratory for analysis.

Migration of matrix fluids will be facilitated by small-scale fractures and fissures. Therefore the matrix fluid chemistry will be related to the chemistry of groundwaters present in hydraulically-conducting minor fractures ($K = 10^{-10}$-$10^{-9} ms^{-1}$), since it will be these groundwaters that may initially saturate the bentonite buffer material.

New Results

Tasks carried out over the last quarter have involved: a) mineralogical studies, b) crush/leaching experiments, c) Äspö diorite permeability test, d) opening of two sections in the matrix borehole for matrix fluid sampling, and e) distribution of the minutes from the Workshop held in September 6/7, 1999.

Mineralogy

General mineralogical characterisation of the drillcore from borehole Section 4 (4.66-5.26 m), earmarked for sampling matrix fluid, has continued at the University of Bern to supplement the data presented at the last Workshop.

Crush/leaching experiments

The third and final crush/leach from the same drillcore material was completed by the University of Waterloo. To guard against any potential contamination from the sealing wax, erroneously applied directly to the drillcore surface following drilling, analyses were carried out on the beeswax product used. The analytical data are now complete from the 3 crush/leaches (i.e. different size fractions) carried out by Waterloo and the single leach carried out by the University of Bern on the same drillcore material. There was good agreement between the first crush/leach of Waterloo and the Bern sample; both samples represented approximately similar size fractions.The composition of the matrix fluids calculated from these experiments are forthcoming.

Permeability test

Since August 1999 a high pressure experimental set-up has been operating at the University of Waterloo. This experiment is essentially trying to force double distilled (Ultrapure) water through a drillcore portion (100x50 mm) in order to extract unbound, intragranular matrix fluid. The drillcore portion, selected adjacent to Section 4, has been mounted in a moisture proof membrane with an applied hydrostatic stress of 11.7 MPa (i.e. equivalent to the lithostatic stress at the Matrix Borehole location in Tunnel 'F') and a pore pressure of 6 MPa has been applied to the distilled water. Up until October 1999 no movement was observed and the pore pressure was accordingly increased to 9.5 MPa. Some activity was observed in November, but this has subsequently slowed down. Monitoring is continuing.

Sampling of matrix fluid

Attempts were made in December 1999 to determine the presence of any accumulated matrix fluid after a time period of 18 months. Section 1 (10.55-11.80 m), initially intended only for pressure monitoring, was opened. No fluid emerged, only a release of gas with a distinct smell of H_2S. This was not altogether surprising since this borehole section is rather long (total volume of 5461 mL) and initially some 65 mL of fluid would need to accumulate (because of the geometry of the borehole) prior to discharging from the borehole section outlet tube which is centrally located in the packer face.

This was followed by opening Section 4 (4.66-5.26 m), initially demarcated for sampling, which had shown a steady build-up and a levelling-off of pressure over the 18 month period. Some 160 mL of water were collected under an inert N_2 atmosphere. This was out of a total borehole section volume of 210 mL, of which 35 mL was considered inaccessible because of the geometry of the borehole. The analytical protocol was prioritised according to the amount of sample available. The sample is presently being analysed, but preliminary data suggest a nearby fracture origin for the water, via diffusion into the sampling section, rather than matrix derived. Microbial activity is also indicated, probably due to some residual contamination in the sampled section following borehole activities.

Distribution of minutes from the September Workshop

Detailed minutes from the Workshop held in September 6/7, 1999 have been distributed.

Planned work

- Fluid inclusion studies start in January at four different laboratories
- Chemical analyses of the matrix fluid will be reported in February
- A status report of the project will be produced by March 2000.

3.7 The Task Force on modelling of groundwater flow and transport of solutes

Background

The Task Force shall be a forum for the organisations supporting the Äspö Hard Rock Laboratory Project to interact in the area of conceptual and numerical modelling of groundwater flow and solute transport in fractured rock. In particular, the Task Force shall propose, review, evaluate and contribute to such work in the project. The work within the Task Force is being performed on well defined and focused Modelling Tasks. The table show on-going tasks

Task No	Modelling Issues	Cooperating organisations
4E	Modelling of tracer test with sorbing tracers in one fracture.	ANDRA, BMWi, CRIEPI, DOE, JNC, NAGRA, POSIVA, SKB
4F	As Task 4E but with half the flowrate.	ANDRA, BMWi, CRIEPI, DOE, JNC, NAGRA, POSIVA, SKB
4G	Resolving discrepancies and issues identified from the full suite of tests 4A-4F.	Proposal for this task is on review with the Task Force Delegates.
5	Compare and integrate hydrology and chemistry through modelling of Äspö tunnel drainage impact on hydraulic and chemical parameters.	ANDRA, BMWi, CRIEPI, ENRESA, JNC, POSIVA, SKB

New results

Task No 4E

A draft final report integrating both task 4E and 4F has been submitted for publication by some modelling groups. Modelling of Task 4F has been ongoing with the modelling groups. The report on the deconvolution of the breakthrough curves for Task 4E (STT1 and STT-1b) has been on review and the final draft has been submitted for printing.

Task No 4F

Modelling has been ongoing for this task within most of the modelling teams.

Task 4G

A proposal for a new sub-task, 4G, has been compiled by the Task Force secretariat which is on review with the Task Force Delegates. Design a new tracer injection equipment and perform a tracer test with conservative tracer in Feature A in the TRUE-1 block.

Task No 5

A workgroup meeting was arranged 28-29 October 1999 where the status and intermediate modelling results were presented by the modelling teams. A reaction modelling plan specifying which hydrogeochemical reactions to include in their modelling was submitted by some teams to the Secretariat. Data were delivered in three batches, #15-17, containing respectively #15:control point coordinates, #16:inclination and declination and #17:comments on tritium values. Potential reviewers were identified and contacted.

Published reports

The following reports were published,

- ICR-99-02: Solute transport modelling of the Äspö STT-1b tracer tests with multiple rates of mass transfer. Sean McKenna, Sandia National Laboratories, SKB International Cooperation Report 99-02, Stockholm, Sweden.

Planned work

For the next quarter we plan to perform are the following tasks:

- Organize the 13th International Task Force meeting, hosted by Sandia National Laboratories
- Organize a Workshop for Task Force Modellers in connection with TF#13
- Organize a Workshop for Task Force Delegates in connection with TF#13
- Publish the results of the deconvolution studies on breakthrough curves of Task 4E.
- Publish the proceeding from the 12th Task Force meeting

- Modelling groups should produce a draft final report for Task 4E&F
- Modelling groups should produce draft modelling report for Task 5
- Deliver the hydrological and hydrochemical data to Task 5 modellers.
- Propose a new modelling Task, Task 6

4 Demonstration of technology for and function of important parts of the repository system

General

Stage goal 4 of the Äspö HRL is to demonstrate technology for and function of important parts of the repository system. This implies translation of current scientific knowledge and state-of-the-art technology, into engineering practice applicable in a real repository.

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

With respect to *technology demonstration* important overall objectives of this program are:

- To furnish methods, equipment and procedures required for excavation of tunnels and deposition holes, near-field characterisation, canister handling and deposition, backfilling, sealing, plugging, monitoring and also canister retrieval.
- To 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*, objectives are:

- To test and demonstrate the function of components of the repository system.
- To test and demonstrate the function of the integrated repository system.

4.1 Prototype Repository

Background

Particular aspects of the repository concept have previously been tested in a number of in-situ and laboratory tests. There is a need to test and demonstrate the integrated function of the repository in full scale and with state-of-the art technology. It is envisaged that this technology can be tested, developed and demonstrated in the Prototype Repository. The design, construction and testing of the prototype repository is aimed at a simulated deposition sequence starting from detailed characterisation of the host rock to resaturation of the backfilled deposition holes and tunnel. The Prototype

Repository experiment is located in the inner part of the TBM tunnel at 450 m level and will include 6 deposition holes in full scale.

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.
- To develop and test appropriate engineering standards, quality criteria and quality systems.

The Prototype Repository will be a long-term test divided into two sections, separated by a concrete plug. One section is planned to be decommissioned after about 5 years and the second section after more than 10 years.

New results

The third Project Meeting during 1999 was held at Äspö during November 18-19. This time all participants in the EC application attended the meeting, i e also ENRESA/CIMNE/AITEMIN of Spain, GRS/BGR of Germany, Univ of Wales of UK, and JNC of Japan besides POSIVA of Finland and SKB who constituted the core group earlier. Each participant's proposal was presented showing mostly contributions in the form of know-how as well as modelling and its supporting laboratory tests but also instrumentation for resistivity measurements of water content in buffer/backfill and rock (GRS) and displacement of canisters (ENRESA/AITEMIN). The additional activities and the adjustments of earlier activities will be incorporated in an up-dated Test Plan, if the EC application is successful; Brussels has indicated information on this matter in January 2000.

The Project Group, consisting of basically Task Leaders, met regularly during the period (approx. once each six weeks) with increased intensity in the decision on techniques and methods as the time for different main purchases approached. A Managing Group, consisting of the Project Manager, the Assistant Project Managers for Science and Methods and Techniques respectively, and the Project Co-ordinator, was organised also with respect to the approaching start of installation (August 2000) and had its first meeting. The intention is to follow-up the progress of the project and to meet regularly, approx. twice per month.

Physical activities in the Prototype Repository tunnel has been limited to mapping of the bored deposition holes and measurement of in-flowing water both into the tunnel and into each deposition hole with specific attention to the spots were the water enters.

The instrument plan for the buffer and backfill has been finalised and reported in Swedish. An English version is scheduled early next year.

A preliminary modelling of the buffer saturation process has been conducted including a sensitivity analysis of the importance of different parameters, i e different hydraulic properties of the rock. And, as expected, the retention curve, i e hydraulic conductivity as function of degree of saturation, is far more important than the piezometric head. By modelling, geological characterisation, and laboratory and in-situ tests it is now possible to create a data base on most important parameters for later use in evaluations when the actual saturation rate of the buffer is measured.

Planning of lead-throughs and how these can be made watertight as well as gastight has been going on. The number of cables is large and in case of lead-throughs with a diameter of 250 mm 3 to 4 are needed per deposition hole. The design for achieving tightness is focused on the same principle as was applied in the Backfill and Plug Test, i e cables in steel pipes which are furnished at the tunnel end with a connecting plate with pins for each cable.

The analysis of data from measurements of cutter forces during boring of the second deposition holes in the Canister Retrieval Test tunnel has continued at Luleå Technical University with:

- Obtaining the final equations for calibration of cutter force measurements,
- Calculating the actual cutter forces according to the measured strain data in-situ,
- Performing spectral analysis of the actual cutter forces,
- Obtaining the measuring results of temperature in the cutter,
- Collecting the material for writing the general report and the report concerning the field experiment.

The equations for normal force F_N, side force F_L and tangential force F_T for the two instrumented cutters (one front and one gauge cutter) have been obtained by calibration work in the laboratory as well as by numerical calculations taken into consideration the strong inter-coupling phenomena between the three forces. The equations are expressed as a function of measured voltages in each of the three strain-gauge groups on the shaft in the cutters.

Figure 4-1 shows one example of the measured normal forces on the gauge cutter, while boring in casing 10 within the first 7 minutes, calculated from the measured voltages based on the obtained equation.

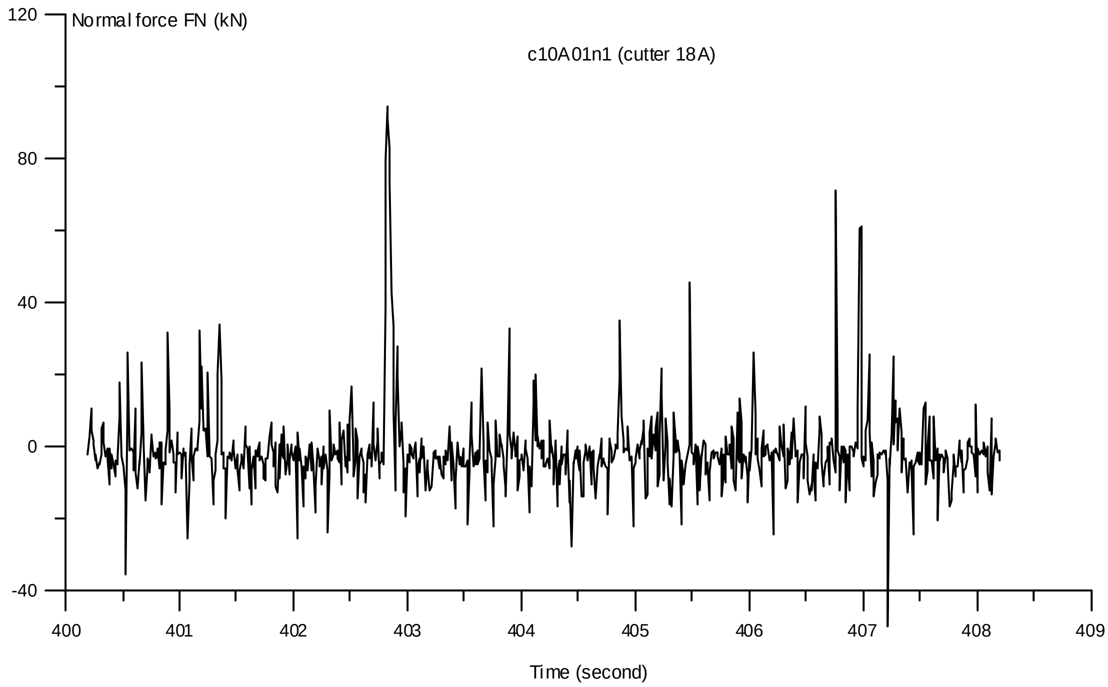


Figure 4-1 *Measured normal force of the gauge cutter*

The results indicate that the maximum, minimum and mean normal forces of the gauge cutter during the 7-minute excavation are 104, -69 and –1.2 kN, respectively. During the same time period the maximum, minimum and mean normal forces of the front cutter were 684, -43 and 120 kN, respectively. It is clear that the maximum normal force of the front cutter is much larger than that of the gauge cutter. The magnitudes of the tangential force and side force are, however, similar for both front cutter and gauge cutter.

Spectral analysis by means of fast Fourier transforms is carried out in order to find the basic characteristics of the force signals. The analysis provides information concerning the frequency range of the acting forces, the maximum probability of the forces, etc, and is useful in the evaluation of the working efficiency of the cutters and their wearing and damage probability.

A curve for the mean temperature variation in cutter shafts is shown in Figure 4-2. It is based on the voltage data measured and the transformation equation obtained by calibration work in the laboratory. It indicates a temperature level that is higher than was estimated by the cutter manufacturer, and also a higher temperature increase by time than assumed.

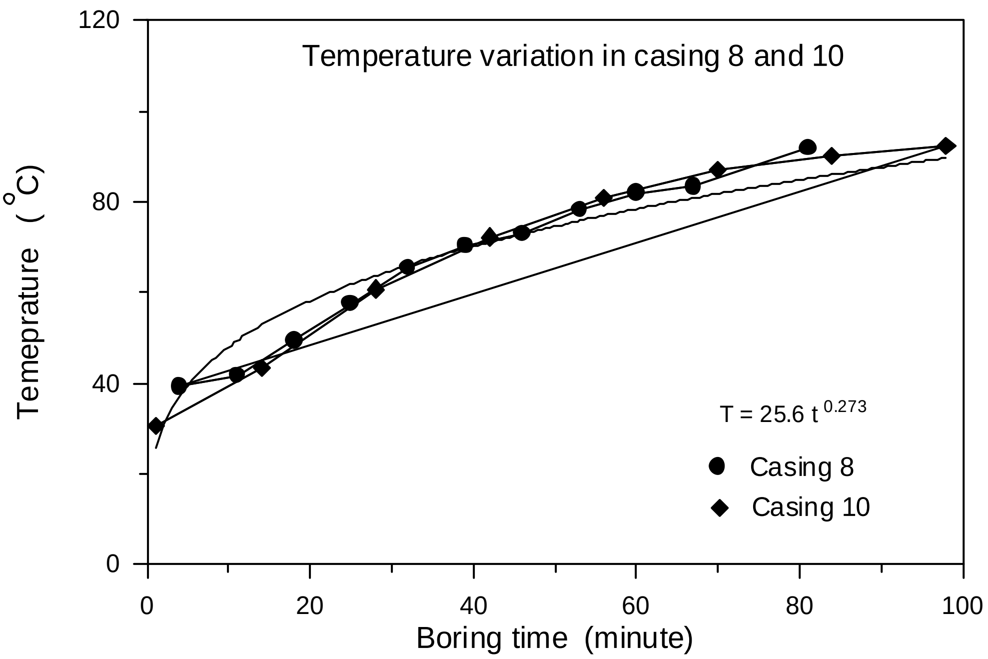


Figure 4-2 *Temperature variation in casing 8 and 10. In casing 8 and 10 the thrust is 182 to 212 ton and 160 ton, respectively, but the rotation speed of the cutter head in both casings is the same (10 rpm).*

The reporting is under way and parts have been finished during the period. The target is to finalise reporting during the first quarter of year 2000.

The supporting project “Test of Deposition Process” has not continued as planned due to malfunction of the small deposition machine and late delivery of the crane. Technique for casting the bottom pad has been developed and the pad in the test hole (in the TBM assembly hall) has been made. The testing of block handling and deposition of canisters has been postponed until the first quarter of year 2000.

The overall time plan of the project has been discussed with respect to the squeezing margins as the Test of Deposition Process is becoming delayed and the thereafter followed installation of the two holes in the Canister Retrieval Test tunnel is consequently also delayed, and no extra margins in the time plans exist anymore. In order to have time to evaluate the practical results in the Canister Retrieval Test installation and make any adjustments prior to start of installation in the Prototype Repository a three to six month period between the installations was earlier judged needed and thus planned for. In the present situation the same view on timing would result in a postponement of the start of installation of the bentonite blocks in the Prototype Repository by three months, and a consequent decision on shifting the start from August 2000 to January 2001 has been taken by SKB. This timing also corresponds better to the now assumed time of a possible contract with the Commission (June/July instead of March/April).

Planned work

The change in time plan will basically affect the purchase activities, while the ongoing planning continues as before. Excavation of slots for the plugs and drilling of lead-through holes are also planned to be made during the first half of year 2000 in accordance with earlier plans. Prior to this the following work is done:

- Decision on size and number of lead-throughs, as well as techniques for obtaining necessary tightness. The basis is instrument plans covering all instruments in canisters, buffer, backfill, plugs and rock as well as electrical cables to heaters. The technique for obtaining tight connections will also have to be chosen before the diameter of the lead-through holes is set.

- Decision on plug design, which is based on the design of the plug in the Backfill and Plug Test but adopted to the TBM excavated tunnel in the Prototype Repository.

In addition the detailed mapping of water inflow to the deposition holes continues and can now be extended in time so that less time-forced methods can be applied.

Sampling and analysing of ground water in the Prototype Repository tunnel with respect to redox conditions has been postponed because of difficulties in developing and manufacturing the new sampler. The plan now, however, is to take the samples in February.

The study of the force the cutters apply on to the rock wall in the deposition holes continues according to the earlier plan with crack examination of the rock-core samples collected from the studied deposition hole, and compilation of the two reports.

Reporting also continues regarding:

- Result from characterisation of bored deposition holes

- Instrumentation plan in the buffer and backfill

- Instrumentation plan for packers and sensors for measuring groundwater pressure

- Instrumentation plan for temperature measurements in the rock
- Instrumentation plan for temperature and stress measurements in plugs
- Predictive temperature modelling
- Result of DFN modelling in Phase II
- Result of AE measurements
- Result of rock stress changes during boring of deposition holes

The Test of Deposition Process is carried through in the deposition hole in the TBM assembly hall.

In case a positive answer is received from the Commission the work with the agreement between the participants in the project and the contract with the Commission will start.

4.2 Backfill and Plug Test

Background

The *Backfill and Plug Test* includes tests of backfill materials and emplacement methods and a test of a full-scale plug. It is a test of the integrated function of the backfill material and the near field rock in a deposition tunnel excavated by blasting. It is also a test of the hydraulic and mechanical functions of a plug. The test is partly a preparation for the Prototype Repository.

In 1998 the preparations and all the required work in the rock in the vicinity of the test tunnel were finished e.g. excavation of the slot for the plug, casting of the first part of the plug, drilling of holes for the through connections, installation of the through connection tubes, installation of all packers for measurement of water pressure in the rock, and installation of the bore hole plugs. The entire test setup with backfilling, instrumentation and building of the plug was finished in the end of September 1999.

New results

Fig 4-3 shows an illustration of the experimental setup. The following main work has been carried out during the fourth quarter of 1999:

- The filling of the concrete at the crown of the slot has been checked by drilling a hole and studying the rock/concrete contact with borehole television. A small slot of about 1 cm can bee seen but is considered to be acceptable.
- The arrangement for filling and pressurising the permeable mats has been installed. It consists of three 1.5 m^3 water tanks, three 150-500 litre hydrofors, two gas tubes with nitrogen gas, two pressure regulators, and two flow meters.
- Every second mat in the sections with bentonite/crushed rock has been filled with water with the salt content 1.6% and pressurised with 100-150 kPa. The mat

sections consist of three mats; one large in the centre and two smaller at the floor and at the roof. The mats at the roof were left unfilled in order to minimise the risk of having piping between the backfill and the roof.

- The reading of the instruments is full progress. It seems as we are receiving acceptable data from all instrument locations with the possible exception of about 7 measuring points located in boreholes in the rock. These borehole sections could not be properly filled with water, probably due to damages on the tubes, which means that it is presently uncertain whether correct water pressure is registered from these points. A few psychrometers are also out of order at present,but may be revived.

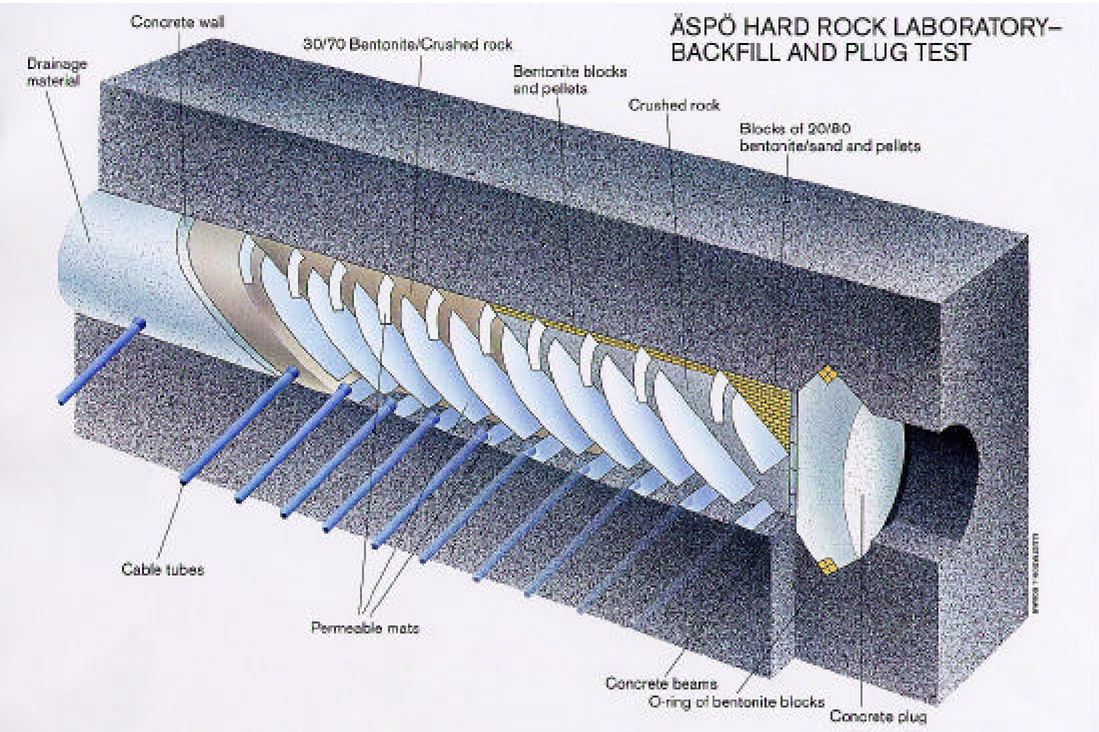


Figure 4-3 *Illustration of the experimental setup of the Backfill and Plug Test.*

Planned work

In the first quarter of 2000 the following main work is planned:

- Registration and following up of the water inflow into the backfill from the permeable mats.
- Continuing registration and following up of the water pressure in the rock and the saturation process and swelling pressure in the backfill.
- Supplementary modelling and laboratory tests.
- Reporting of the experimental setup.

4.3 Demonstration of repository technology

Background

The development and testing of methodology and equipment for encapsulation and deposition of spent nuclear fuel in the deep repository is an important part of SKB's programme. In addition to the technical aspects, it is also important to be able to show in a perceptible way the different steps in encapsulation, transport, deposition, and retrieval of spent nuclear fuel for specialists and the public. As part of the overall programme an Encapsulation Laboratory is under construction in Oskarshamn and it will be put in operation late 1998. Demonstration of deposition and retrieval of canisters will be made in the Äspö Hard Rock Laboratory. The demonstration project complements the Prototype Repository and the Backfill and Plug Test which focus on the integrated function of the engineered barriers in a realistic environment.

Demonstration of Repository Technology is organised as a project under the Facilities Department. Development of equipment for handling and deposition of canisters will be the responsibility of the Deep Repository Department while the Äspö HRL will be responsible for the field activities. The description below focuses on the work that will be performed at the Äspö HRL.

The objectives of the demonstration of repository technology are:

- to develop and test methodology and equipment for encapsulation and deposition of spent nuclear fuel,
- to show in a perceptible way for specialists and the public the different steps in transport, deposition, and retrieval of spent nuclear fuel, and
- to develop and test appropriate criteria and quality systems for the deposition process.

The demonstration of deposition technology will be made in a new tunnel south of the ZEDEX drift excavated by drill and blast. This location is expected to provide good rock conditions, a realistic environment for a future repository, and allows transport of heavy vehicles to the test area.

New results

Two of the four large deposition holes have been mapped and two remains to be done.

Planned work

The remaining mapping is done with the new overhead crane, if any slot is available in the time schedule for finalising all installations and trimming the deposition machine.

Installations are finalised and the inauguration is scheduled to take place on March 9.

4.4 Canister Retrieval Test

Background

SKB's strategy for the disposal of canisters with the spent nuclear fuel is based on an initial emplacement of about 10% of the number of canisters followed by an evaluation of the result before any decision is made on how to proceed. One outcome can be that the result is not accepted and that the canisters have to be recovered. In such case some, if not all, canisters can be surrounded by a saturated and swollen buffer, which holds the canister in such a grip that the canister can not just be pulled up. First the bentonite grip has to be released, for which two alternative principles can be applied; remove or shrink the bentonite. Then the canister is free to be lifted up to the tunnel and placed in a radiation shield. A concern is any type of radioctive contamination that the bentonite has been exposed to.

The retrieval test is aiming at demonstrating the readiness for recovering of emplaced canisters also after the time when the bentonite has swollen. The process covers the retrieval up to the point when the canister is safely emplaced in a radiation shield and ready for transport to the ground surface. The test is separated into two phases; Design and Set-up, and the actual Retrieval Test.

New results

The Test Plan has been completed and the budget for the first Phase concerning installation and monitoring up-dated (increased in comparison with the preliminary one from early 1997) and approved by SKB.

The project has many Task Leaders and others in the organisation, who are also engaged in the Prototype Repository. The discussions of scientific and technical solutions therefore take place in Project Group Meetings in common for both projects. These meetings have been held regularly during 1999 with a frequency of one per approx. six weeks. Since November a project Managing Group has been organised with frequent meetings, each second week, consisting of the Project Manager, the two Assistant Project Managers (for Science and for Methods and Techniques) and the Project Co-ordinator. All theses meetings are documented in minutes.

The adjustment of the bentonite block fabrication press at Ystad has been finalised and the quality of the blocks the press produces has been controlled, and the pallets for transporting and storing the blocks have as well been fabricated. The first batch of cylindrical blocks for the two holes have been made, and these blocks are stored in the Canister Laboratory in Oskarshamn.

The plan on instrumentation of the buffer has been completed and the purchase process for these instruments has been initiated.

Testing of the canister heat transport performance at Kockums has been completed, and it is clear that the temperature inside the canister will be "low" and far from the unfavourable scenario of 400^{o}C. The choice of heater quality will be based on this finding (less sophisticated design). The design of the canisters will be focused on one being furnished with thermocouples and strain gauges inside. The lead-throughs in the lid are weak points and extra precaution is taken in the design to prevent forces to act directly on these.

The results from the acoustic emission measurement and changes in rock stresses around the holes have been evaluated and presented in draft reports. One article on the rock stress monitoring has been compiled for presentation at the EUROCK 2000 in Aachen, Germany. In this paper the interpretation of the stress data reviles an increase of the maximum stress after boring in a direction that is parallel to the direction of the global principal stress in five out of eight investigation holes (drilled at a distance of approx. 300 mm from the hole wall). In the other three the direction is perpendicular to the direction of the global principal stress, thus indicating the complex nature of rock stresses and complex impact of tunnel, bored hole and maybe cutters on the boring head. Another finding is that the velocity of ultrasonic waves changes in the rock at approx. 20-30 mm from the hole walls, indicating a drop in the rock elastic modulus. The evaluation continues.

The work on the design of the plugs on top of the holes has concentrated on a combined concrete/steel plug placed in the hole below the floor level. This plug will be anchored to the rock by means of up to a dozen cable bolts, which can resist a swelling pressure from the bentonite of up to 10 MPa (design pressure is 5 MPa).

The proposed artificial watering system with permeable mats on the rock wall has been studied with the result that about 1/3 of the rock surface should be covered in order to provide for a homogeneous saturation of the buffer. Possible fabricates of mats are being tested in the laboratory.

Planned work

Start of installation of bentonite blocks is now planned to be in April. The start is linked to the completion of the testing of the deposition process and the equipment to be used. This project needs the crane for handling the bentonite blocks and the "small" deposition machine; the first mentioned is ready and will be in place in early January, and the second requires repairs and adjustments in accordance to findings during the first tests under ground.

The two holes have not yet been mapped because of the late delivery of the above mentioned overhead crane and a non-magnetic cages. However, as the equipment is available the mapping can take place in early January. The geological characterisation report can thereafter be finalised. Additional geological information may be obtained from cores, if the holes for thermocouples in the rock are drilled radially out from the bore holes.

After mapping and possible drilling of instrumentation holes radially outward, a horizontal bottom pad is cast in the holes, grooves are made for cables in the walls and the permeable mats are attached to the rock wall, all activities made as part of the preparation prior to start of block installation. Another preparatory activity is to seal-off the tunnel by a plastic wall so that the air in the holes may be conditioned to contain a relative humidity of only 75-80% compared to natural 85-90%, the reason being to prevent the bentonite from sorbing water and consequent swelling.

The design of the plugs will be completed in January as well as the fabrication of the remaining bentonite blocks. The design of the two canisters including lid and lead-throughs will also be completed and necessary machining work done. Heaters in a spent fuel configuration are manufactured and installed in the canisters. The lid is only bolted on to the copper cylinder.

A number of quality plans have been identified and the completion of these as well as follow-up and evaluation of lessons learned with respect to quality assurance are part of the project objectives as well as part of the preparation for the Prototype Repository installation. These plans will be in focus during the next six months.

Instruments, materials and services are going to be purchased and a major part is going to be administrated during the first quarter of year 2000.

4.5 Long term test of buffer material (LOT)

Background

Bentonite clay has been proposed as buffer material in several concepts for HLW repositories. In the Swedish KBS3 concept the demands on the bentonite buffer are to serve as a mechanical support for the canister, reduce the effects on the canister of a possible rock displacement, and minimise water flow over the deposition holes.

The decaying power from the spent fuel in the HLW canisters will give rise to a thermal gradient over the bentonite buffer by which original water will be redistributed parallel to an uptake of water from the surrounding rock. A number of laboratory test series, made by different research groups, have resulted in various buffer alteration models. According to these models no significant alteration of the buffer is expected to take place at the prevailing physico-chemical conditions in a KBS3 repository neither during nor after water saturation. The models may to a certain degree be validated in long term field tests. Former large scale field tests in Sweden, Canada, Switzerland and Japan have in some respects deviated from possible KBS3 repository conditions and the testing periods have generally been dominated by initial processes, i.e. water uptake and temperature increase.

The present test series aims at validating models and hypotheses concerning physical properties in a bentonite buffer material and of related processes regarding microbiology, radionuclide transport, copper corrosion and gas transport under conditions similar to those in a KBS3 repository. The expression ”long term” refers to a time span long enough to study the buffer performance at full water saturation, but obviously not ”long term” compared to the lifetime of a repository. The objectives may be summarised in the following items:

- Data for validation of models concerning buffer performance under quasi-steady state conditions after water saturation, e.g. swelling pressure, cation transport and gas penetration.
- Check of existing models concerning buffer-degrading processes, e.g. illitisation and salt enrichment.
- Information concerning survival, activity and migration of bacteria in the buffer.
- Check of calculation data concerning copper corrosion, and information regarding type of corrosion.
- Data concerning gas penetration pressure and gas transport capacity.

- Information which may facilitate the realisation of the full scale test series with respect to clay preparation, instrumentation, data handling and evaluation.

The testing philosophy for all tests in the series (Table 4-1) is to place prefabricated units of clay blocks surrounding heated copper tubes in vertical boreholes. The test series are performed under realistic repository conditions except for the scale and the controlled adverse conditions in three tests.

The test series have been extended, compared to the original test plan, by the A0 parcel in order to replace the part which was lost during the uptake of the previous A1 parcel.

Table 4-1 Layout of the ongoing Long Term Test series

Type	No.	T °C	Controlled parameter	Time years
A	0	120<150	T, $[K^+]$, pH, am	1
A	2	120<150	T, $[K^+]$, pH, am	5
A	3	120<150	T	5
S	2	90	T	5
S	3	90	T	>>5

A = adverse conditions
T = temperature
pH = high pH from cement
S = standard conditions
$[K^+]$ = potassium concentration
am = accessory minerals added

Adverse conditions in this context refer to high temperatures, high temperature gradients over the buffer, and additional accessory minerals leading to i.a. high pH and high potassium concentration in clay pore water. The central copper tubes are equipped with heaters in order to simulate the effect of the decay power from spent nuclear fuel. The heater effect are regulated or kept constant at values calculated to give a maximum clay temperature of 90°C in the standard tests and in the range of 120 to 150°C in the adverse condition tests. Test ”parcels” containing heater, central tube, clay buffer, instruments, and parameter controlling equipment are 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 will be extracted by overlapping core-drilling outside the original borehole. The water distribution in the clay will be determined and subsequent well-defined chemical, mineralogical and physical testing will be performed.

New Results

The assemblage and placement of the four long-term test parcels and the extra one-year parcel are completed. The S3-parcel was assembled and submerged during week 35, the S2-parcel week 38, the A3-parcel during week 41, A2-parcel during week 43 and finally the A0-parcel during week 50. All parcels were equipped with instruments, bacteria, copper coupons and with radioactive tracers according to plans. The instruments are found to work properly with the exception of two optical sensors. The fibres have been damaged in the tunnel part and are thereby possible to repair.

Laboratory characterisation of the bentonite test material has been made. Pressure and water-flow from the water supply hole have been determined. The water pressure is around 1.5 MPa and the maximum flow is far more than what is needed for the saturation of the parcels. A mechanical packer is placed in the borehole and the ground-water is connected to the test parcels via tubes and titanium filter. The one year test parcel (A0) will be saturated by filter inlets in three directions at three levels. The long term parcels will be connected to the ground water by filters in the upper part of the bentonite, in order to simulate water coming from a back-filled tunnel.

Planned work

The official test start, i.e. full ground-water pressure and beginning of heating, will take place in the end of January, 2000. The monitored water pressure, total pressure, temperature and moisture in the parcels will continuously be analysed during the test period. Supplementary laboratory work will be made concerning gas penetration pressure and characterisation of the original bentonite material. Chemical analyses of ground-water and if possible of water from the “passive” filters in the bentonite will be made regularly during the test period.

5 Äspö facility operation

5.1 Facility operation

The ”five year inspection” of the underground facility has been completed. The inspection identified a few areas were intense reinforcement is necessary. Systematic bolting and mesh/spray concrete will be used.

The electrical supply to the facility comes today from two different sources. The underground part is supplied direct from the nuclear power station, while the Äspö village gets its electricity from an airborne net on the mainland. The latter is a relatively weak net and especially during the autumn and winter, there are several cuts in the delivery. A new cable from the nuclear station to Äspö is now in progress and will be in operation within a few months.

The net surrounding the hoist shaft on the different landings has been changed to material in stainless steel to avoid corrosion.

A project for hands free registration when going down or up from the tunnel system has started. According to the plan, it will be in operation before next summer.

The project for automatic supervision of the facility is more or less completed. Final inspection remains as well as a test period.

Service contracts has been signed for the different alarm systems.

5.2 Data management and data systems

Background

The regulatory authorities are following SKB’s siting work. Before each new stage, they *examine and review the available data.* A repository will never be allowed to be built and taken into service unless the authorities are convinced that the safety requirements are met. Hence, SKB is conducting *general studies* of the entire country and *feasibility studies* in 5-10 municipalities. *Site investigations* will then be conducted on a couple of specific sites. With the result of the studies as supporting material, SKB will then apply for permission to carry out *detailed characterisation* of one of the sites. The licence application for detailed characterisation will include a *safety assessment* and the results will be reviewed under the Act on Nuclear Activities and the Act concerning the Management of Natural Resources by the regulatory authorities, the municipality and the Government.

Management of investigation data is a highly demanding and critical task in the presented licensing process. The safety assessment must be based on correct and relevant data sets. Hence, the data management routines need to be focused on the following aspects in a long term perspective:

- traceability,

- accessibility,
- data security and
- efficiency (system integration and user friendly applications).

A high quality baseline for the safety assessment will be established if the aspects specified above are met. The data needed in a typical safety assessment have been reported in Andersson et al /1998/.

The different parts of SKB's Data Management System will be improved in conjunction with the ongoing and planned activities in SKB' siting work. This to fulfil the requirements expected from the regulatory authorities and the internal organisation as well. The current status and the actual plans of GIS, SICADA and RVS is presented in the following subsections.

New results

GIS

A Geographical Information System (GIS) based on ArcInfo and ArcView has been and are still used successfully by SKB in the ongoing feasibility-study projects. GIS will also be an important tool in the planning and performance of the pre-investigation phase. A plan to implement GIS as a effective tool in the coming pre-investigation phase has been decided, and as a first step some pre-study data has been set up at the Äspö Hard Rock Laboratory as a basis for a pilot case. Some external GIS experts has also been contacted for some more detailed discussions on how to go further.

SICADA

A new database server, Sun Microsystem ULTRA Enterprise 450, has been installed and configured to be used as a dedicated SICADA server. On this server the latest version of the relation database system Ingres, called CA/Ingres II, has been installed as a basis for SICADA. SICADA it self was copied to the new server just in time before the new millennium was entered. It has been controlled and verified that the whole system is not affected by any problems associated with year 2000.

A new software connection between HMS (Hydro Monitoring System) and SICADA has been implemented. All measured data in HMS are now available in SICADA. This will serve RVS with measured data for visualisation of pressure transients in instrumented borehole sections during drilling of new boreholes. This should increase the understanding of the hydraulic connections between different open discontinuities in the investigated rock mass.

A specification for incorporation of the HMS instrument database into SICADA has been written and the data in this database has been moved to SICADA.

RVS

RVS version 2.1 has been delivered. This new version embodies about 30 new or improved existing functions. Some of these functions are described briefly in the following text.

The unique *Object List* has been improved. As a result it will be more easy to have an overview of all active objects in a model or set of visualisations. As an example all borehole visualisations are stored as sub-objects to the borehole it self. A new column, named *user*, has also been inserted in the Object List. This column stores the name of the person who have created a certain object in the model. Some other columns in the list has been renamed in order to be more understandable.

The new feature *Work Set* has been introduced to make it possible for the user to reduce the amount of borehole data in the local database. As an additional positive effect the number of boreholes in some lists are shortened as wanted.

In the previous version a discontinuity surface, describing a single fracture plane, was automatically extended to the borders of the modelled rock mass. This restriction has been removed. *A discontinuity is now extended by rules given by the user*. It is also possible to *remodel discontinuities*.

Earlier imported *DGN-files can now be reloaded* if they have been updated in standard MicroStation/J during the modelling process.

November 24th a RVS seminar was held in Stockholm. The status and abilities of the system was first presented as a background, and then a discussion was held around the subject: Programming of interfaces between RVS and software packages used in the complete range of numerical modelling used until now. The seminar was closed with a special task given to all participating organisations.

Planned work

GIS

The following subjects will be under consideration during the first three months of year 2000:

- Set up of a more complete set of GIS data for the Äspö research area.
- Selection and implementation of hardware and software platforms for GIS applications
- Scrutinise for applications that will utilise the power of GIS and then implement them.

SICADA

The implementation of the HMS instrument database as a part of SICADA will be realised in January 2000.

A set of new improvements in SICADA will be set up in January and then purchased according to established and well working routines between SKB and Ergodata AB. This new development stage will take place during the first half of year 2000.

The licensing routines for CA/Ingres II and other CA-products has caused severe problems during 1999, but CA(Computer Associates) has recently released a new server side supported licensing method. We are planning to implement this method in January 2000. This means that we do not need to handle complex individual licenses on individual PC clients.

The problems associated with the access to SICADA trough an encrypted IP-tunnel must be solved or an alternative technique implemented as an alternative.

RVS

A final delivery test of RVS version 2.1 will start January 10th. This test will be performed according to proven routines. All test are documented in detail. The new version of RVS is planned to be released in February 2000. Somewhat later the current version of the self-instruction packages will be adjusted to the new version. A on-line help system will also be released as soon it is adapted to RVS version 2.1.

RVS version 2.2 will be purchased in February 2000. The contents of this development step is not yet decided in detail, but it will be focused on tools to build a complete continuum model of the rock mass modelled. The plan is then to release RVS version 2.2 in June 2000.

Currently a visit to Quantisci Ltd is planned to take place in January. We are planning to show most of the features in RVS and then discuss if there exists reasons of a more extended collaboration.

An interface between FracMan/MAFIC and RVS will be programmed by Golder Grundteknik AB. The most of the programming work will be finished before the end of March 2000. FracMan/MAFIC is owned and developed by Golder Associates Inc.

5.3 Program for monitoring of groundwater head and flow

Background

The Äspö HRL operates a network for the monitoring of groundwater head, flow in the tunnel and electrical conductivity, as the core parameters. This system goes under the acronym of HMS (Hydro Monitoring System). Water levels and pressure head are collected from surface drilled and tunnel drilled boreholes. Additionally, the electrical conductivity of the water in some borehole sections and in the tunnel water is measured. The network includes boreholes on the islands of Äspö, Ävrö, Mjälen, Bockholmen and some boreholes on the mainland at Laxemar.

Data is transferred by means of radiolink, cable and manually to a dedicated computerised database. The HMS computer system runs on Pentium computers with the Windows NT operating system where a real time engine is accessing the HMS database.

This engine provides integrated data acquisition, monitoring, data logging and report generation.

New results

The HMS program has been running providing real time data acquisition in support of the various projects undertaken in the Äspö Hard Rock Laboratory.

This support consists of providing data from boreholes affected by an experiment and of utilising the HMS infrastructure for collection and monitoring of experiment specific data. The system has been utilised mainly by the Geomode, TRUE and the Prototype Respository projects.

The HMS was used to detect responses in groundwater head induced by an earthquake of magnitude 7.2 with its epicenter in Turkey. A compilation of data was compiled to this effect.

Planned work

For the next quarter it is planned to

- continued support to various projects
- produce a plan for the overall evaluation and assessment of the HMS. This will be part of the Testplan for the groundwater monitoring of the geoscientific site characterisation program.
- Initiate the overall evaluation and assessment of the HMS.

5.4 Program for monitoring groundwater chemistry

Background

During the construction phase of the Äspö Hard Rock Laboratory, 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 the cored boreholes drilled from the ground surface and from percussion and cored boreholes drilled from the tunnel.

Objectives

At the beginning of the operational phase, sampling was replaced by a groundwater chemistry monitoring program, aiming to sufficiently cover the hydrochemical conditions with respect to time and space within the Äspö HRL. This program should provide information for determining where, within the rock mass, the hydrochemical changes are taking place and at what time stationary conditions have been established.

Planned work

The results from the sampling in April and in October will be presented in Technical Documents in February-March. Next sampling occasion is scheduled to take place w016 and 017.

5.5 Technical systems

Background

The monitoring of groundwater changes (hydraulic and chemical) during the construction of the laboratory is an essential part of the documentation work aiming at verifying pre-investigation methods. The great amount of data calls for efficient data collection system and data management procedures. Hence, the Hydro Monitoring System (HMS) for on-line recording of these data have been developed and will continuously be expanded along with the tunneling work and the increased number of monitoring points.

New results

The installation of the presentation system started in August. The system consist of two parts an PLC (Programable logic controller) and the Process system.

The PLC is made by Siemens and the Process system is made by IC(Intouch).

The last six pressure transducers in Weir have been replaced with Ultra sonic transducer in December.

Borehole KI0023F03 has been connected to HMS in October.

Planned work

The presentation system will be in full operation during Spring 2000.

5.6 Information

Background

The information group´s main goal is to create public acceptance for SKB in cooperation with other departements in SKB. This is achieved by giving information about SKB, the Äspö HRL and the SKB siting programme. The visitors are also given a tour of the Äspö HRL. Today there are one visitor´s administrator and three public relations officers stationed at the Äspö HRL.

New results

During the fourth quarter of 1999 2870 visitors visited the Äspö HRL. The groups have represented the general public, communities where SKB performs feasibility studies, teachers, students, politicians, journalists and visitors from foreign countries.

	Number of visitors fourth quarter 1999	Number of visitors totally 1999
General public	806	4 525
Students	877	3 424
Teachers	567	1 067
Politicians	247	800
Journalists	3	16
Foreign visitors	174	658
Oskarshamn Community	1 886	4 560
Nyköping Community	143	452
Tierp Community	166	405
Hultsfred Community	327	919
Östhammar Community	146	165
Älvkarleby Community	25	65
Total numbers of visitors	2 870	12 211

Urberg 500

The entrance building for ”Urberg 500” was completed during the third quarter of 1999 and has been taken into use during the fourth quarter of 1999. The visitors get a presentation of SKB and the Hard Rock Laboratory in the entrance building before going down in the tunnel by bus. The tour finishes in the exhibition hall on Äspö.

Extra ”Urberg 500” tours were arranged during school holidays in week 36.

OKG´s visitors booking system has been installed, tested and validated.

Planned work

The booking system will be improved.

A safety/instruction video for consultants concerning work and safety under ground will be produced.

6 International cooperation

6.1 Current international participation in the Äspö Hard Rock Laboratory

Nine organisations from eight countries are currently (January 2000) participating in the Äspö Hard Rock Laboratory.

In each case the cooperation is based on a separate agreement between SKB and the organisation in question. Table 6-1 shows the scope of each organisations participation under the agreements.

Most of the organisations are interested in groundwater flow, radionuclide transport and rock characterisation. Several organisations are participating in the Äspö Task Force on groundwater flow and radionuclide migration, which is a forum for cooperation in the area of conceptual and numerical modelling of groundwater flow and solute transport in fractured rock.

Table 6-1 Scope of international cooperation

Organisation	Scope of participation
Agence Nationale pour la Gestion des Déchets Radioactifs, **ANDRA**, France.	Detailed investigation methods and their application for modelling the repository sites Test of models describing the barrier function of the bedrock Demonstration of technology for and function of important parts of the repository system
Bundesministerium für Wirtschaft und Technologie, **BMWi**, Germany	Two-phase flow investigations including numerical modelling and model calibration Participation in the Task Force on modelling of groundwater flow and transport of solutes by using "German" computer codes Participation in the geochemical modelling efforts in the Äspö HRL Work related to transport and retention of radionuclides and colloids in granitic rock In-situ geoelectrical measurements with respect to water saturation of rock masses in the near field of underground tunnels Work on design and performance of in-situ tests using methods and equipment similar to those used in the Grimsel investigations

Organisation	Scope of participation
Empresa Nacional de Residuos Radiactivos, **ENRESA**, Spain	Test of models describing the barrier function of the bedrock (TRUE Block Scale) Demonstration of technology for and function of important parts of the repository system, (Backfill and Plug Test)
Japan Nuclear Cycle Development Institute, **JNC**, Japan. The Central Research Institute of the Electronic Power Industry**, CRIEPI,** Japan	The Tracer retention understanding experiments (TRUE) The detailed scale redox (REX) experiment Radionuclide retention experiments Task Force on modelling of groundwater flow and transport of solutes. Prototype repository project. Long-term test of buffer materials
Nationale Genossenschaft für die Lagerung Radioaktiver Abfälle, **NAGRA**, Switzerland	Test of models describing the barrier function of the bedrock Demonstration of technology for and function of important parts of the repository system
United Kingdom Nirex Limited, **NIREX**, Great Britain	TRUE Block Scale
POSIVA , Finland.	Detailed investigation methods and their application for modelling the repository sites Test of models describing the barrier function of the bedrock Demonstration of technology for and function of important parts of the repository system - *Prototype repository*
USDOE/**Sandia National Laboratories**, USA	Test of models describing the barrier function of the bedrock

6.2 Summary of work by participating organisations

6.2.1 Work performed by Posiva Oy

Fieldwork at Äspö HRL

During the last quarter of 1999 Posiva has participated in the fieldwork of the Äspö HRL mainly within the Hydrochemical Stability project. The Posiva groundwater sampling method has been tested in the borehole KLX02. In addition to the testing of the equipment the aim of the project was to get samples for characterising the hydrochemistry of the deep saline groundwater.

Groundwater sampling with PAVE equipment

Groundwater sampling was carried out with the PAVE sampler, Posivas pressurised groundwater sampling equipment, in deep borehole conditions. The expected results of the PAVE sampling at borehole KLX02 were to get representative water samples from well-defined isolated sections for the characterisation of local hydrogeochemical conditions and salinity at different depth levels, and also groundwater samples representing in-situ pressure conditions for gas and microbe analyses.

Sampling was successfully accomplished with the PAVE equipment during July – December from the following depths:

- 1090-1097 m
- 1155-1165 m
- 1345-1355 m
- 1385-1392 m.

The flow rates in the sections one to three varied from 450 ml/h to 5,7 l/h. One of the planned sampling sections, 1280-1290 m, was abandoned because of the low flow (<120 ml/h). Due to some technical problems no samples for dissolved gas and microbes could be obtained with the PAVE containers from section 1090-1097 m. The last section, 1385-1392 m, had a very low flow, around 30 ml/h. Because of the very low flow and denser water (according to the manual logging) the pumping technique had to be changed to a manual one with the water-pressure instead of nitrogen-gas-pressure. The groundwater and PAVE samplings for gases and microbes was accomplished also in this section but some of the sampling activities were cancelled because of the low yield.

The exercise showed that the PAVE sampler due to it's design and low weight is easy to operate and is robust in it's function and samples of good quality for dissolved gases and microbes could be obtained from three sections. The low flow caused sometimes difficulties for the on-line Eh-measurements. The field measurements (from the automatic and manual logging) indicate same salinity levels (chloride contents) as obtained during previous sampling campaigns such as SKB packer sampling 93, Tube samplings 93 and 97.

Planned fieldwork

As a part of the Joint Project between Posiva and SKB the testing of the **Posiva flowmeter** will continue in borehole KLX02 in the beginning of 2000. The measuring programme is revised according to the experience gained from the measurements during the spring 1999. The leakage in the rubber disks at depth should be avoided by measuring the borehole downwards instead of usual direction upwards. With the direction change the accumulation of the loose material between the borehole wall and the rubber disks should be reduced. Also a new longer measuring cable (length 1500 m) has been installed in the equipment. This will make measurements faster and the problems with the contact of the cable (1100 m) and the extension cable (400 m) are avoided. The fieldwork will be carried out in two campaigns, one for difference flow measurements in normal mode and the second campaign for difference flow measurements in detailed mode. A methodology study (at the borehole section 400-600 m) with the three different groundwater levels will be added to the second campaign. The first campaign will be started at the beginning of January 2000 and the second campaign will follow it in April-May 2000.

7 Other matters

Documentation

During the period October-December, 1999, the following reports have been published and distributed:

7.1.1 Äspö International Cooperation Reports

McKenna S A, 1999
Solute Transport Modelling of the Äspö STT-1b Tracer Tests with Multiple Rates of Mass Transfer. Task 4E. Äspö Task Force on Modelling of Groundwater Flow and Transport of Solutes.
ICR 99-02

7.1.2 Äspö International Progress Reports

Zeng L, Dahlström L-O, 1999
Prototype repository. Finite Element Analyses of Mechanical. Consequences due to the Rock Excavation and Thermal Load
IPR-99-16

Yoshida H, Hama K, West J M, Bateman K, Milodowski AE, Baker S J, Coombs P, Hards V L, Spiro B, Wetton P D, 1999
Redox Experiment in detailed Scale (REX): Laboratory work to examine microbial effects on Redox and quantification of the effects of microbiological perturbations on the geological disposal of HLW (TRU)
IPR-99-19

Nyberg G, Jönsson S, Onkenhout J, 1999
Hydromonitoring program. Report for 1998.
IPR-99-20

Äspö Hard Rock Laboratory, 1999
Status Report January - June 1999.
IPR-99-21

Äspö Hard Rock Laboratory, 1999
Status Report July - September 1999.
IPR-99-24

Nordlund E, Li C, Carlsson B, 1999
Prototype repository at Äspö HRL. Laboratory tests.
IPR-99-25

Svemar C, 1999
Canister Retrieval Test. Test plan. Part 1 – Geotechnical Characterisation, test installation and monitoring during saturation.
IPR-99-26

Puigdomenech I, Pedersen K, 1999
Prototype Repository. Test plan for subtask. Sampling and monitoring of microbial activities and chemical conditions during 20 years of operation.
IPR-99-34

20 Technical Documents

10 International Technical Documents

References

Andersson, P., Johansson, H., Nordqvist, R., Skarnemark, G., Skålberg, M., Wass, E., 1998a.
Parameters of importance to determine during geoscientific site investigation.
TR 98-02

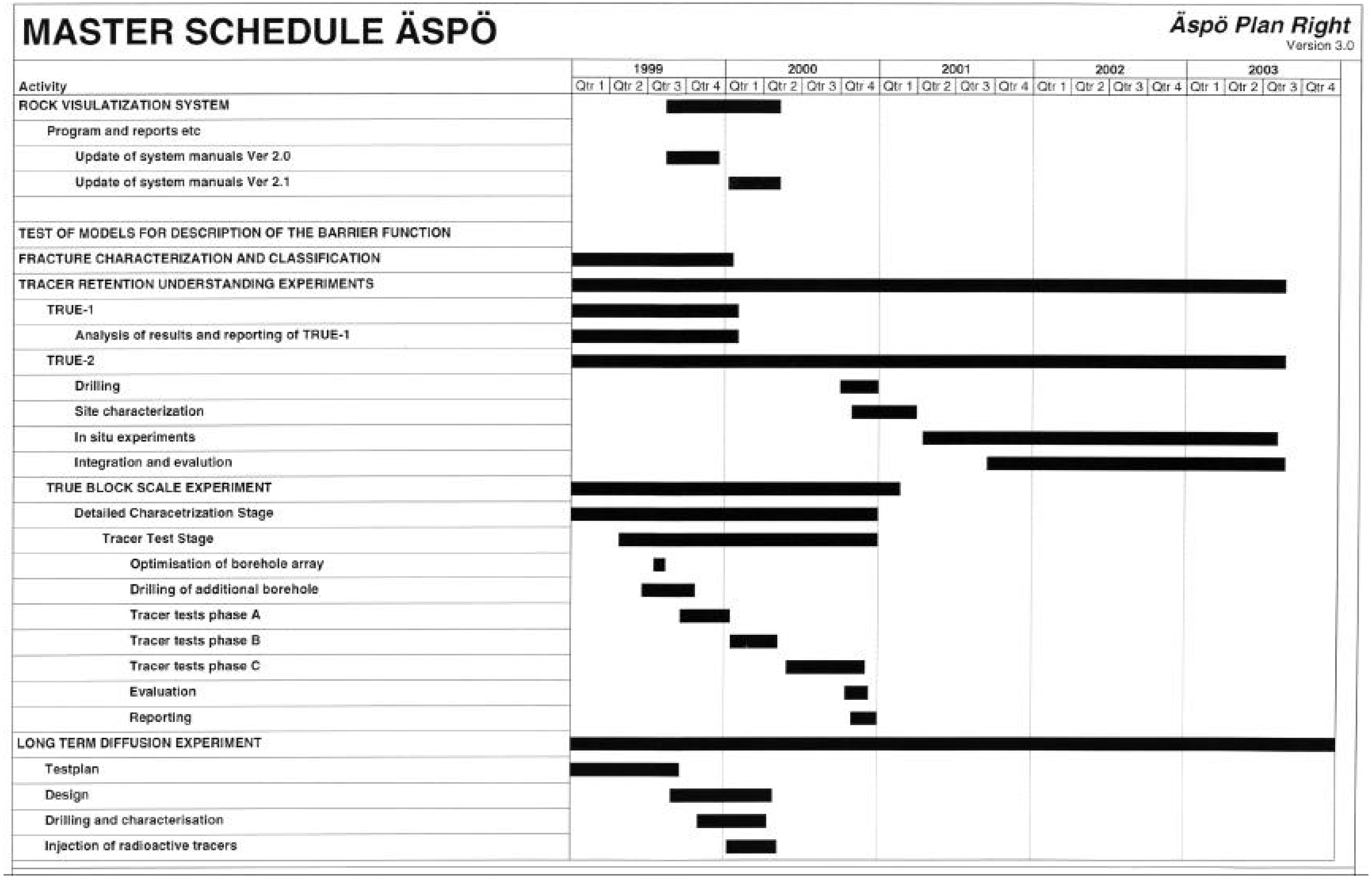
Byegård J, Johansson H, Skålberg M, Tullborg E-L, 1998
The interaction of sorbing and non-sorbing tracers with different Äspö rock types – Sorption and diffusion experiments in the laboratory scale. Swedish Nuclear Fuel and Waste Management Co.
TR-98-18

Bäckblom, G, Olsson O, 1994.
Program for tracer retention understanding experiments.
PR 25-94-24

Olsson O, Bäckblom G, Gustafson G, Rhén I, Stanfors R and Wikberg P, 1994.
The structure of conceptual models with application to the Äspö HRL Project. Swedish Nuclear Fuel and Waste Management Co.
TR 94-08

Rhén I (ed), Gustafson G, Stanfors R and Wikberg P, 1997.
ÄSPÖ HRL - Geoscientific evaluation 1997/5. Models based on site characterization 1986-1995. Swedish Nuclear Fuel and Waste Management Co.
TR 97-06

Appendix A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Version 3.0
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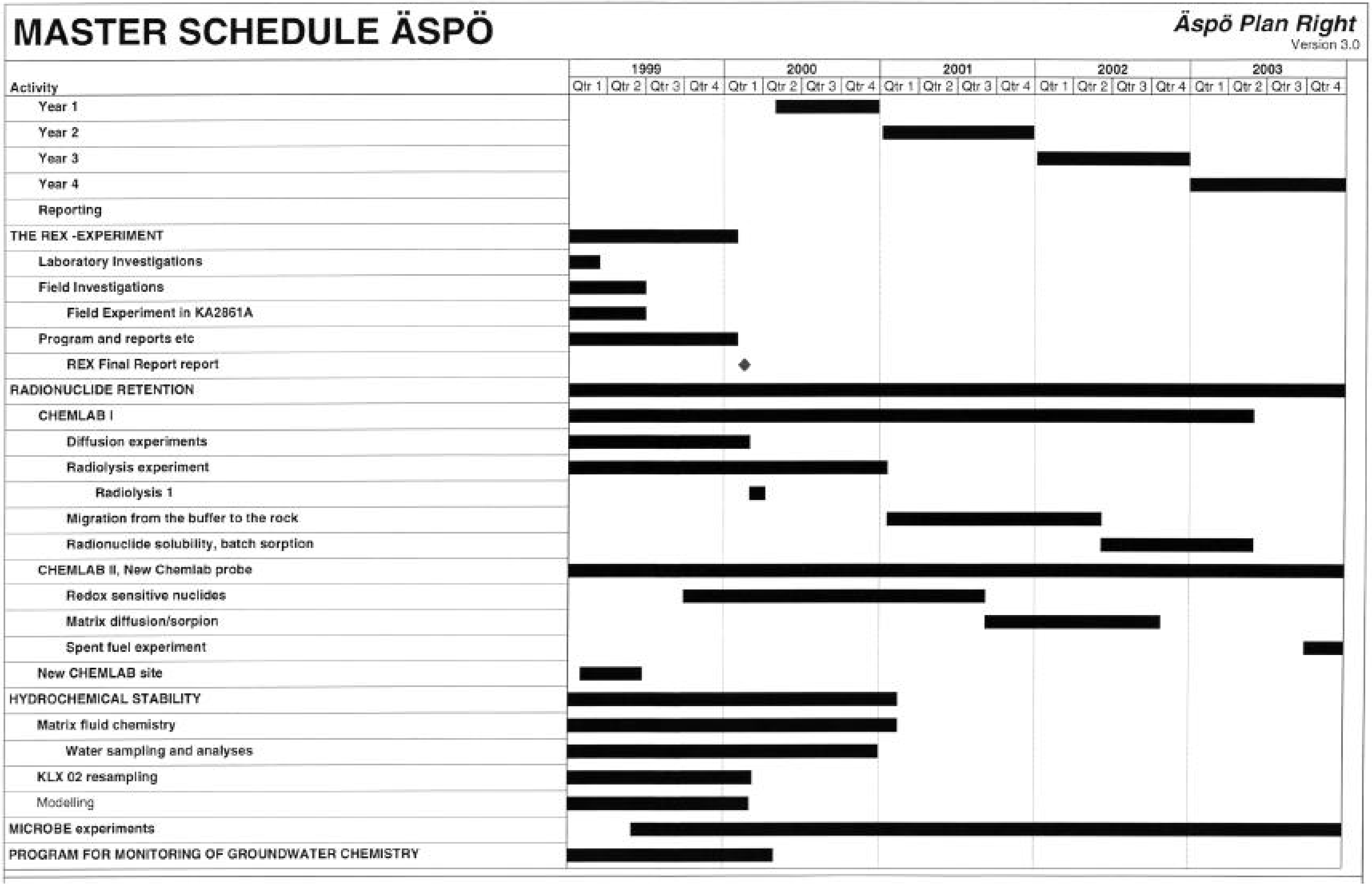
1999
2000
2001
2002
2003
Qtr 1 Qtr 2 Qtr 3 Qtr 4
ROCK VISULATIZATION SYSTEM
Program and reports etc
Update of system manuals Ver 2.0
Update of system manuals Ver 2.1
TEST OF MODELS FOR DESCRIPTION OF THE BARRIER FUNCTION
FRACTURE CHARACTERIZATION AND CLASSIFICATION
TRACER RETENTION UNDERSTANDING EXPERIMENTS
TRUE-1
Analysis of results and reporting of TRUE-1
TRUE-2
Drilling
Site characterization
In situ experiments
Integration and evalution
TRUE BLOCK SCALE EXPERIMENT
Detailed Characetrization Stage
Tracer Test Stage
Optimisation of borehole array
Drilling of additional borehole
Tracer tests phase A
Tracer tests phase B
Tracer tests phase C
Evaluation
Reporting
LONG TERM DIFFUSION EXPERIMENT
Testplan
Design
Drilling and characterisation
Injection of radioactive tracers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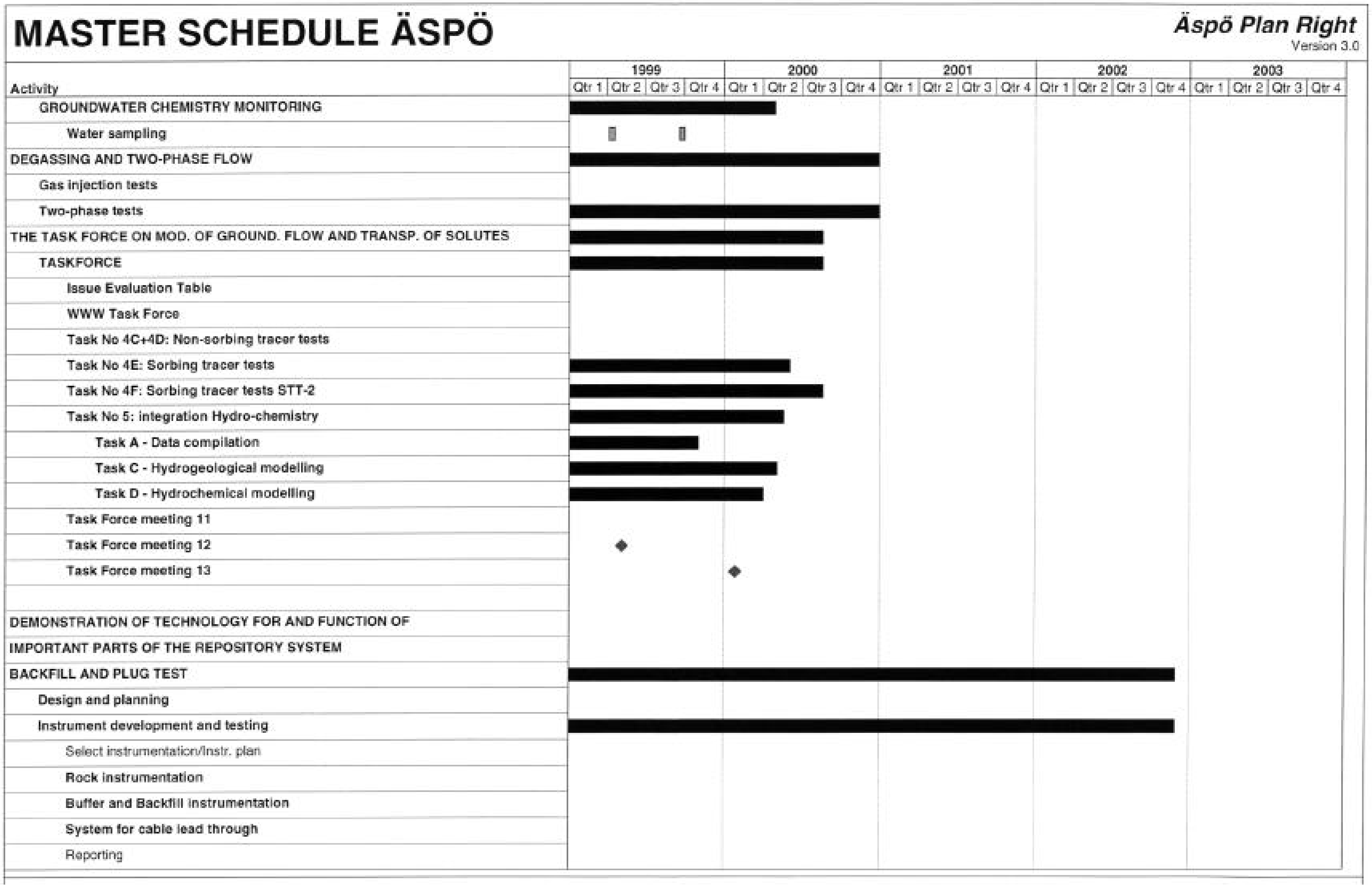
Qtr 3
Qtr 4
Year 1
Year 2
Year 3
Year 4
Reporting
THE REX -EXPERIMENT
Laboratory Investigations
Field Investigations
Field Experiment in KA2861A
Program and reports etc
REX Final Report report
RADIONUCLIDE RETENTION
CHEMLAB I
Diffusion experiments
Radiolysis experiment
Radiolysis 1
Migration from the buffer to the rock
Radionuclide solubility, batch sorption
CHEMLAB II, New Chemlab probe
Redox sensitive nuclides
Matrix diffusion/sorpion
Spent fuel experiment
New CHEMLAB site
HYDROCHEMICAL STABILITY
Matrix fluid chemistry
Water sampling and analyses
KLX 02 resampling
Modelling
MICROBE experiments
PROGRAM FOR MONITORING OF GROUNDWATER CHEMISTRY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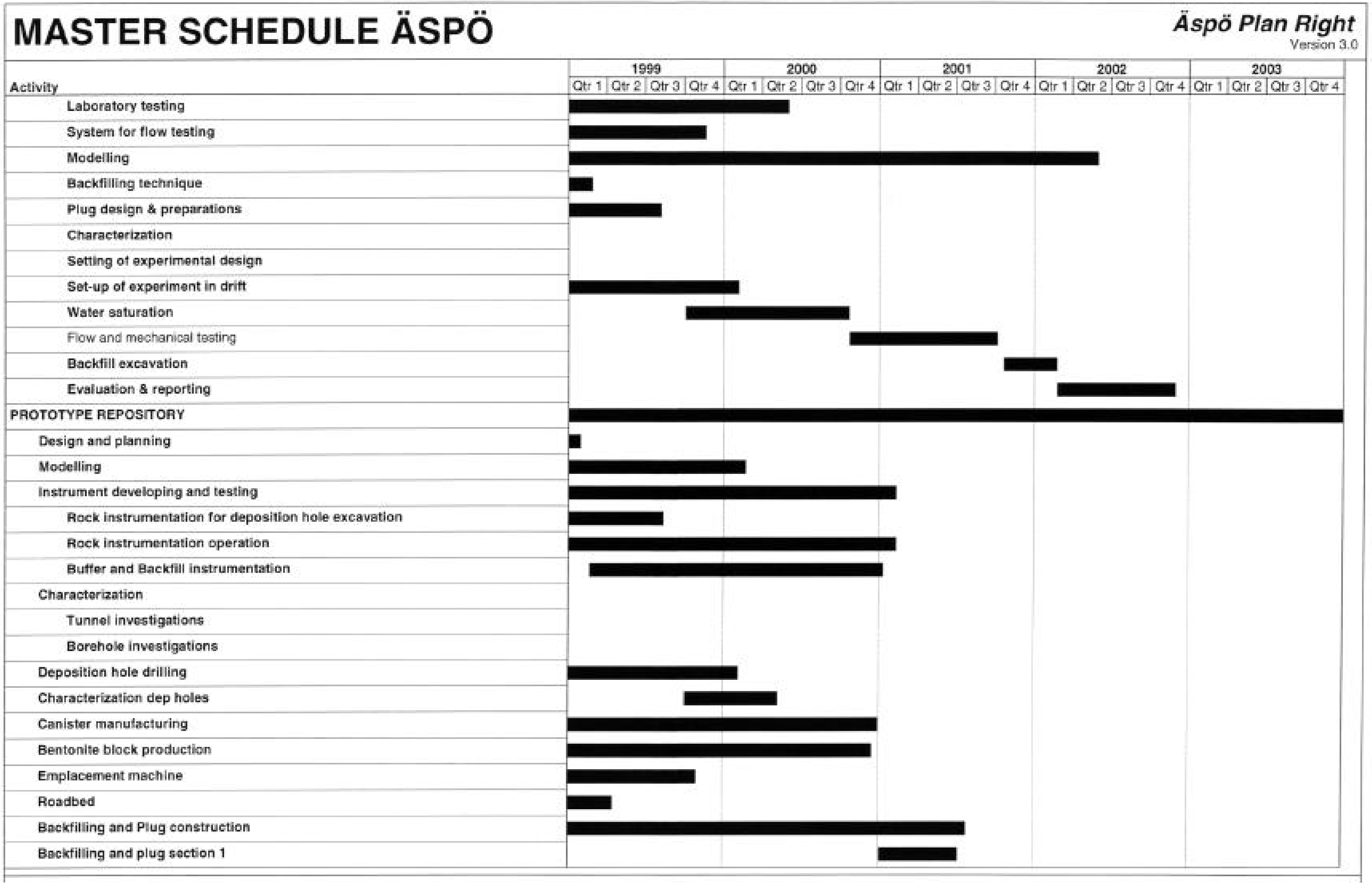
Qtr 1 Qtr 2 Qtr 3 Qtr 4
GROUNDWATER CHEMISTRY MONITORING
Water sampling
DEGASSING AND TWO-PHASE FLOW
Gas injection tests
Two-phase tests
THE TASK FORCE ON MOD. OF GROUND. FLOW AND TRANSP. OF SOLUTES
TASKFORCE
Issue Evaluation Table
WWW Task Force
Task No 4C+4D: Non-sorbing tracer tests
Task No 4E: Sorbing tracer tests
Task No 4F: Sorbing tracer tests STT-2
Task No 5: integration Hydro-chemistry
Task A - Data compilation
Task C - Hydrogeological modelling
Task D - Hydrochemical modelling
Task Force meeting 11
Task Force meeting 12
Task Force meeting 13
DEMONSTRATION OF TECHNOLOGY FOR AND FUNCTION OF
IMPORTANT PARTS OF THE REPOSITORY SYSTEM
BACKFILL AND PLUG TEST
Design and planning
Instrument development and testing
Select instrumentation/Instr. plan
Rock instrumentation
Buffer and Backfill instrumentation
System for cable lead through
Reporting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Activity
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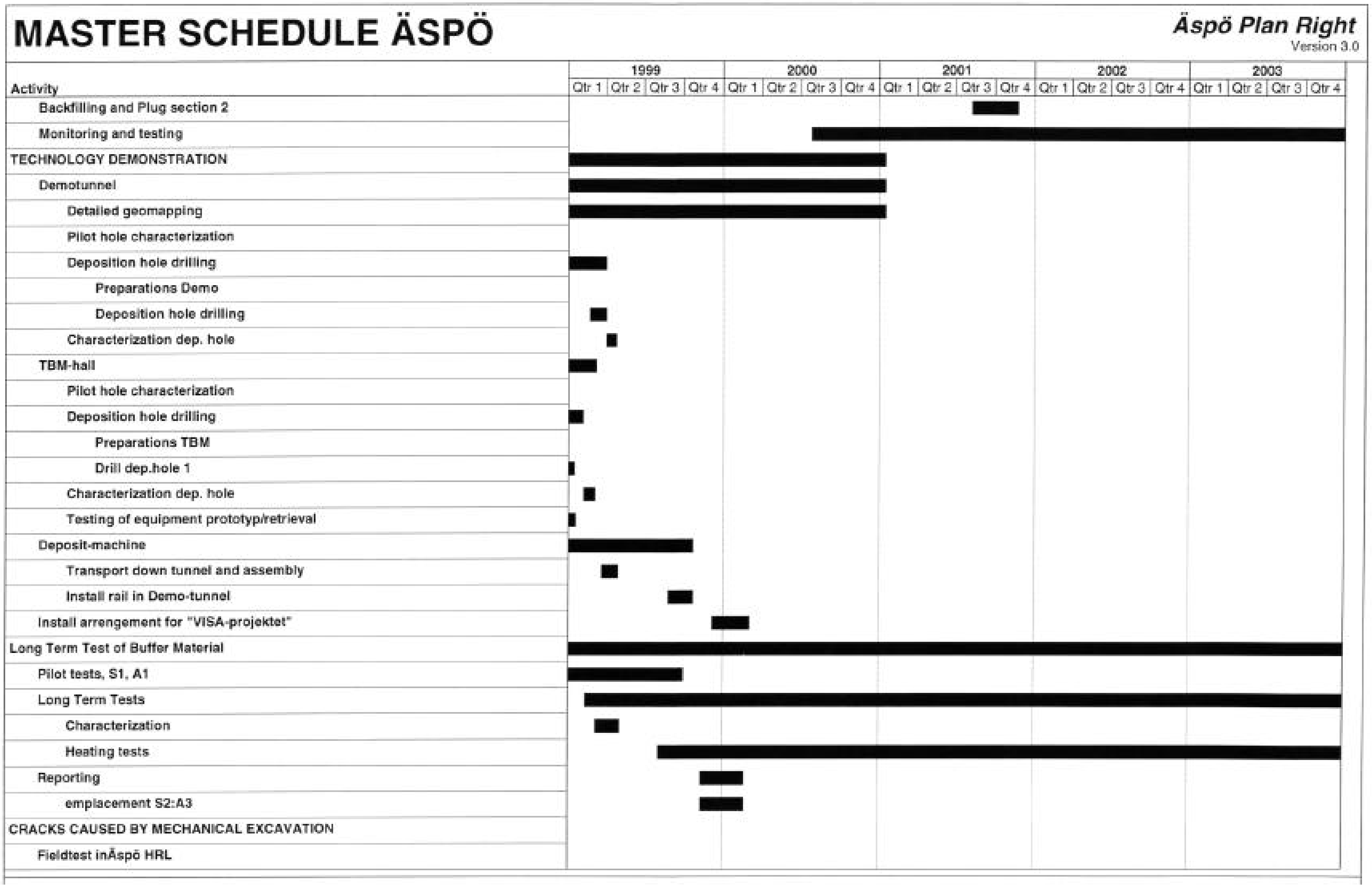
Qtr 1
Qtr 2
Qtr 3
Qtr 4
Laboratory testing
System for flow testing
Modelling
Backfilling technique
Plug design & preparations
Characterization
Setting of experimental design
Set-up of experiment in drift
Water saturation
Flow and mechanical testing
Backfill excavation
Evaluation & reporting
PROTOTYPE REPOSITORY
Design and planning
Modelling
Instrument developing and testing
Rock instrumentation for deposition hole excavation
Rock instrumentation operation
Buffer and Backfill instrumentation
Characterization
Tunnel investigations
Borehole investigations
Deposition hole drilling
Characterization dep holes
Canister manufacturing
Bentonite block production
Emplacement machine
Roadbed
Backfilling and Plug construction
Backfilling and plug section 1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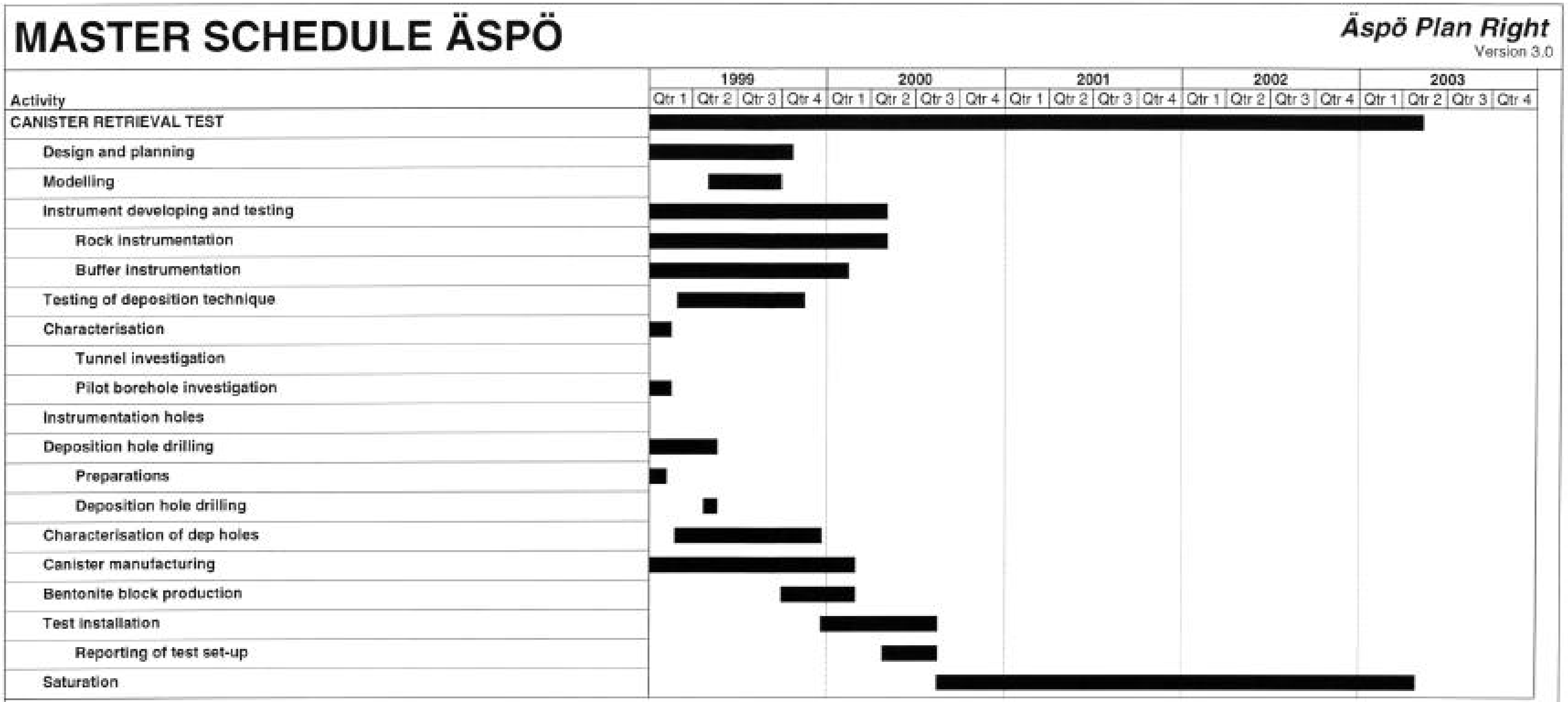
Qtr 1 | Qtr 2 | Qtr 3 | Qtr 4
Backfilling and Plug section 2
Monitoring and testing
TECHNOLOGY DEMONSTRATION
Demotunnel
Detailed geomapping
Pilot hole characterization
Deposition hole drilling
Preparations Demo
Deposition hole drilling
Characterization dep. hole
TBM-hall
Pilot hole characterization
Deposition hole drilling
Preparations TBM
Drill dep.hole 1
Characterization dep. hole
Testing of equipment prototyp/retrieval
Deposit-machine
Transport down tunnel and assembly
Install rail in Demo-tunnel
Install arrengement for "VISA-projektet"
Long Term Test of Buffer Material
Pilot tests, S1, A1
Long Term Tests
Characterization
Heating tests
Reporting
emplacement S2:A3
CRACKS CAUSED BY MECHANICAL EXCAVATION
Fieldtest inÄspö HRL


MASTER SCHEDULE ÄSPÖ
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Version 3.0
Activity
1999
2000
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2003
Qtr 1 Qtr 2 Qtr 3 Qtr 4
CANISTER RETRIEVAL TEST
Design and planning
Modelling
Instrument developing and testing
Rock instrumentation
Buffer instrumentation
Testing of deposition technique
Characterisation
Tunnel investigation
Pilot borehole investigation
Instrumentation holes
Deposition hole drilling
Preparations
Deposition hole drilling
Characterisation of dep holes
Canister manufacturing
Bentonite block production
Test installation
Reporting of test set-up
Saturation