International Progress Report

IPR-01-12

Äspö Hard Rock Laboratory

Planning Report for 2001

March 2001

Svensk Kärnbränslehantering AB
Swedish Nuclear Fuel
and Waste Management Co
Box 5864
SE-102 40 Stockholm Sweden
Tel +46 8 459 84 00
Fax +46 8 661 57 19

Äspö Hard Rock Laboratory

Äspö Hard Rock Laboratory

Planning Report for 2001

March 2001

The Äspö Hard Rock Laboratory,
Planning Report for 2001

This report presents the planned activities for year 2001 with background, objectives, experimental concepts (where applicable) and scope of work. It details the programme for the Äspö HRL , that was described in SKB`s Research, Development and Demonstration Programme 98, and serves as a basis for the management of the laboratory. The plan is revised annually.

Svensk Kärnbränslehantering AB

Safety and Technology
Repository Technology

Christer Svemar
Acting Director

Executive summary

General

The Äspö Hard Rock Laboratory, Äspö HRL, constitutes an important part of SKB's work to design and construct a deep geological repository for spent nuclear fuel and to develop and test methods for characterisation of a suitable site. The Äspö HRL has been designed to meet the needs of the research, development, and demonstration projects that are planned for the Operating Phase. The underground part of the laboratory consists of a tunnel from the Simpevarp peninsula to the southern part of Äspö where the tunnel continues in a spiral down to a depth of 450 m. Construction of the facility began in 1990 and was completed in 1995 when the Operating Phase began.

The Äspö HRL and the associated research, development, and demonstration tasks are managed by the Repository Technology Unit within SKB, and has so far attracted considerable international interest. As of March 2001 nine foreign organisations are participating in the work at the laboratory.

To meet the overall time schedule for SKB's RD&D programme the work has been structured according to four stage goals as defined in SKB's RD&D Programme 1998.

The Planning Report provides an overview of the planned activities for 2001. Some main activities for 2001 are summarised below:

Investigations and experiments

Stage goal 2 - Finalise detailed investigation methodology

This Stage Goal includes projects with the aim to develop technology and tools to facilitate refinement of site models through investigations from underground excavations and boreholes. The refined models will provide the basis for updating the layout of the repository and adapting it to local conditions.

Different methods for characterisation from underground excavations and boreholes will be tested as part of a number of projects undertaken at the Äspö HRL. An evaluation will be made of the Canadian method of measuring in situ stresses by overcoring, and the method compared with the Swedish method earlier used in the laboratory. Available data are used for compiling rock mechanics and heat transport models for the Äspö rock volume, and supplementary data are collected when deemed necessary. The aim is to support the plan for site investigations scheduled to start after year 2001.

Stage goal 3 - Test of models for description of the barrier function of the host rock

This Stage Goal includes projects with the aim to evaluate the usefulness and reliability of different models and to develop and test methods for determination of parameters required as input to the models. An important part of this work is performed in the Äspö Task Force on Groundwater Flow and Transport of solutes. The work in the Task Force is closely tied to ongoing and planned experiments at the Äspö HRL. Specified tasks are defined where several modelling groups work on the same set of field data. The modelling results are then compared to experimental outcome and evaluated by the Task Force delegates. The group consists of nine organisations from eight countries. Currently active tasks are evaluation of predictive modelling undertaken of the TRUE-1 experiment (Task 4) and coupling between hydrochemistry and hydrogeology (Task 5). A Task 6 will be initiated.

Further development of codes for groundwater flow and transport will be undertaken and applied to Äspö data.

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. Experiments in the detailed scale have been completed and reported and the tracer test stage of the block scale is in progress. The work is focused on development of mathematical models, evaluation and reporting during year 2001.A matrix diffusion experiment (LTDE) is scheduled to be installed and tracer circulation initiated. 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, and the focus during year 2001 is on radiolysis experiments. All experiment with the CHEMLAB will be conducted in the J niche at 450 m depth. The experiment with radiolysis was prepared in 1999 and will be conducted and completed within 2000. A second CHEMLAB unit, which will be used for experiments with redox sensitive nuclides and transuranics was delivered during 1999. The first experiment in this probe will be the migration of actinides, Americium, Neptunium and Plutonium, in a rock fracture.

The study on concentration, stability, and mobility of colloids in the Äspö environment.was initiated during 2000, and will continue with laboratory experiments and background measurements during year 2001.

A site has been set up at the 450 m level for studies of microbial activity in groundwater at in situ conditions. Microbial effects on redox conditions, radionuclide migration, and gas composition and consumption will be in focus, starting with the development of a formation groundwater circulation system and a system for sensible measurement of hydrogen and other reducing gases in the Äspö granitic rock environment.

The main objective of the Matrix Fluid Experiment is to understand the origin and age of matrix fluids and their possible effect on fluid chemistry in the bedrock. Matrix fluids will be sampled from a borehole drilled into matrix (fracture free) rock, when the water sample is sufficiently large. Fluid inclusions will be studied on core samples.

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

The Äspö HRL makes it possible to demonstrate and perform full scale tests of the function of different components of the repository system which are important for the long-term safety of a repository. It is also important to show that high quality can be achieved in design, construction, and operation of the repository. The main projects within this Stage Goal are the project on Demonstration of Repository Technology, the Prototype Repository, the Backfill and Plug Test, the Canister Retrieval Test and the Long Term Tests of buffer material, which together provide a complete testing of the integrated function of the engineered barriers.

The project of Demonstration of Repository Technology provides a full scale example of canister deposition under radiation shielded conditions and works with testing of canister handling in full size deposition holes. Four full-scale deposition holes have been drilled for the demonstration project at the 420 m level, and the deposition machine was delivered during 1999 and put into operation during 2000. Testing and demonstration of the deposition process is ongoing.

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. The Prototype Repository should, to the extent possible, simulate the real deep repository system, regarding geometry, materials, and rock environment. Instrumentation will be used to monitor processes and properties in the canister, buffer material, backfill and the near-field rock. Preparations are basically completed and most of year 2001 is allocated for installation of the inner section with four simulated deposition holes. The plug, that seals off this inner part, is scheduled to be cast before the end of the year. Section II is installed 2002.

The Backfill and Plug Test is a test of different backfill materials and emplacement methods and a test of a full-scale plug. It is a test of the hydraulic and mechanical function of the backfill materials and their interaction with the near field rock. During 1999 the experimental setup was finished, the tunnel backfilled, and the plug to seal the drift put in place. Water saturation was started and will continue until full saturation is obtained before testing of backfill properties will start. As only one third of the backfill has been saturated so far the saturation goes on the whole year.

Two full-scale deposition holes have been drilled for the purpose of testing technology for retrieval of canisters after the buffer has become saturated. These holes have also been used for comprehensive studies of the drilling process and the rock mechanical consequences of drilling the holes. A canister and bentonite blocks were emplaced in one of the holes during 2000, the hole was sealed with a plug, heater turned on and artificial water supply started. The time for reaching full saturation is expected to be 3-4 years.

The Long Term Tests of Buffer Material aim to validate models and hypotheses concerning long term processes in buffer material. Five 300 mm diameter test holes have been drilled and instrumented. Four of the tests are planned to run for at least five years. The temperature for two of the test holes will be 90ºC and the remaining three holes will have a temperature in the range 120-150ºC. Recovery of one of the holes having the temperature of 90ºC will be initiated during fall 2001.

Contents

1 General

In 1986 SKB decided to construct an underground rock laboratory in order to provide an opportunity for research, development, and demonstration in a realistic and undisturbed underground rock environment down to the depth planned for a future deep repository. In the autumn of 1986, SKB initiated field work for the siting of an underground laboratory in the Simpevarp area in the municipality of Oskarshamn. At the end of 1988, SKB decided in principle to site the laboratory on southern Äspö about 2 km north of the Oskarshamn power station. Construction of the Äspö HRL started on October 1st, 1990 after approval had been obtained from the authorities concerned. Excavation work was completed in February 1995.

The Äspö HRL has been designed to meet the needs of the research, development, and demonstration projects that are planned for the Operating Phase. The underground part of the laboratory consists of a tunnel from the Simpevarp peninsula to the southern part of Äspö where the tunnel continues in a spiral down to a depth of 450 m (Figure 1-1). The total length of the tunnel is 3600 m where the last 400 m have been excavated by a tunnel boring machine (TBM) with a diameter of 5 m. The first part of the tunnel has been excavated by conventional drill and blast techniques. The underground tunnel is connected to the ground surface through a hoist shaft and two ventilation shafts. Äspö Village is located at the surface on the Äspö Island and it comprises office facilities, storage facilities, and machinery for hoist and ventilation (Figure 1-2).

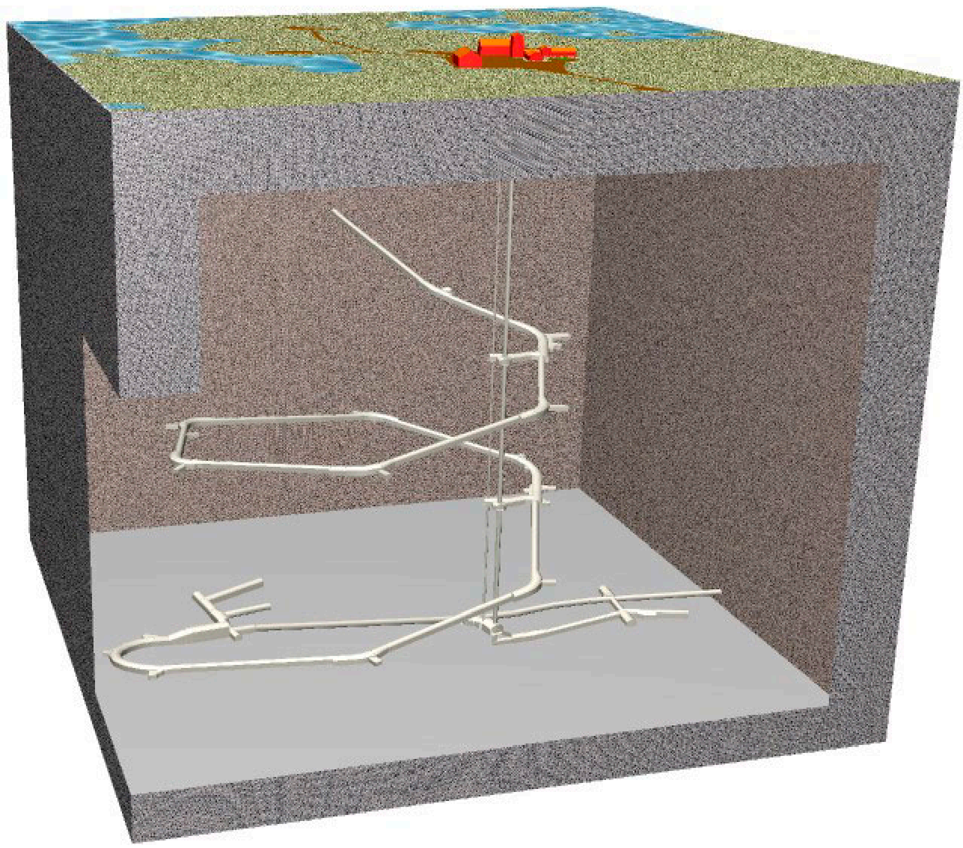


Figure 1-1 *Overview of the Äspö HRL Facilities*

Figure 1-2 *Overview of the Äspö Village*

The work with the Äspö HRL, has been divided into three phases: the pre-investigation phase, the construction phase, and the operating phase.

During the **Pre-investigation phase, 1986-1990,** studies were made to provide background material for the decision to locate the laboratory to a suitable site. The natural conditions of the bedrock were described and predictions made of geological, hydrogeological, geochemical etc. conditions to be observed during excavation of the laboratory. This phase also included planning for the construction and operating phases.

During the **Construction phase, 1990-1995,** comprehensive investigations and experiments were performed in parallel with construction of the laboratory. The excavation of the main access tunnel to a depth of 450 m and the construction of the Äspö Research Village were completed.

The **Operating phase began in 1995**. A preliminary outline of the program for the Operating phase was given in SKB's Research, Development and Demonstration (RD&D) Programme 1992. Since then the program has been revised and the basis for the current program is described in SKB's RD&D Programme 1998.

Annual Reports have been published for the Äspö HRL in SKB’s Technical Report series and the reader is referred to these publications for a more detailed account of achievements to date.

The Planning Report gives an overview of the planned activities for the calendar year 2001. The activities have been structured according to the stage goals defined below.

1.1 Goals

SKB decided to construct the Äspö HRL for the main purpose of providing an opportunity for research, development and demonstration in a realistic and undisturbed underground rock environment down to the depth planned for the future deep repository. Important tasks for the Äspö HRL 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.

To meet the overall time schedule for SKB's RD&D work, the following stage goals have been defined for the work at the Äspö HRL.

1 Verify pre-investigation methods

demonstrate that investigations on the ground surface and in boreholes provide sufficient data on essential safety-related properties of the rock at repository level, and

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.

During year 2001 work will only be undertaken within Stage Goals 2, 3, and 4.

1.2 Organisation

1.2.1 SKB's organisation

The current organisation of SKB that became effective on July 1st 1998 is shown in Figure 1-3. The organisation is set up to provide a focus of activities and use of resources to meet SKB's main near term goal, which is to get acceptance for performing site investigations at two sites in 2001. Investigations, including drilling, should commence in 2002. The strategy to reach this goal is described in the latest Research, Development and Demonstration Programme 98, which SKB delivered to the Swedish government at the end of September 1998.

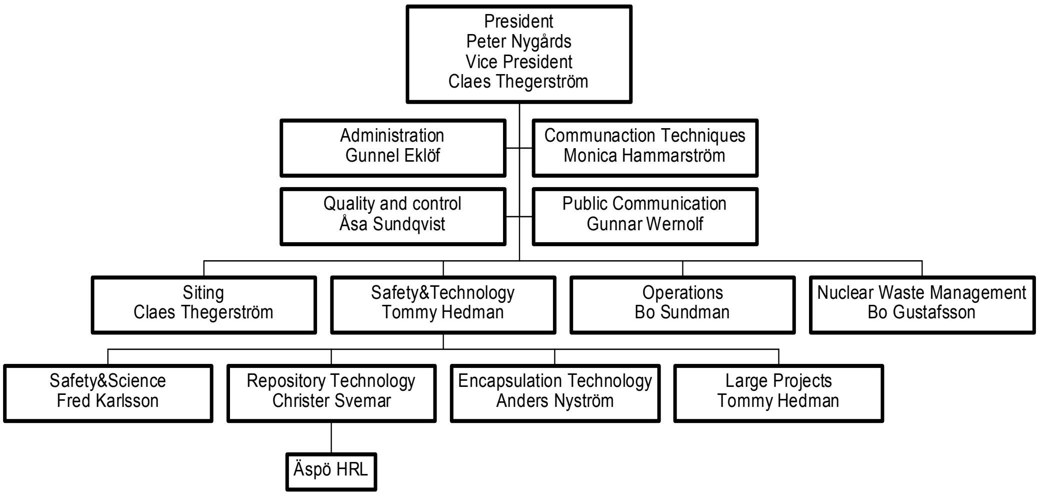


Figure 1-3 *Organisation of SKB valid from July 1st 1998.*

All research, technical development, and safety assessment work is organised into one department, Safety and Technology, in order to facilitate co-ordination between the different activities. The Safety and Technology department is organised into four units;

- Safety and Science with responsibility for research, safety assessments, and systems analysis.

- Repository Technology with responsibility for development of site investigation programs and methods, development and testing of deep repository technology, and in situ research on the natural barrier. The unit is also responsible for the operation of the Äspö HRL and the co-ordination of the research performed in international cooperation there.

- Encapsulation technology is responsible for development and testing of the copper canister and the design of the Encapsulation Plant. This unit is also responsible for the operation of the Encapsulation Laboratory located in Oskarshamn.

- Large construction projects have been organised in a separate unit. The main future task of this unit is the construction of CLAB 2, the expansion of CLAB to a total storage capacity of 8000 tons of spent nuclear fuel.

1.2.2 Repository Technology and the Äspö HRL

The Repository Technology unit is organised as a matrix organisation with three Senior Project Managers with responsibility to define the programme and manage the projects within their respective areas of responsibility (Figure 1-4). The three main tasks are:

- Site investigations with responsibility to provide an appropriate site investigation program, methods, equipment, and a competent organisation for site and detailed investigations to be applied when needed.

- Repository technology with responsibility for development, testing, planning, design, and demonstration of the technology and the methods needed to construct a deep repository.

- Natural barriers with responsibility for management and performance of research projects at the Äspö HRL aimed at resolving issues concerning the function of the natural barrier.

The Senior Project Managers report normally directly to the Director of Repository Technology, but a somewhat different structure is applied in the temporary organisation prevailing during 2001. The difference is that the Senior Project Managers report to others than the acting Director of Repository Technology, as indicated below, the sole reason being an even distribution of work load.

- Senior Project Manager of Site Investigation reports to the Project Director of Site Investigations (which is the former Director of the Äspö HRL).

- Senior Project Manager of Repository Technology reports to the Director of Safety and Technology.

- Senior Project Manager of Natural Barriers reports to acting Director of Safety and Science.

The staff is organised into the following groups:

- The Technology and Science group is responsible for the co-ordination of projects undertaken at the Äspö HRL and to maintain knowledge about the methods that have been used and the results that have been obtained from work at Äspö.

- The Experiment Service group is responsible for providing service (design, installations, measurements etc.) to the experiments undertaken at Äspö HRL. They are also responsible for operation and maintenance of monitoring systems and experimental equipment at Äspö.

- The Computer Systems group is responsible for operation and maintenance of computer hardware at SKB's offices in Oskarshamn and Hultsfred. They are also responsible for the further development and administration of SKB's geoscientific database, SICADA, GIS systems, and the RVS system.

- The Facility Operations group is responsible for operation and maintenance of the Äspö HRL offices, workshops and underground facilities.

- The Information group is responsible for arranging visits to SKB's facilities and providing information to visitors to Äspö HRL and SKB's other facilities in Oskarshamn.

- The Administration group is responsible for providing administrative service and quality systems.

The Äspö HRL and the associated research, development, and demonstration tasks are managed by the Director of Repository Technology (Christer Svemar acting Director during 2001). The International Cooperation at the Äspö HRL is the responsibility of the Director of Repository Technology, and SKB's International Coordinator, Monica Hammarström.

Each major research and development task is organised as a project that is led by a Project Manger who reports to one of the Senior Project Managers. Each Project Manager will be assisted by an On-Site Co-ordinator from the Site Office with responsibility for co-ordination and execution of project tasks at the Äspö HRL. The staff at the site office provides technical and administrative service to the projects and maintains the database and expertise on results obtained at the Äspö HRL.

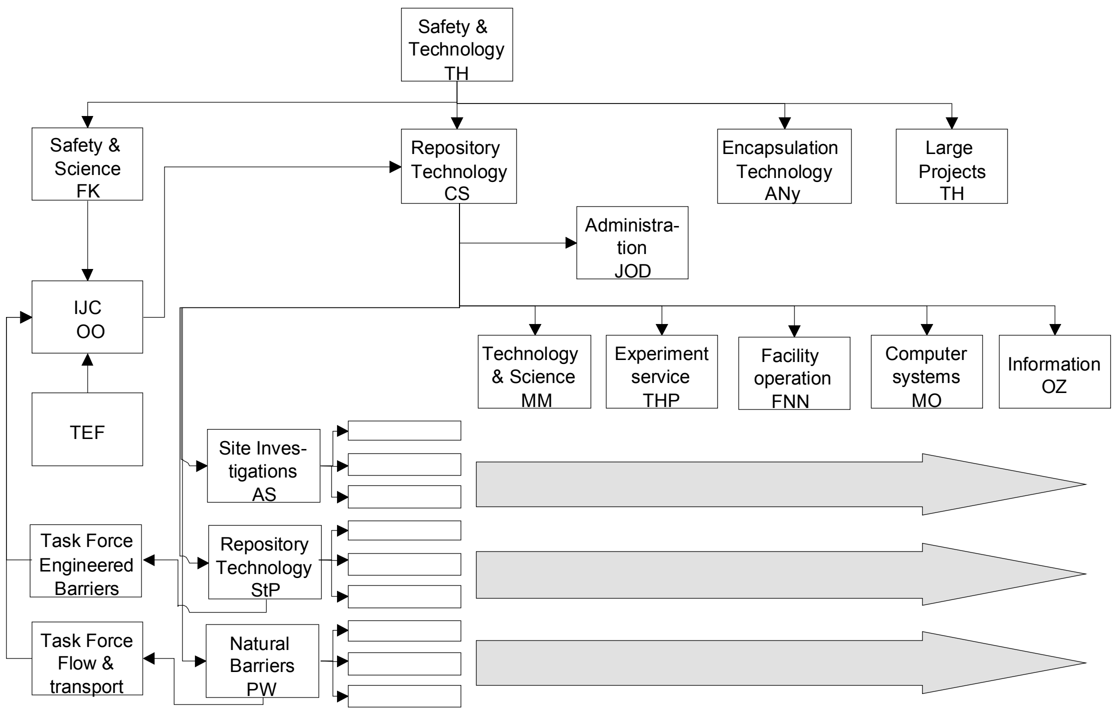


Figure 1-4 Organisation of Repository Technology 2001.

1.2.3 International participation in Äspö HRL

The Äspö HRL has so far attracted considerable international interest. As of December 2000 nine foreign organisations are participating in the Äspö HRL in addition to SKB.

These organisations are: Japan Nuclear Cycle Development Institute (JNC), Japan; Central Research Institute of Electric Power Industry (CRIEPI), Japan; Agence National Pur la Gestion des Dechets Radioactifs (ANDRA), France; POSIVA Oy, Finland; UK Nirex, United Kingdom; Nationale Genossenschaft für die lagerung von radioaktiver Abfälle (NAGRA), Switzerland; Bundesministerium für Wirtschaft und Technologie (BMWi), Germany; Empresa Nacional de Residuos Radiactivos (ENRESA), Spain, and United States Department of Energy, Carlsbad Field Office (USDOE/CBFO).

1.2.4 Advisory Groups

The international partners and SKB reached a joint decision to form the Äspö International Joint Committee (IJC) to be convened in connection with Technical Evaluation Forum (TEF) meetings. The role of the IJC is to co-ordinate the contributions of organisations participating in the Äspö HRL. The TEF meetings are organised to facilitate a broad scientific discussion and review of results obtained and planned work. Technical experts from each participating organisation and the IJC delegates participate in the TEF meetings. Chairman of IJC/TEF is Olle Olsson and secretary is Monica Hammarström (March 2001).

For each experiment the Äspö HRL management will establish a Peer Review Panel consisting of three to four Swedish or International experts in fields relevant to the experiment.

1.2.5 Task Forces

The Technical Co-ordinating Board (TCB) which preceded the IJC established the Task Force on modelling of groundwater flow and transport of solutes. The Task Force reviews and or proposes detailed experimental and analytical approaches for investigations and experiments at Äspö HRL. The group convenes twice a year. Approximately ten different modelling groups are now actively involved in the work. Chairman (December 2000) is Gunnar Gustafson, CTH and secretary is Mansueto Morosini, SKB.

During 2000 the IJC decided to initiate a Task Force on Engineered Barriers, which initially will focus on the saturation process of the bentonite buffer, and co-ordinating its work with the modelling with the similar work that is made in the European Commission project for the Prototype Repository.

1.3 Formulation of experimental programme

Each experiments to be performed in the Operating Phase will after formal initiation decision be described in a Test Plan, one for each major experiment. The Test Plans should give a detailed description of the experimental concept, scope, and organisation of each project. The Test Plans are structured according to a common outline. In cases where experiments are planned to extend over long time periods (up to 10 years) it is not appropriate or even possible to plan the experiment in detail in advance. In such cases, Test Programmes will be prepared outlining the objectives and overall scope of the programmes, which will be divided into stages with a duration of 2-3 years. Detailed

Test Plans will then be prepared for each stage, following an evaluation of results obtained to date. These evaluations may result in programme revisions.

Initially, draft Test Plans will be prepared which will be submitted for review by the Task Force and other bodies. After review, as well as scoping or design calculations, the Test Plans will be updated, detailed where appropriate, and published as Progress Reports or International Cooperation Reports. The general strategy is to begin preparation of the Draft Test Plans approximately one year before field work or some other significant preparation work is planned to start. The intention is also to actively engage the Task Forces in the planning, design, and evaluation experiments within their field of tasks.

1.4 Allocation of experimental sites

The rock volume and the available underground excavations have to be divided between the experiments performed at the Äspö HRL. It is essential that experimental sites are allocated so that interference between different experiments is minimised. The current allocation of experimental sites within the Äspö HRL is shown in Figure 1-5.

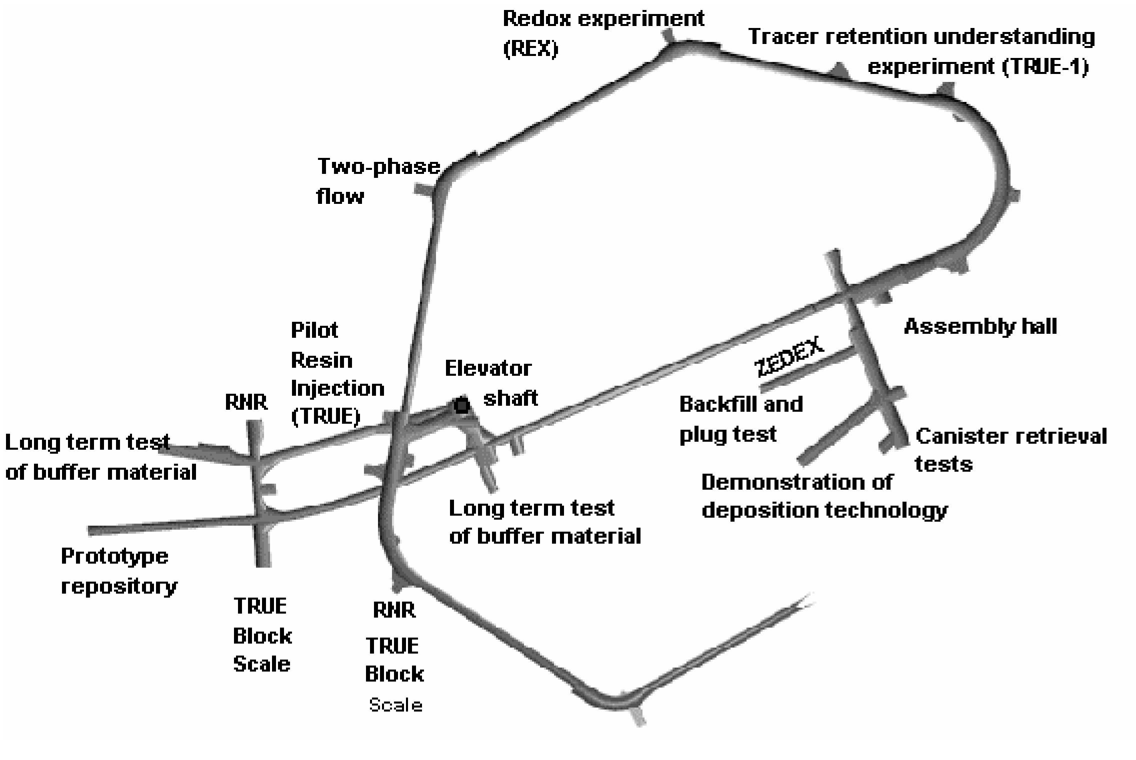


Figure 1-5 Underground excavations at the 300-450 m levels and current allocation of experimental sites.

1.5 Documentation

Data produced are mainly stored in SKB's database SICADA. Data and evaluations for specific tasks are published in International Progress Reports (IPR). The information from Progress Reports is summarised in Technical Reports (TR) at times considered appropriate for each project. SKB also endorses publications of results in international scientific journals. In order to facilitate quick distribution of results Technical Documents (ITD) are sometimes prepared. Planning is often also documented in Technical Documents (ITD). Technical Documents constitute working material and are not distributed to third parties.

Joint international work is reported in Äspö International Cooperation Reports (ICR).

Status Reports are published 4 times a year. The Äspö HRL Annual Report is published as an SKB Technical Report.

Table 1-1 provides an overview of the policy for review and approval of Äspö HRL documents.

Table 1-1. Review and approval of Äspö HRL Reports

Report	Reviewed by	Approved by
Äspö HRL-related parts of SKB RD&D Programme	Swedish Authorities	SKB
Annual Reports (Summary of work covering each calendar year)	Director Repository Technology	SKB
Technical Reports	Case-by-case	Director Äspö HRL
Äspö International Cooperation Report	Contributing organisation	Director Äspö HRL
Status Reports (Short summary of work covering each 3 month period)		Director Äspö HRL
International Progress Reports	Project Manager	Director Äspö HRL
Technical Documents	Author	Project Manager

1.6 Quality Assurance

Background

Quality Assurance means to ensure that activities are undertaken with due quality and high efficiency. In order to achieve this goal it is required that a smoothly running system is in place to manage projects, personnel, purchasing, economy quality, safety and environment.

The structure of a quality assurance system is based on procedures, handbooks, instructions, identification and traceability, quality audits etc. The overall guiding document for issues relating to management, quality and environment are written as routines.

Employees and contractors related to the SKB organisation are responsible that works will be performed in order to achieve SKB quality goals and guidelines.

Scope for year 2001

SKB is in progress of implementing a common management system to break down all requirements from legislator, authorities and other interested parties as well as from internal requirements of SKB´s own organisation. The aim of the project is to certify SKB according to the Environmental Management System ISO 14001 and the Quality Management Standard ISO 9001 before the summer, year 2001. One internal audit has been performed. Actions have been taken to take care of the identified deviations from ISO-standards.

Äspö HRL is in progress of authorising the water chemistry laboratory in the Äspö Village and the mobile facilities operating in the field. Submittal of application documents is scheduled for spring 2001.

Projects shall follow established guidelines and routines. Requirements (from legislator, authorities and internal demands) on quality, safety and environment shall be implemented in the projects. The plant design for a deep repository in the future and site investigations should also follow these quality procedures.

A new identification and archival system shall be implemented during the year. Documents from activities shall be recorded and archived in an integrated and traceable manner.

1.7 Information and public relations

Background

In Oskarshamn municipality SKB operates three facilities. These are the Äspö HRL, CLAB and the Canister Laboratory. The evaluation of the six feasibility studies for siting a deep repository has indicated Oskarshamn of being one out of three municipalities with the highest potential for hosting a deep repository.

The main goal for the information is to create public acceptance for SKB´s work. This is done in co-operation with other departments at SKB. To achieve the goal information is given about SKB, the Äspö HRL and the SKB siting programme. The visitors are also given a tour at the Äspö HRL.

Scope for 2001

The information activities will be to focus on the siting process, and with the help of a special exhibition site on Äspö visits may be organised that give more information on the siting process.

The guided summer tours of the Äspö HRL will start in the beginning of June.

Special events, like the Äspö Day, will focus on information on the siting programme and the exhibitions at Äspö will be configured to fit the siting process.

A new booking system for the administration of visits is scheduled for implementation during the spring of 2001.

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

2.1 General

The Natural Barriers in the deep geological repository for radioactive wastes are the bedrock, its properties and the on-going physical, chemical and biological 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, 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 adopted.

Isolation is the prime function of the KBS-3 type repository. It is obtained through the co-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 2001 focus is on further development of the numerical tools used for groundwater flow and transport calculations. A major part of this work will be to start the TASK#6 modelling work.

Hydrochemical stability and potential variablility is assessed within several projects that were completed during 1999 and 2000. The final project report will be printed during 2001.

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 that 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, which occur in the nearfild and farfield. Some elements are strongly retarded while others are escaping with the flowing groundwater. The major emphasis in the safety assessment calculations has therefore been on the weakly retarded nuclides even if they don´t dominate the hazard of the waste.

The large amount of activity in a repository is caused by the fission products, Cs, Sr, I, Tc, and the transuranic elements Am, Np, and Pu. The transuranics, Cs, and Tc are, if dissolved, effectively sorbed in the near field. However, in case neptunium and technetium are oxidized to neptonyl and pertechnetate by radiolyses from the waste they might be transported into the bentonite buffer before they are reduced to the insoluble tetravalent state.

Strontium and all negatively charged elements will be transported through the bentonite buffer by diffusion. They will then be retarded by the interaction with the fracture minerals in the flow paths of the rock and through the diffusion into the rock matrix. The effective retention of these nuclides is a combination of radioactive decay, sorption and diffusion.

The more long-lived and the weaker the sorption of the nuclide, the more important is the actual groundwater flow for the migration. The chemical composition of the groundwater is important for the magnitude of sorption for some of the nuclides. Negatively charged nuclides are retarded from the groundwater flow only through the diffusion into the stagnant pores of the rock matrix.

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 2001 the goals are to report the TRUE Block Scale experiment and to plan future tracer experiments. The Long Term Diffusion Experiment (LTDE) will be running for 3 to 4 years to assess the matrix diffusion into an isolated fracture surface. 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 2001 experiments include effects of radiolysis and migration of actinides in a rock fracture.

COLLOID investigations made previously at Äspö and elsewhere yielded concentrations that were not possible to detect. New findings of colloidal transport and more sensitive instruments for colloid measurements have motivated a new project with the purpose to study the natural concentration, the stability and the mobility of colloids.

Microbes are of particular interest since they can directly influence the chemistry of the groundwater, and indirectly transport nuclides attached to them. Experiments will start within the project MICROBE.

Dilution is the third barrier function. It will take place in the rock volume surrounding the repository. The magnitude of dilution is very much depending on the site specific conditions, and for performance assessment calculations on the conceptualisation of the flow. In the geosphere the dilution is caused by the dispersion in the groundwater flow.

No specific experiment is focussing on dilution. However, this process is included in TASK#6 within the Äspö Task Force for groundwater flow and transport of solutes.

2.2 Tracer Retention Understanding Experiments

A programme has been defined for tracer tests at different experimental scales, the so-called Tracer Retention Understanding Experiments (TRUE), (Bäckblom and Olsson, 1994). The overall objective of the defined experiments is to increase the understanding of the processes which govern retention of radionuclides transported in crystalline rock, and to increase the credibility in the computer models for radionuclide transport which will be used in licensing of a repository. The basic concept is that tracer experiments will be performed in cycles with an approximate duration of 3-4 years. At the end of each test cycle, results and experience will be evaluated and the programme revised.

The tracer experiments should achieve the following general objectives;

- Improve understanding of radionuclide transport and retention in fractured crystalline rock.
- Evaluate to what extent concepts used in models are based on realistic descriptions of rock and whether adequate data can be collected during site characterisation.
- Evaluate the usefulness and feasibility of different approaches to modelling radionuclide migration and retention.
- Provide in situ data on radionuclide migration and retention.

The basic idea is to perform a series of tracer tests with progressively increasing complexity. In principle, each tracer experiment will consist of a cycle of activities beginning with geological characterisation of the selected site, followed by hydraulic and tracer tests, after which epoxy resin will be injected. Subsequently the tested rock volume will be excavated and analysed with regards to flow path geometry, and tracer concentration.

The first test cycle - TRUE-1 (Winberg et al., 2000), which was performed on a detailed scale (< 10 m) - was of limited duration in time, and was primarily aimed at technology development, although comprehensive tracer tests using radioactive sorbing tracers.

The initial test cycle were originally planned to be followed by a second series of tracer tests in the detailed scale, of longer duration, and allowing full address of different retention mechanisms. However, due to resource priorities this stage (denoted TRUE-2) has been postponed indefinitely.

An experiment in the block scale (10-100 m), the so-called TRUE Block Scale Project, has been in progress since 1996 and will come to its conclusion during the year 2001, cf. Section 2.2.1.

However, the palette of experiments have recently been complemented with an experiment focused on the in situ diffusion and sorption of radioactive sorbing tracers from a natural fracture surface, through an altered zone and into unaltered fresh wall rock. The project, Long-Term Diffusion Experiment (LTDE), thus constitutes a natural extension of the dynamic experiments conducted as part of TRUE-1 and TRUE Block Scale, with the difference that the longer duration (3-4 years) is expected to enable an improved understanding of diffusion and sorption in the vicinity of a natural fracture surface.

Together with supporting laboratory studies of diffusion and sorption characteristics made on core samples, the results of the in situ tests will provide a basis for integrating data on different scales, and testing of modelling capabilities for radionuclide transport up to a 100 m scale, c.f. Figure 2-1.

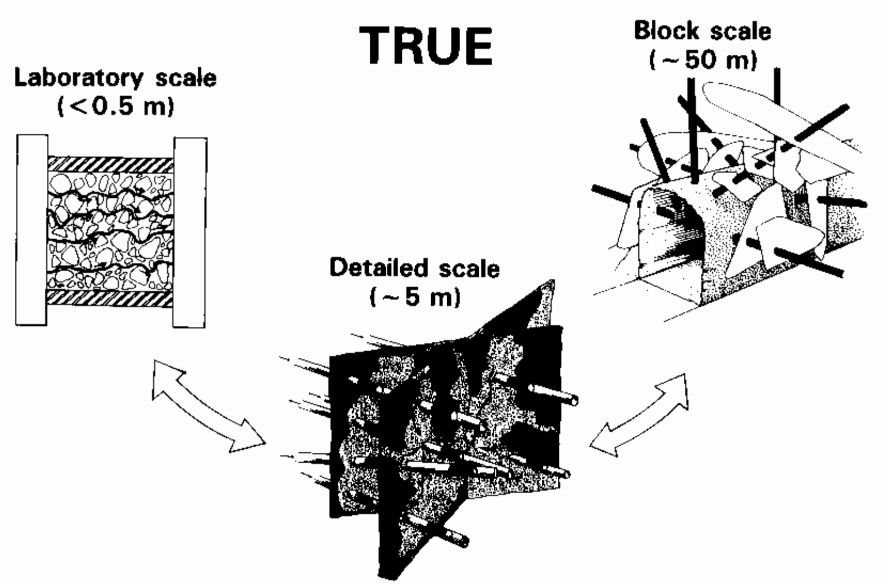


***Figure 2-1**. Schematic representation of transport scales addressed in the TRUE programme*

Basic results from the First TRUE Stage

The basic results and conclusions drawn by the SKB project group are:

- Feature A follows a reactivated mylonite, exposed to brittle deformation which has formed the main fault plane = main conductive element. One undulating structure, or alternatively several interconnected fractures. Bounded by a rim zone of altered Äspö diorite. Different mineralogical composition, grain size and porosity relative to the mylonite. Indications of clay minerals suggest presence of gouge material.

- Available tracer test methodology successfully adapted and applied in the detailed scale under prevailing conditions.

- Cationic sorbing tracers featured by sorption through cation exchange successfully applied in laboratory experiments and in in situ experiments. The sorbtivity of the tracers show the relative order; $^{22}Na^{+} < {}^{47}Ca^{2+} \approx {}^{85}Sr^{2+} << {}^{86}Rb^{+} \approx {}^{133}Ba^{2+} < {}^{137}Cs^{+}$.

- Unlimited diffusion/sorption in the rock matrix is the dominant retention mechanism for the tested time scales. Surface sorption, limited sorption in gouge material and diffusion into stagnant zones are second order for the strongly sorbing tracers.

- The use of laboratory data on diffusion/sorption parameters constitutes a basis for predictions of reactive tracer breakthrough, this provided that the water residence time distribution (conservative breakthrough) is known (can be assessed) and that variability in the β parameter is accounted for.

- The important processes identified at the time scales of the TRUE-1 in situ experiments are assumed valid also over PA time scales. Laboratory transport data on unaltered rock, not associated with fracture rim zone, are assumed applicable over PA time scales.

- The performed characterisation provides a powerful set of tools for assessment of conductive geometry and connectivity in future preliminary site characterisation, and in particular during future detailed site characterisation.

The experiments conducted during the First TRUE Stage have also been subject to predictions and evaluations using an assortment of different modelling concepts within the framework of the Äspö Task Force on modelling of groundwater flow and radionuclide transport (Elert, 1999, Elert, in prep.), cf. Section 2.9. The results of the project team evaluation modelling are reported by Cvetkovic et al (2000). In September the 4th International Äspö Seminar was held fully devoted to discussion of the TRUE-1 data and results and relevant studies and results from elsewhere. The basic conclusions from the seminar are presented by Winberg, ed, (in prep);

– There is a general consensus that the observed retardation observed in the TRUE-1 experiments requires diffusion into geological material to be an active process. This is supported by the –3/2 slope noted in log-log breakthrough curves. Whether this is due to diffusion (and subsequent sorption) in the altered matrix rock, or in possible fault gouge cannot be differentiated with available data,

– Some researchers claim that the observed enhanced retardation may be explained by diffusion into stagnant water pools, pure surface sorption, or may be due to an underestimation in the flow-wetted surface area. The latter effect may be attributed to a more complex flow path (multi-layered structure) or three-dimensional effects,

– A clear differentiation between the principal active process can only be assessed by resin injection and subsequent excavation and analysis,

– It was identified that experiments of TRUE type are important for improving the understanding of retention processes. However, this type of experiment may not necessarily be part of a site characterisation programme,

– It was recommended to broaden the data base from the TRUE-1 site before characterising pore space with resin techniques. This includes tracer dilution tests using sinks in other features than Feature A.

2.2.1 TRUE Block Scale Experiment

Background

The block scale (10-100 m) completes the sequence of scales addressed within the TRUE programme which in addition include detailed scale (0.5-10 m) and laboratory scale (≈ 0.5 m). The TRUE Block Scale project is an international partnership funded by ANDRA, ENRESA, Nirex, POSIVA, JNC and SKB. The TRUE Block Scale project is divided into five basic stages comprising;

- Scoping stage (1996-1997)
- Preliminary Characterisation stage (1997-1998)
- Detailed Characterisation stage (1998-1999)
- Tracer test stage (1999-2000)
- Evaluation stage (2000-2001)

The objectives and a basic experimental strategy are defined the test plan (Winberg, 1997).

Objectives

The specific objectives of the TRUE Block Scale Experiment, listed in the test plan for the experiment (Winberg, 1997), 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,

Results

During the period 1996 through 1999 five boreholes have been drilled, characterised and completed with multi-packer systems. The characterisation in single holes has included basic geological and structural logging, borehole TV imaging (BIPS), borehole radar, various types of flow logging (including Posiva´s flow logging), flow and pressure build-up tests. Cross-hole tests included collection and analyses of pressure responses due to drilling, cross-hole seismic surveys and cross-hole hydraulic interference tests. The latter type of tests performed during the Spring of 1998 and tracer Pre-tests performed during the Spring of 1999 included simultaneous tracer dilution tests, which enabled, apart from drawdown due to the pumping, assessment of change in flow rate in selected packer intervals, and selection of suitable injection sections. The possibility to perform well controlled (high mass recovery) block scale tracer tests in a fracture network (> 1 structure) has been demonstrated (Winberg (ed), 2000). The results of the performed characterisation has resulted in a focus on the fracture network defined by Structures #20, #13, #21, #22 and #23, cf. Figure 2-2.

In the course of the project the hydrostructural model of the major deterministic structures within the studied block has been updated five times, cf. Figure 2-3 for the March'2000 update. In the building of these models existing geological, geophysical, hydraulic and transport information is utilised. The studied block is characterised by a predominant set of structures that are oriented in the northwest. In addition, a few northesterly structures and three subhorizontal structures have been interpreted. The performed seismic and hydraulic cross-hole studies both show that these latter two sets are subordinate, and more importantly also from the hydraulic standpoint.

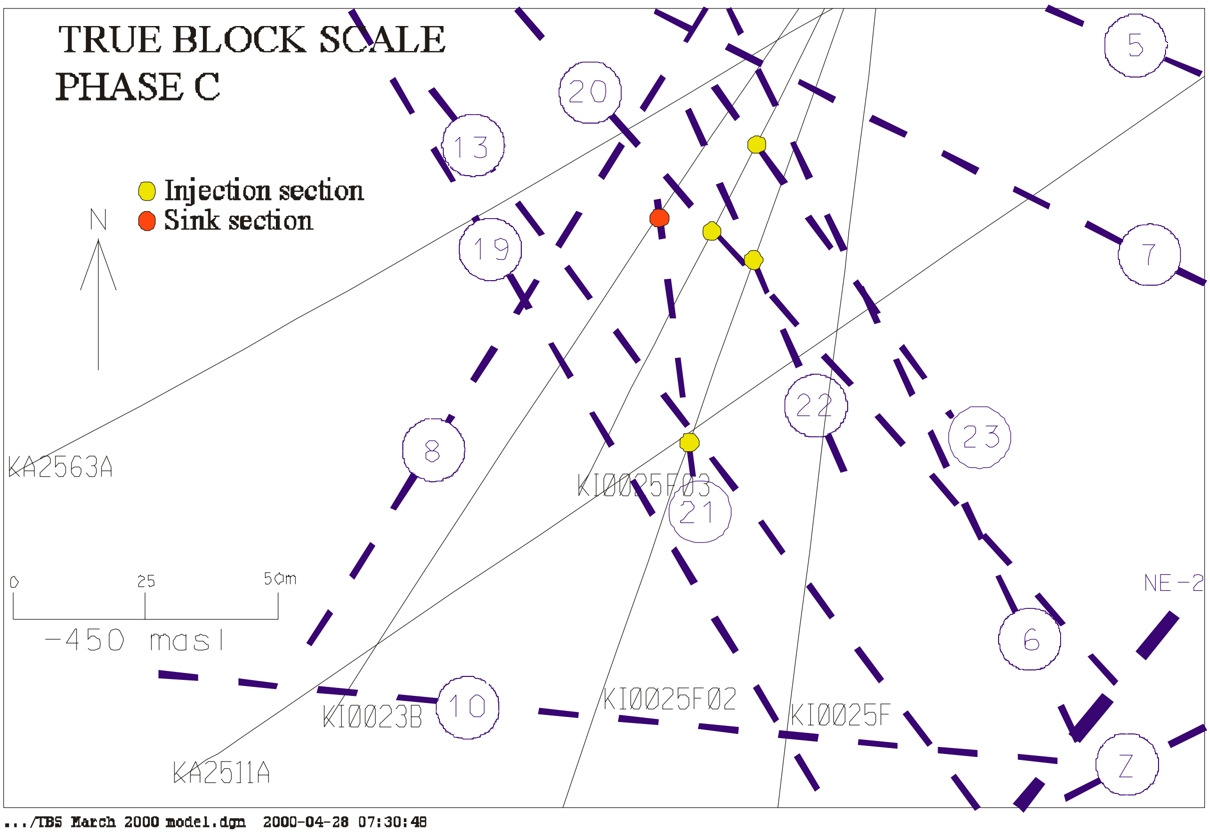


***Figure 2-2** Plan view of detail of the area where block scale tracer tests are performed*

Numerical modelling has involved stochastic continuum (SC), discrete fracture network (DFN) and channel network models (CN). The DFN modelling has been performed on a site scale, primarily to produce boundary conditions for developed models of the volume of interest. The channel network (CN) modelling has ia. focused on scoping calculations on the possibility to identify effects of fracture intersection zones (FIZ). The results show that the intersections are difficult to identify from conservative tracer tests. However, use of sorbing tracers may give a chance to identify these effects for selected test configurations. In addition the model has been used to predict the concluding tracer test as part of the Spring 1999 Pre-tests.

A tentative planning document for the Tracer Test Stage was presented in late June 1999. The document was further updated and presented at a Review meeting in late October 1999. The final document (Winberg (ed), 2000) presents the results of the performed tracer pre-tests and identified the basic issues/questions to be addressed by the planned tracer tests. The issues identified were;

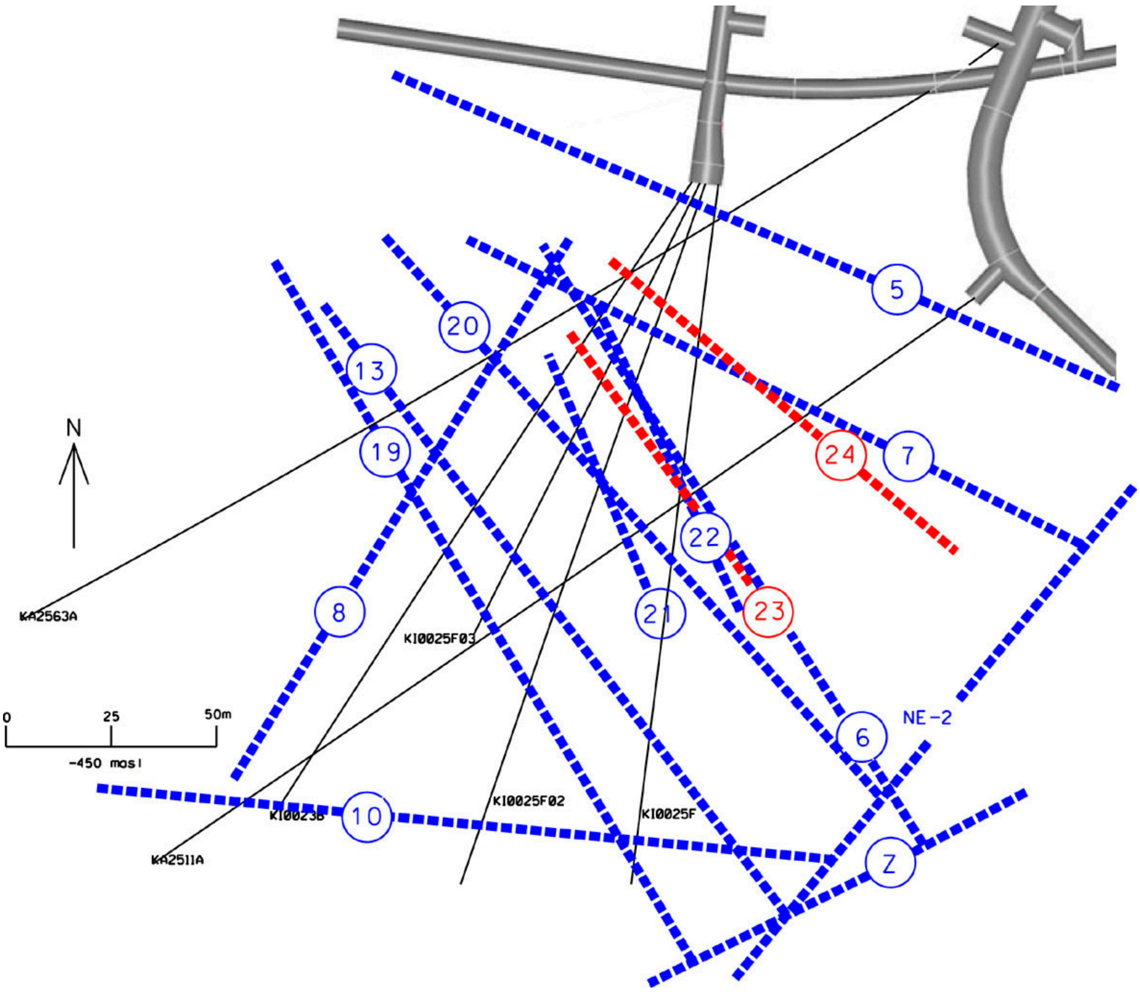


***Figure 2-3** Plan wiew of the reconciled March '2000 structural-geological conceptual model of the TRUE Block Scale rock volume (Hermansson and Doe, 2000) (Plan view of a horizontal section at 450 meters depth). The structures indicated in red are new structures, # 23 was indicated alredy in the March '99 model.*

Q1 "What is the conductive geometry of the defined target volume for tracer tests within the TRUE Block Scale rock volume? Does the most recent structural model reflect this geometry with sufficient accuracy to design and interpret tracer tests?"

Q2 "What are the properties of fractures and fracture zones that control transport in fracture networks?"

Q3 "Is there a discriminating difference between breakthrough of sorbing tracers in a detailed scale single feature, as opposed to that observed in a fracture network in the block scale?"

On the basis of the identified issues/questions, a set of hypotheses were developed (Winberg (ed), 2000), to be addressed by the planned tests.

In addition it was proposed to drill yet another characterisation borehole to allow shorter transport paths for radioactive sorbing tracers, and as a means of verification of the model of the conductive geometry. The new borehole, KI0025F03, has been drilled and characterised.

Subsequently, the first phase, Phase A, of the tracer Test Stage has been performed including use of KI0025F03. The objectives of these tests were to provide a basis for selecting the best sink section for the continued testing. Further, to provide complementary pressure drawdown and tracer dilution data. The phase was concluded with a tracer test with injection in a limited (4-5) sections (Andersson, et al., 2000a). The Phase A tests were also subject to model predictions using the developed SC, DFN, and CN models. The Phase A results indicated that the sink in KI0023B:P6 in Structure #21 (although well connected to Structure #20) is the best sink interval.

Subsequently the Phase B were performed with the principal objective to demonstrate that the suitable flow paths also were characterised by a satisfactory high mass recovery (> 80%) to ensure that tests with radioactive sorbing tracers could be performed with minimised risk for uncontrolled losses. In order to demonstrate the effects of diffusion Phase B was divided in an initial phase (B1) at a reduced flow rate (Q=1.1-2 l/min) after which the flow rate was increased to 2.3 l/min (Andersson et al., 2000b). The combined use of two flow rates and the used of the high-diffusive He-3 dissolved in water, enabled a clear identification of effects of diffusion, with an observed retardation compared to a conservative dye tracer in the same flow path, and a somewhat reduced peak in the breakthrough curve. These tests were not subject to blind model predictions, but the experimental results were simulated and integrated into the numerical models to allow best possible basis for predictions of the Phase C tests. Two additional modelling concepts have been added for the prediction/evaluation of the Phase C tests. These are the LaSAR concept, previously employed in the TRUE-1 analysis (Cvetkovic et al, 2000) now extended for use in the analysis of block scale transport in networks. The second is the so-called Posiva concept which is founded on the use of measured flow rates supported by detailed DFN modelling.

Complementary studies include ^{14}C PMMA impregnation of wall rock and gouge particles in mm-cm size from intercepts of structures involved in the tracer tests. In addition, the existing data and information is being used to produce simplified conceptual sections and models of structures of interest. Parallel to the concluding field work and modelling work, work on the final evaluation and reporting has started up. The TRUE Block Scale project will be reported in a series of four final reports;

#1 Characterisation and model evolution

#2 Tracer tests in the block scale

3 Modelling of flow and transport

#4 Synthesis of flow, transport and retention in the block scale

Scope of work for 2001

The following activities are planned for 2001:

- Integration of PMMA results with developed conceptual models of individual structure intercepts and for structures as a whole,
- Continued development of numerical models, where the main task will be the evaluation of the Phase C tests, which include tests with radioactive tracers.
- Evaluation
- Reporting

2.2.1 TRUE Block Scale Continuation

Background

In year 2000 it was decided to collect all future TRUE work within one project with a main focus on the existing TRUE Block Scale site. In this context it was identified that work at the TRUE Block Scale site can focus not only on continued study of transport and retention processes in the block scale, but also on corresponding studies carried out on in single fractures/structures. A tentative programme was prepared mid 2000 which presented a number of optional levels of ambitions for a continuation. These included;

BS 2a) continuation of the Phase C tracer test pumping with continued sampling (including employment of developed enrichment techniques to lower detection limits. Complementary modelling work.

BS 2b) additional tracer injection in injection sections with documented recovery < 80% (to be negotiated with SSI on the basis of results obtained and the environmental monitoring programme in the surrounding environment).

BS 2c) reassessment of the need for remediation of the KI0023B piezometer possibly followed by additional flow logging in the borehole, updated packer configuration and cross-hole tests with tracer dilution tests.

Commitment to a possible second level of continuation (denoted BS 3), which included development of a new access tunnel, new boreholes in complementary angles was inhibited by the TRUE Block Scale Steering Committee and SKB.

As indicated in Section 2.2.1, the outcome of the 4th International Äspö Seminar (focused on the First TRUE Stage) re-emphasised the need for conducting the planned injection of epoxy resin at the TRUE-1 site. However, before conducting such an impregnation, some complementary testing is foreseen, including crosshole hydraulic interference tests with tracer dilution tests. These tests would use sink sections others than those employed in the previously performed tests. A complication for the scheduling of planned work lies in the fact that the TRUE-1 and LTDE sites are hydraulically connected. In view of the urge for a relative hydraulic tranquillity on the part of LTDE, a priority for advancing LTDE has been set by SKB. Consequently, the resin impregnation at the TRUE-1 site will be postponed accordingly. According to the present plans injection will be possible early 2004.

Scope of work for 2001

Q3

Complementary modelling (Block Scale site)

Planning of resin injection work (techniques, hardware, radiation safety aspects)

Q4

Complementary tracer injections (TRUE Block Scale site)

2.3 Long term test of diffusion in the rock matrix

Background

A deep granitic rock repository for radioactive waste will not only serve as a long term physical barrier sheltering the waste containment in geological time scales, it will also act as a chemical barrier preventing migration of several radionuclides. A chemical barrier could be of significance in the case of waste containment failure releasing radionuclides to the water. Transport of radionuclides by water will occur by water flow in fractures and by diffusion in the rock matrix. Transport of radionuclides in rock fractures is studied within the current TRUE experimental programme, whereas matrix diffusion studies will require a somewhat modified experimental approach. Based on results from laboratory experiments, the expected low matrix diffusivities for different radionuclides will be difficult to observe in the ongoing and planned dynamic experiments in the TRUE programme, given the practical time constraints of the planned experiments. Hence, a static long-term diffusion experiment is proposed. It should, however, be stated that diffusion into the matrix with subsequent sorption on inner surfaces are included in evaluation concepts used by most teams analysing the TRUE-1 experiment within the context of the Äspö Task Force, including the evaluation concept used by the SKB TRUE team.

The chemical reactions involved in sorption of radionuclides can according to a simple view be divided in ion exchange, inner-sphere complexation and outer-sphere complexation. The mobility of radionuclides is strongly affected by the interaction with geologic materials. The transport of dissolved solutes can be regarded as a distribution between species in solution (ionic species, inorganic- and organic-complexes), mobile solid phases (particulate matter, colloids, precipitates etc.) and stationary solid phases (minerals). The distribution is often expressed as a distribution coefficient, K_d, which is an equilibrium constant for a reversible sorption process. Kinetic effects and irreversible sorption mechanisms are thus not included in a K_d value. Since most of the radionuclides in nuclear waste are influenced by any of the sorption mechanisms mentioned above during their transport in the rock matrix it is possible to take advantage of a combined diffusion and sorption experiment. By using sorbing radionuclides in a diffusion experiment one will automatically have a fixation of the tracer in the diffusion pathways. It is however important that one knows the sorption behaviour of the tracers, (e.g. specific sorption mechanisms, ”sites” and reversibility or kinetics) in order to evaluate the diffusion pathways.

Matrix diffusion studies of radionuclides have been performed in several laboratory experiments and also *in situ*. Some experimental conditions such as pressure and natural groundwater composition are, however, difficult to simulate in laboratory experiments. Investigation of rock matrix diffusion in laboratory scale implies that rock specimens are used in which damage due to drilling and unloading effects (rock stress redistribution) may have caused irreversible changes of the rock properties. Investigation of matrix diffusion in non-disturbed rock is therefore preferably investigated *in situ.* Through the proposed experimental technique it is also possible to get some information of the adsorption behaviour of some radionuclides on fresh granitic rock surfaces, which is of interest for the short term safety in a repository

Scoping calculations for the planned experiment have been performed (Haggerty, 2000) using the multi-rate diffusion concept which accounts for pore-scale heterogeneity. A test plan was drafted and presented at the combined TRUE-2/LTDE review meeting in March 1999. The review and desires of SKB redirected the experiment towards an assessment of diffusion from a natural fracture surface, through the altered zone into the intact unaltered matrix rock. The new direction resulted in a revision of the test plan to its final form (Byegård et al. 1999). The experimental concept is shown in Figure 2-4.

The objectives of the Long-Term Diffusion Experiment project are:

- To investigate diffusion into matrix rock from a natural fracture *in situ* under natural rock stress conditions, hydraulic pressure and groundwater chemical conditions .
- To obtain data on sorption properties and behaviour 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.

Experimental concept

A core stub of 50 mm length with a natural fracture surface is isolated in the bottom of a large diameter telescoped borehole. A cocktail of non-sorbing and sorbing tracers are circulated in the test section for a period of 3-4 years after which the core stub is over-cored, and analysed of tracer content and tracer fixation, cf Figure 2-4.

The experiment is planned to be focused on a typical conductive fracture identified in a pilot borehole (KA3065A02) drilled within the context of the SELECT-2 project. A telescoped large diameter borehole (300/196.5 mm) is to be drilled subparallel to the pilot borehole in such away that it intercepts the identified fracture some 10 m from the tunnel wall and at an approximate separation of 0.3 m between the mantel surfaces of the two boreholes, cf. Figure 2-4, leaving a 50 mm deep core stub with a diameter of 177 mm in the borehole.

The stub is sealed off with a polyurethane cylinder and a peek lid which constitutes a "cup-like" packer, cf. Figure 2-5. The remainder of the borehole will be packed off with a system of one mechanical and two inflatable packers. The system of packers and an intricate pressure regulating system will be used to eliminate the hydraulic gradient along the borehole.

During the circulation of tracer, samples of water will be collected at various times over the duration of the experiment. The redox situation in the circulation loop will be monitored continuously with a flow through cell, which will measures pH, Eh (3 different electrodes) and temperature. After completion of tracer circulation, the core stub is over-cored, sectioned and analysed for tracer content.

The project also involves a variety of mineralogical, geochemical and petrophysical analyses. In addition, as in the REX project, a "replica" laboratory through diffusion experiment is planned on the corresponding "stub" collected from the small diameter KA3065A02.

Experimental concept

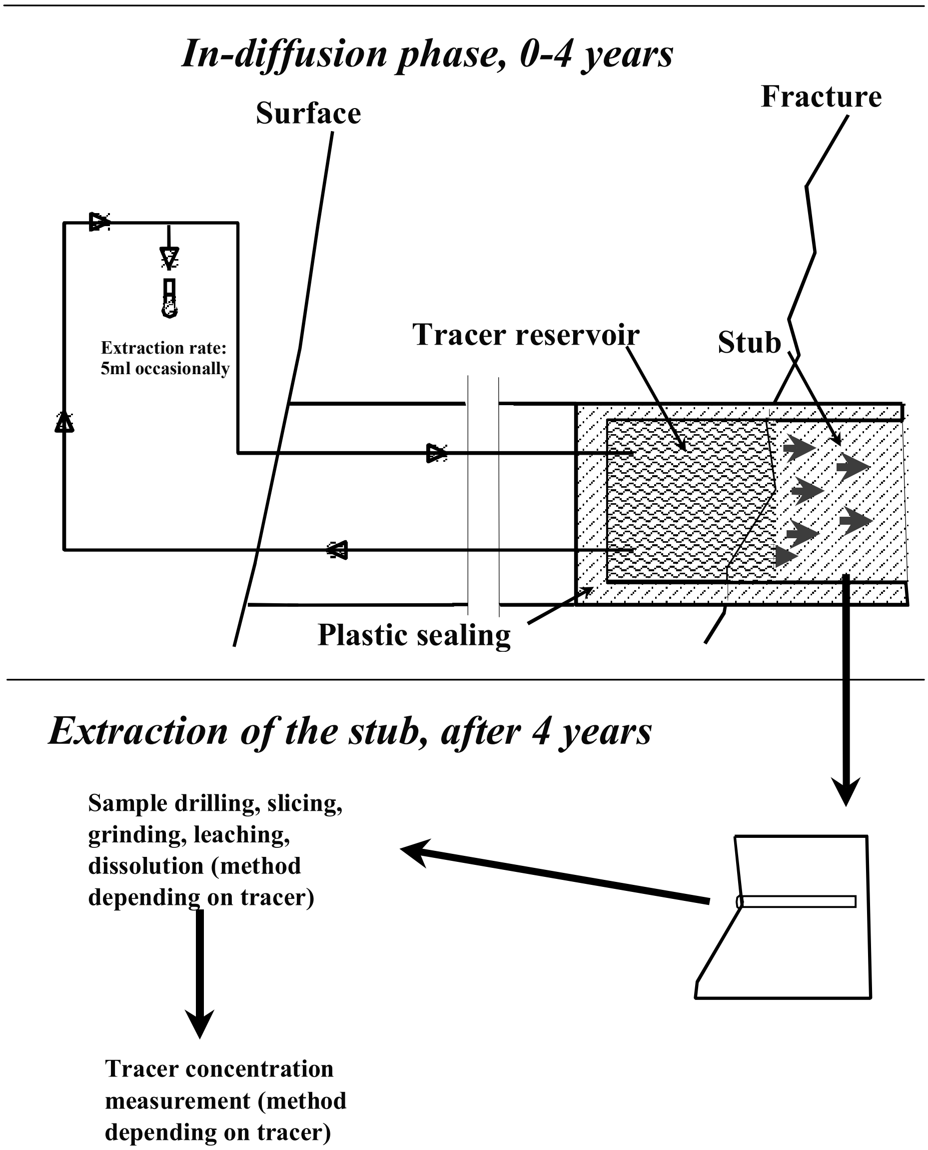


Figure 2-4 *Experimental concept of the Long-Term Diffusion Experiment (Byegård, et al., 1999)*

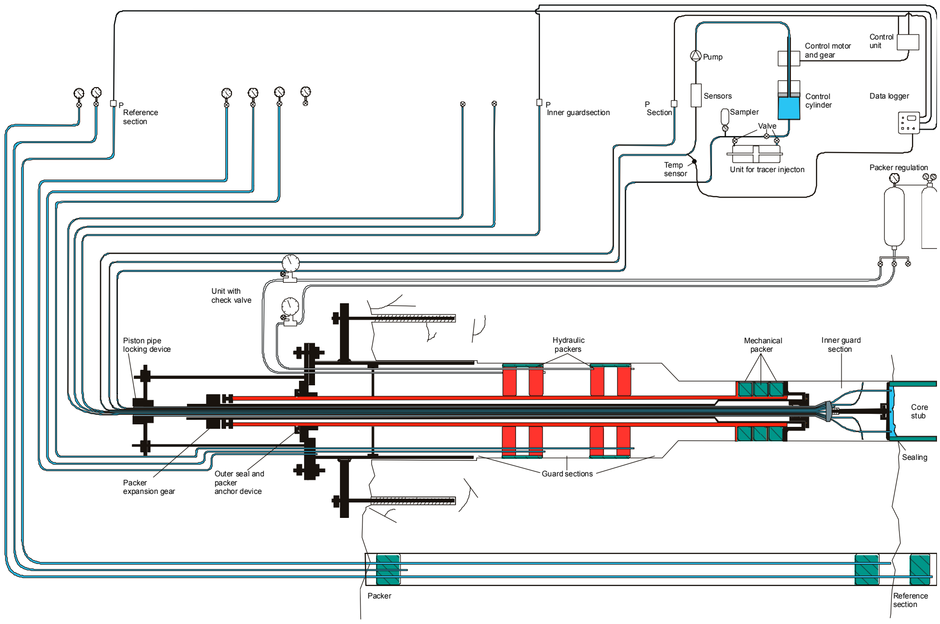


Figure 2-5 *Schematic drawing showing the surface and down-hole equipment in the telescoped larger diameter LTDE borehole and the adjacent pilot borehole*

Results

The drilling of the telescoped large diameter experimental borehole was performed with a high degree of interactivity between; careful iterative drilling in short uptakes (particularly in the inner part of the bortehole), BIPS imaging, core examination and on-site structural modelling/updating of structural model. The original plan was that the target fracture should be intercepted and passed in such a way that an approximately 50 mm long "stub" remained in the borehole. However, due to poor visibility caused by degassing, which seriously impaired the BIPS imaging, and the fact that a critical part of the core immediately adjacent to the target structure fell out of the core barrel at the bottom of the borehole, the resulting stub turned out three times longer, ie. 150 mm.

The implications of this state of affairs are;

1. The projected diffusion length in the core is three times longer than originally planned. The diffusion front for the least sorbtive tracers is expected to be in the order of 0.3-0.4 m, ie. 50% of the diffusion path of the least sorbing tracers will be in the core stub. The core stub may to a variable degree be affected by sample disturbance due to; (i) stress concentrations associated with the advancing drill bit, and (ii) unloading of stress acting of the remaining core stub.

2. The sealing length of the stub is 150 mm, compared to the optimal sealing length of 50 mm. This was originally regarded as a serious constraint, but through a sandwiched polyurethane cylinder with progressively less deformable material towards the surface of the stub, the problem was resolved.

To investigate the effects noted under item (1) above a series of in situ and laboratory measurements have been conducted which have been compared with existing in situ Äspö data/results and results in the literature. The performed in situ measurements included endoscope video imaging of the walls of the core stub in the 9.75 mm cylindrical slot. In addition the experimental borehole and the stub surface has been documented by analog video using a remote controlled vehicle. The results showed that no macroscopic fractures could be seen on the walls of the stub. Second, the inflow points along the boreholes could be established in a tentative way from the video recordings. The location of inflow points was subsequently established in more detail using single packer flow logging. The laboratory work, apart from basic mineralogy and geochemistry along the pilot and experimental boreholes, included micro-seismic measurements on drill cores, and thin sections analyses in various directions, the latter two measurements aimed at quantifying the degree of sample disturbance on the core. Performed mechanical modelling and performed measurements indicate that no, or insignificant disturbance due to formation of new micro fractures is to be expected. However, opening of existing grain boundaries and widening of existing micro fractures will occur throughout the core stub. The degree to which unloading of rock stresses will create significant damage is intimately tid to the in situ state of rock stress conditions at the site. While the effect of the unloading in the relatively low-stressed rock at Äspö is expected to be small, the effect of unloading in terms of opening of grain boundaries and widening of existing micro fractures is expected to be minimal. Hence, although the geometrical premises for the experiment as originally planned are not fulfilled, the experiment is still doable and relevant.

The updating of the hydro-structural model of the LTDE site has been more problematic than anticipated. The problem lies not so much in the linking of the marker structure in the pilot borehole with the target structure in the large diameter borehole. Instead it has been found difficult to link structures/fractures predicted from the pilot borehole with those found in the large diameter experimental borehole. The main problem is interpreted to be associated with scale (smaller structures=fractures) compared to eg the structures which have been connected between boreholes at the TRUE Block Scale site, cf. Section 2.2.2, in combination with an undulating character in the fractures considered. Detailed mineralogy and geochemistry has in this context helped out in improving the correlation of structures between the two boreholes.

Within SKB work is ongoing on updating quality systems. In addition a general policy decision has been taken that equipment and experimental setups used should be marked with the CE marker, governed by European Union regulations. The CE marker is not a quality qualifier, but rather a signature that the equipment/equipment set up is safe from a personal and functional safety standpoint, and that the risk for environmental hazard is minimised. The LTDE in this context constitutes a training set for SKB. The CE process has had a positive effect on the final phase of the LTDE construction phase, although it has delayed the project in relation to the original schedule.

Scope of work for 2001

- Installation of equipment in experimental borehole
- Installation of sampling and regulation equipment in container
- Performance of pre-tests
- Obtaining permit from Swedish Radiatation Protection Agency (SSI)
- Start of tracer circulation (initiation of experiment)

– Start-up of replica experiment

2.4 Numerical modelling of groundwater flow and transport of solutes

Background

Mathematical models for groundwater flow and transport are important tools in the characterisation and assessment of underground waste disposal sites. SKB has during the years developed and tested a number of modelling tools. At the Äspö HRL several modelling concepts such as Stochastic Continuum (SC) and Discrete Fracture Network (DFN) concepts have been used. The SC approach has been used for the regional and site scale models (Svensson 1997a,b) and in the laboratory scale model the starting point has been a fracture network for assigning hydraulic properties to a SC model (Svensson, 1999b). The methodology of how to transform the fracture network to the SC was shown in Svensson (1999a); the methodology developed is called the GEHYCO concept. Based on the new data available since the Äspö model 1996, reported in Rhén et al (1997b), and the new concept of generating the conductivity field (Svensson,1999a), it is planned to update the site, laboratory and regional models of the Äspö area. However, some of this updating may be performed within the context of the Task Force. Furthermore, it has recently been decided to prepare the modelling tool for use within the future site investigation programme.

Objectives

The general objective is to improve the numerical model in terms of flow and transport and to update the site-scale and laboratory scale models for the Äspö HRL. The models should cover scales from 1 to 10 000 metres and be developed for the Äspö site, but be generally applicable.

The specific objectives with the updated models are:

- Test and improve new methodology of generating a conductivity field based on a fracture network in a continuum modelling approach.
- Develop models for transport and dispersion.
- Improve the methodology for calibration and conditioning the model to observed conductive features of the groundwater flow models.
- Improve the handling of the inner boundary conditions in terms of generating the tunnel system and applying boundary conditions.
- Improve the data handling in terms of importing geometrical data from RVS to the numerical code for groundwater flow and to export modelling results to RVS.
- Increase the details in the models based on new knowledge of the Äspö site collected during the last years.

Modelling concept

Experiences gained from international modelling tasks within the Äspö Task Force on modelling of groundwater flow and transport of solutes have shown that the different concepts used are all useful but there are needs to develop both the codes in terms of data handling and visualisation. It is also necessary to continue developing and testing the concepts (Gustafson and Ström, 1995 and Gustafson et al, 1997). The model code to be used is DarcyTools (previously called PHOENICS when a different solver was used), which has been used in regional scale, sites scale and laboratory models (Svensson 1997a,b and 1999b).

The results from the construction phase of the Äspö HRL showed a relatively high number of events with a high inflow rate during drilling. Features with a high transmissivity were drilled through at a number of times and these features were in several cases not a part of the deterministically defined major discontinuities. This has also been seen in bore holes made in the operation phase of the Äspö HRL. These features were called High Permeability Features (HPF). The spatial distributions of these features, and features with lower transmissivity, have been studied and are a base for modifying the modelling concepts (Rhén and Forsmark, 1999, Rhén et al 1997b).

(High Permeability Feature (HPF), as defined in Rhén and Forsmark (1999) consist of a fracture, system of fractures or fracture zone with an inflow rate (observed during drilling or flow logging) which exceeds 100 l/min or alternatively show a transmissivity $T \geq 10^{-5}$ m^2/s. Some of the conclusions from the study of the data from the pre-investigation and the construction phase of the Äspö HRL (Rhén and Forsmark, 1999).)

Scope of work for 2001

The main tasks are:

- Finalising of Part 1 of NUMMOD (feasibility studies)
- Launching of the first official and documented version (0.0) of DarcyTools
- Execution of Part 2 of NUMMOD (implementation of version 0.0 for updated Äspö models)
- Participation in Task 6 of the Äspö Task Force

The first task aims at developing and testing the numerical code for the flow and transport calculations, which is made before the Äspö models are updated. The second task aims at obtaining a tool applicable for the site characterisation phase, while the third task entails implementing DarcyTools version 0.0 for models of Äspö at local and regional scales. The fourth task involves groundwater flow and radionuclide transport modelling at Äspö on block to site scales. The tasks are described shortly below and in more detail in relevant Test Plans.

Feasibility studies

During 2000 a number of feasibility studies were performed (transport and dispersion, porosity concepts, conductivity and scale relations). What remains to be done is related to various modelling techniques that may be utilised, transport and dispersion of a continuous phase (e.g., salt), and finally a summary of all feasibility studies performed.

DarcyTools version 0.0

The objective is to obtain an official and documented version (version 0.0) of DarcyTools. This is to be accomplished by mid 2001 when Part 1 of NUMMOD is finalised. After the complete NUMMOD project has been terminated, DarcyTools will be evaluated and an official version 1.0 will be launched in time for the initiation of the site investigations.

Implementetion of DarcyTools version 0.0 for updated Äspö models

Using DarcyTools version 0.0, updated models of Äspö at regional and local scales will be produced. The objective is twofold; first, to test the different concepts and techniques that have been developed during Part 1 of NUMMOD, and second, to obtain better and more realistic models of Äspö for use within other Äspö HRL projects. Specific differences between the previous models and the new models are e.g. the use of the GEHYCO technique for obtaining conductivity fields, and the use of embedded grids.

Task 6

The scope of Task 6 is to model flow and radionuclide transport in a single fracture and in a fracture network (block scale) for typical field-scale experimental conditions and for conditions relevant for performance assessment. The objective is to evaluate how models perform when applied on different temporal and spatial scales. This exercise may substitute the previously planned update of the Äspö model at laboratory scale.

2.5 Radionuclide retention (CHEMLAB)

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 properties of the radionuclides, 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 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, organic matter, bacteria, etc. are present in the experiments. Laboratory investigations have difficulties to simulate these conditions and are therefore dubious as verification exercises. The CHEMLAB borehole-laboratory has been constructed and manufactured for verification experiments in situ at undisturbed natural conditions. Figure 2-6 illustrates the principles of the CHEMLAB 1 and CHEMLAB 2 units.

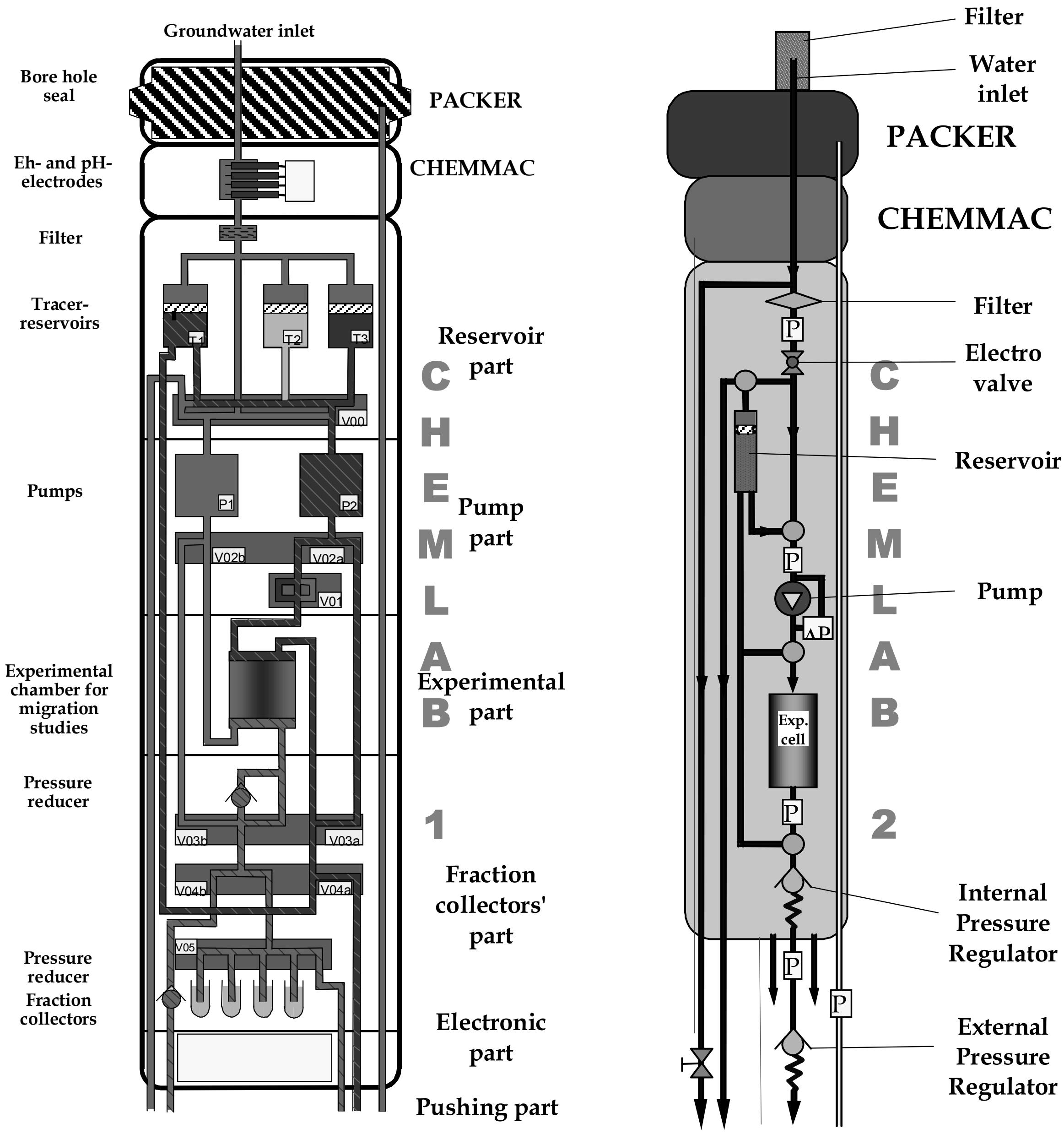


Figure 2-6 *Schematic illustration of CHEMLAB 1 and 2*

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 relevant radionuclides

Experimental concept

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

Initially one "all purpose" unit was constructed in order to meet any possible experimental requirement. This unit CHEMLAB 1 has been used for the "diffusion in bentonite" experiments and will now be used for similar experiments including the effects of radiolysis. Others to follow are:

- Migration from buffer to rock
- Desorption of radionuclides from the rock
- Batch sorption experiments

The CHEMLAB 2 unit is a simplified version of CHEMLAB 1, designed to meet the requirements by experiments where highly sorbing nuclides are involved. These are:

- Migration of redox sensitive radionuclides and actinides
- Radionuclide solubility
- Spent fuel leaching

Scope of work for 2001

The experiment with radiolyses was prepared in 1999 and planned to be conducted and completed within 2000. Due to delays in the final evaluation of the previous experiment, diffusion in bentonite, radiolysis experiments are to be conducted during 2001. The execution of the experiment is similar to the previous diffusion experiment.

The first experiment to be carried out in CHEMLAB-2 is the migration of actinides, Americium, Neptunium and Plutonium, in a rock fracture. This experiment is conducted in co-operation with Institut für Nuklear Endsorchung in Karlsruhe, INE. Three different runs are planned. Two for obtaining data on nuclide migration, one experiment for demonstrating actinide fixation.

2.6 Colloid

Background

It has been argued that e.g. plutonium is immobile owing to its low solubility in groundwater and strong sorption onto rocks. Field experiments at the Nevada Test Site, where hundreds of underground nuclear tests were conducted, indicate that plutonium is associated with the colloidal fraction of the groundwater. The $^{240}Pu/^{239}Pu$ isotope ratio of the samples established that an underground nuclear test 1.3 km north of the sample site is the origin of the plutonium (Kersting et al., 1999). Based on these results SKB decided to initiate the project COLLOIDS at Äspö-HRL to study the stability and mobility of colloids.

Objectives

The objectives of the SMC project is to:

1. Study the role of bentonite clay as a source for colloid generation
2. Verify the colloid concentration at Äspö HRL
3. Investigate the potential for colloidal transport in natural groundwater flow paths

Experimental concept

The experimental concept for the Colloid project is: laboratory experiments, background measurements and fracture specific measurements. These concepts are described below:

Laboratory experiments: The role of the bentonite clay as a source for colloid generation at varying groundwater salinities (NaCl/CaCl) will be studied in a laboratory experiment performed at KTH (Royal Institute of Technology) and at the company Clay Technology AB (Figure 2-7).

Background measurements: The background colloid concentration associated with the different water types found at Äspö will be sampled at specific locations along the Äspö HRL-tunnel. The colloid content will be measured on-line from the boreholes by using a modified laser based equipment LIBD (Laser-induced Breakdown-Detection) which has been developed by INE in Germany (Figure 2-8). The advantage is that the resolution of this equipment is higher compared with standard equipment of this type. It is therefore possible to detect the colloid contents at much lower concentrations than previously possible. The outcome of these measurements will be compared with standard type of measurements such as particle counting by using Laser Light Scattering (LLS) at KTH and at INE. Standard type of filtration performed on-line at the boreholes are used in order to be able to compare/transform these results to all the earlier colloid sampling campaigns at Äspö.

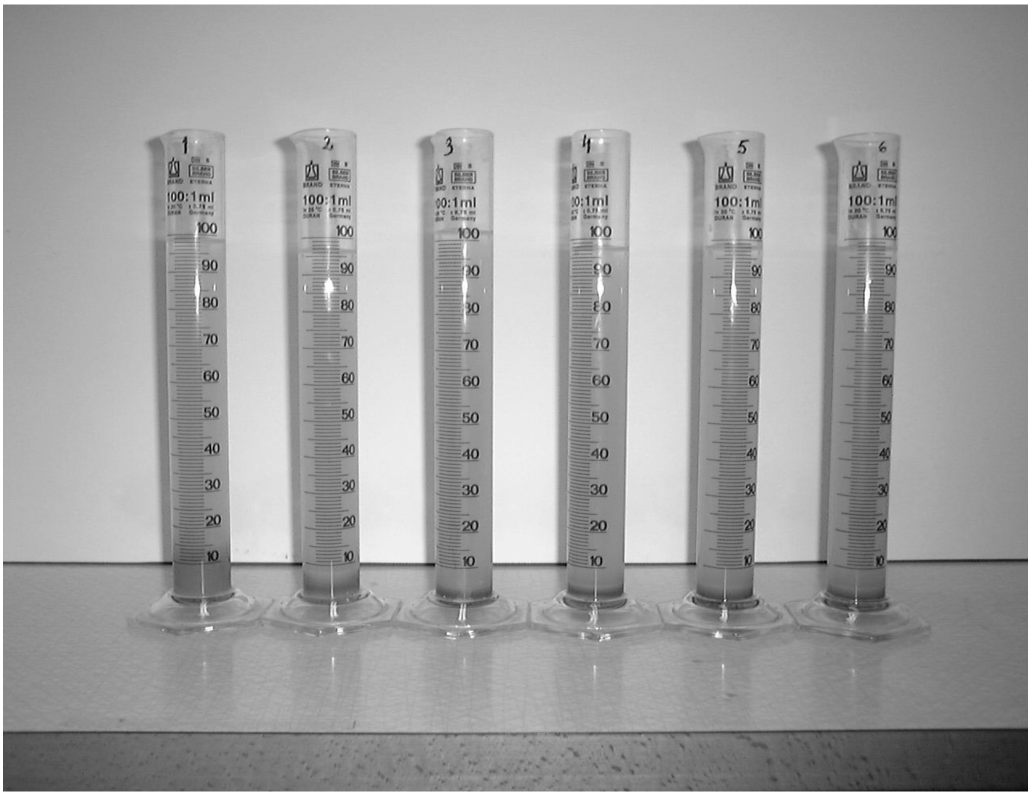


Figure 2-7 *The salinity of the water may affect the colloid generation. The experiment show different degrees of sedimentations of bentonite clay dependent of the ion content (NaCl) in the water. A very high or low ion content may result in bentonite instability and colloid generation.*

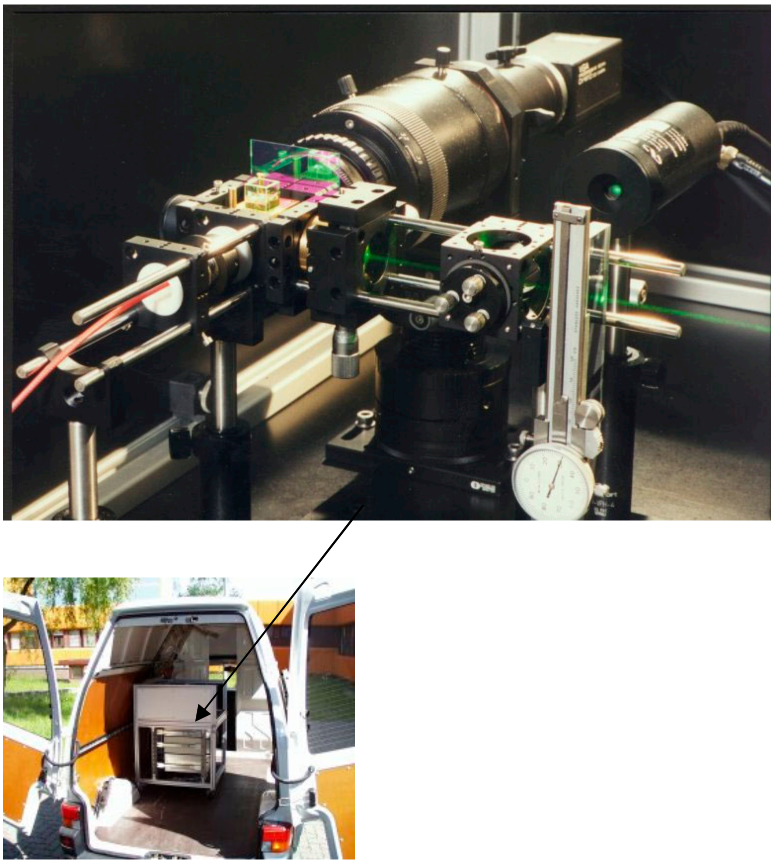


Figure 2-8 *Equipment for Laser-induced Breakdown-Detection (LIBD) of colloids (upper picture). The equipment is installed in a van in order to allow mobility and on-line measurements (lower picture).*

Fracture specific measurements: For the fracture specific measurements two nearby boreholes at HRL will be selected for the experiment. One of the boreholes will be used as an injection borehole and the borehole downstream will be used as a monitoring borehole. The boreholes intersect the same fracture and have the same basic geological properties. After assessing the natural colloid content in the groundwater bentonite clay will be dissolved in ultra pure water to form colloidal particles. These clay colloids will be labelled with a water conservative tracer (uranine). The mixture will be injected into the injection borehole (Figure 2-9). From the monitoring borehole the colloidal content will be measured with laser (LIBD/LLS), the water will be filtered and the amount of tracers will be measured.

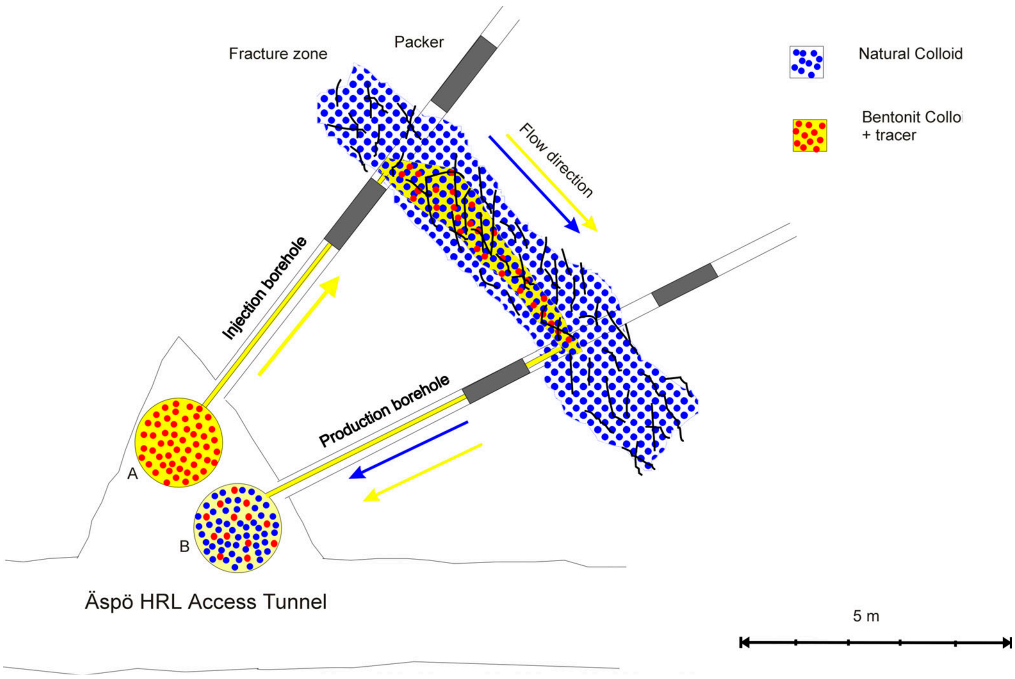


***Figure 2-9** Injection of bentonite colloids and a tracer at the injection borehole and monitoring of the injected and natural colloids in the production borehole.*

The following results are of interest 1) is the colloid content lower after the transport? 2) is the nuclide association irreversible on the colloids? And 3) is the bentonite clay a potential source for colloid generation? The outcome of the experiment is used to check the calculations in the safety assessment report TR 91-50 to be used in future colloid transport modelling. The experiment will be performed in association with the TRUE-trace experiment programme.

Scope of work for 2001

The scope of the work for 2001 contains to conduct the laboratory tests (January-June) and to perform the background measurements (August-December).

2.7 Microbe

Background

A set of important microbiology research tasks for the performance assessment of high level radioactive waste (HLW) disposal has been identified by Pedersen and Karlsson (1995) and Pedersen (1996, 1999) They are:

1. Microbial influence on radionuclide migration. To what extent can bacterial dissolution of immobilised radionuclides and production of complexing agents increase radionuclide migration rates?

2. Microbial corrosion of copper. Bacterial corrosion of the copper canisters, if any, will be a result of sulphide production. Two important questions arise: Can sulphide producing bacteria survive and produce sulphide in the bentonite

surrounding the canisters? Can bacterial sulphide production in the surrounding rock exceed a performance safety limit?

3. Microbial production and consumption of gases. Will bacterial production and consumption of gases like carbon dioxide, hydrogen, nitrogen and methane influence the performance of repositories?

4. The subterranean biosphere. Is there a deep subterranean biosphere and how does it sustain its life processes? What energy sources and fluxes of energy will be available for microorganisms in and around a HLW repository?

5. Microbial reducing activity. Will bacterial oxygen consumption significantly contribute to oxygen removal from a HLW and to what extent may bacterial production of reduced compounds such as organic material, methane, sulphide and ferrous iron contribute to keeping the repository host rock reduced?

6. Microbial recombination of radiolysis products. Will bacterial recombination of radiolysis products significantly contribute to the removal of unwanted oxidised molecules such as oxygen?

7. Alkaliphilic microbes and concrete. Do relevant microorganisms survive at pH equivalent to that of repository concrete and can they possibly influence repository performance by concrete degrading activities such as acid production?

These tasks have been addressed in a range of projects, of which several is ongoing. Important conclusions have been obtained based on laboratory and field data (Pedersen et al. 2000a, 2000b). While some results seem very solid with general applicability, others are pending inspection at *in situ* conditions. This is especially true for data generated at the laboratory only. *In situ* generated data must be obtained for microbial activities in the far- and near-field environment at realistic HLW repository conditions. This can only be achieved at an underground site, developed for microbiological research, using circumstantial protocols for contamination control during drilling and operation. An *in situ* site allows experiments at natural pressure with correct gas content in groundwater which is of great importance for microbial activity and very difficult to obtain in vitro. Such a site was drilled in May 1999 in the J-niche at Äspö HRL, 450 m underground. Three boreholes were produced.

Objectives

The demands on a high level nuclear fuel waste (HLW) include reaching reduced conditions before significant oxygen corrosion of the copper canisters occurs. It is also important that sulphate reducing bacteria do not produce sulphide in the buffer in amounts that may threat the canister intergrity. Reducing conditions will also be necessary for correct functioning of the host rock. Several radionuclides fail to sorb to the rock at oxidising conditions. Microorganisms will contribute to create reducing conditions in the reduction of the repository environment, thereby providing improved conditions for HLW disposal compared to conditions without microbes. Their ability to do so is very much related to available energy sources in rock, groundwater, buffer and backfill. Hydrogen produced or entrapped in very deep rock environments is expected to support a sustainable energy source for the indigenous microbial populations at repository depth. Earlier research concerning microbiology and nuclear waste disposal has included investigations at laboratory and at various sites during the pre-investigation and constructions phases of Äspö HRL. The microbe site will significantly help to clarify and demonstrate to what extent microbial reactions may support, or threat, the repository concept. The major objectives for the MICROBE site are:

- To assay microbial activity in groundwater at in situ conditions. Influence on redox conditions, radionuclide migration and gas composition and consumption will be in focus.
- To establish data on hydrogen generation and flow in granitic rock environments. The flow of hydrogen from the source will determine the possible rate of long term microbial subterranean activity.
- To enable experiment where the engineered barriers, bentonite, backfill and copper can be investigated for the influence of microorganisms at realistic and controlled conditions with a significant knowledge about the microbiology of the groundwater used.
- To generate accurate data about rates of microbial reactions at repository conditions for performance assessment calculations.

A detailed testplan has been published recently (Pedersen 2000a).

Experimental concept

The microbe site consists of three core drilled boreholes, KJ0050F01, J0052F01 and KJ0052F03, intersecting water conducting fractures at 12.7, 43.5 and 9.3 m respectively. Each borehole is equipped with packer systems that allow controlled sampling of respective fracture. Special attention was directed towards the use of clean, non-contaminating instrumentation. An underground laboratory, approximately 7 x 2.5 m has been installed and is equipped with a large anaerobic chamber, a computer terminal and possibility for set up of on line GC measurement of dissolved gases. Tubing from the boreholes will be connected to the box, allowing for anaerobic sampling in the box. The microbe site does, to the extent possible, simulate real aquifer conditions. Details about the characterisation of the MICROBE site can be found in the characterisation report (Pedersen 2000b).

Scope of work for 2001

Set up of a circulation system

A system that allows circulation of groundwater under full formation pressure is presently being designed (Pedersen 2000b). This system should enable work with microbes at very close to in situ conditions. It will possibly be operative early summer 2001.

Analysis of reductive gas flow in aquifers

A system for sensible measurement of hydrogen and other reducing gases will be developed. A reduction gas detector (Trace Analytical, USA) will be used, having a detection limit for hydrogen, carbon monoxide and methane close to 1 ppb. This system will be used for characterisation of hydrogen generation and flow in granitic rock environments. The results will be compared with theoretical calculations performed at KTH, Stockholm.

Set up of buffer tests

The site will enable a continuation of buffer tests (Pedersen et al. 2000b), including a study of the potential for microbial copper corrosion at repository conditions. The planned start for those experiments is spring 2001.

2.8 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.

Scope of work for 2001

Mineralogy and petrophysical studies

With respect to understanding the movement of fluids through low transmissive bedrock, very useful information has resulted from these studies. It is therefore planned to expand the coverage of drillcore porosity measurements (some integrated with the crush/leach experiments) to achieve a better idea of large-scale heterogeneity or homogeneity in the matrix block, and also to further characterise the Äspö granite rock type. Moreover, a detailed study of a single micro-fracture/fissure, which may have contributed to some of the water already collected from borehole Section 4, will be carried out with respect to in- or out-diffusion processes. This will include measurements of the U-decay series, ^{37}Cl, ^{11}B, ^{86}Sr and ^{87}Sr along rock profiles perpendicular to the fracture intersection with the drillcore,

Leaching and permeability experiments

To try and achieve more information on the source and chemistry of the matrix fluid, earlier studies are to be expanded to include crush/leach experiments on drillcore material with specific emphasis on sections showing variations in lithology (range of acid to basic types chosen generally from the Äspö site) and porosity. To complement the crush/leaching experiments, a simple matrix fluid(?) leaching of drillcore material using distilled water under an inert atmosphere will also be carried out.

The high pressure permeability experiment to try and force matrix fluid from an intact drillcore section will be continued.

Fluid inclusion studies

The nature of the matrix fluid may be strongly influenced by leakage of saline fluids from fluid inclusions which are commonly included in matrix quartz. Four groups are participating in characterising the fluid inclusions (Universities of Stockholm, Bern and Waterloo, together with a group from Kivitieto, Oulu, Finland, sponsored by Posiva) and some preliminary studies have already been reported to the project group at the 2nd Matrix Fluid Experiment Workshop (September 25/26, 2000) and they reported and discussed in the mid-way International Progress Report (IPR) (submitted).

The main scope of the fluid inclusion studies for 2001 is to complete the characterisation and, based on the results, select strategic samples for more sophisticated chemical analysis (e.g. Raman Probe). Ideally this will be carried out by the same laboratory to facilitate comparison. These studies are scheduled to be completed by the summer provided that no instrumental/analytical problems are encountered.

Further matrix fluid sampling and analysis

Monitoring pressure data from the two borehole sections demarcated for matrix fluid sampling (Sections 2 and 4) show steady increases. It is hoped that eventual sampling of borehole Section 2 (and possibly a second sampling of Section 4) will be carried out when indications show that enough water has accumulated (total Section 2 volume of 245 ml). This time a more sophisticated sampling approach will be planned than that used for Section 4, including gas analysis. The much slower accumulation of fluid in Section 2, plus the absence of large fluid volumes in the adjacent Section 1 (already opened), may suggest a more representative matrix fluid composition than that collected from Section 4.

Near-vicinity low transmissive fractures

A scoping study to locate further examples of low transmissive features already characterised in other experiments will be carried out to increase the hydrogeological/hydrochemical database.

Additional boreholes

There will be an attempt to coordinate with other planned Äspö experiments requiring borehole drilling to locate a suitable sampling site to measure in- and out-diffusion profiles on drillcore material using helium and chlorine-37.

Reporting

With the possible exception of the in- and out-diffusion studies, all of the above tasks will be reported during 2001, initially as an IPR or ITD, and finally as part of the final synthesis Technical Report for the whole experiment scheduled for late December 2001 or early 2002.

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

Background

The Äspö Task Force on modelling of groundwater flow and transport of solutes was initiated in 1992. The group consists of nine organisation from eight countries. Each participating organisation is represented by a Task Force delegate and the modelling work is performed by modelling groups. The Task Force meets regularly about once to twice a year. Different experiments at the Äspö HRL are utilised to support the Modelling Tasks. To date modelling issues are as follow:

Task No 1: The LPT-2 long term pumping and tracer experiments. Completed.

Task No 2: Scoping calculations for some of the planned detailed scale experiments at the Äspö site. Completed.

Task No 3: The hydraulic impact of the Äspö tunnel excavation. Completed.

Task No 4: TRUE - The Tracer Retention and Understanding Experiment, 1st stage. On-going.

Task No 5: Coupling between hydrochemistry and hydrogeology. On-going.

Task No 6: Performance Assessment (PA) Modelling Using Site Characterisation (SC) Data (PASC). New.

Task 6 Background

The objective of Task 6 is to bridge the gap between PA and SC models by applying both approaches for the same tracer experiment, and also for PA boundary conditions. This should help to identify the relevant conceptualisations (in processes/structures) for longer term PA predictions and identify site characterisation data requirements to support PA calculations.

Flow and transport at two spatial scales, 5m and 50-100m, will be addressed by applying both SC-type models and/or PA-type models to two different transport modes characterised by different temporal scales:

- Tracer test time scale (Tracer test mode): The selected sets of TRUE-1 (5m scale) tracer experiment will be modelled. The purpose of the modelling study is to provide constraints to all the models before invoking assumptions for PA time scale predictions.

- PA time scale (PA mode): Nuclide or sorbing tracer transport modelling with PA type boundary conditions will be performed. Modellers can make any assumptions as long as they honour the material properties used for TRUE-1 tracer transport modelling.

- Flow and transport at the two spatial scales will thus be analysed for both current boundary conditions and for PA relevant time scales; i.e, four different combinations of spatial and temporal scales will be addressed. Modellers are free to apply traditional SC models, pure PA models, or a combination of both for all four combinations of spatial/temporal scales.

Transport is considered from a virtual canister emplacement location in the Äspö HRL rock mass to a structural feature at a specified distance (starting from a few meters to 50-100 m). As an option, the addressed scale may be extended to the site scale (i.e., canister to biosphere). For this option, geochemical data may also be utilised similar to Task 5 (i.e., models may be constrained by an assessment of the models' capabilities to predict the geochemical conditions observed today).

Objectives

The Äspö Task Force shall be a forum for the organisations supporting the Äspö HRL 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 Task Force shall interact with the principal investigators responsible for carrying out experimental and modelling work for Äspö HRL of particular interest for the members of the Task Force.

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

Scope for 2001

The main objectives targeted to be accomplished during 2001 are summarised below:

- Publish the remaining Task 4 final reports in the ICR series.

- Perform an overall evaluation of the modelling conducted in Task 4 and publish a report to this effect.

- Publish the Task 5 final reports from the modelling groups in the ICR report serie.

- Produce and publish the Task 5 reviewers report

- Produce and publish the Task 5 summary report

- Start the modelling in Task 6

- Arrange a Workshop for Task 6 on the development of a 50-100m block scale synthesised structural model using data from the Prototype Repository, TRUE Block Scale, TRUE-1 and FCC.

- Arrange the 15th International Task Force meeting, hosted by BMWi/BGR in Hannover, Germany.

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

3.1 General

One of the goals for 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 focuses 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.

3.2 Demonstration of Repository Technology

Background

Some of the planed engineering experiments at Äspö are now implemented and are in the operational phase for data collection. This is valid for the Backfill and Plug Test, the Long Term Testing of Buffer Material (LOT) and the Canister Retrieval Test (CRT). Regarding the Prototype Repository, the buffer material and the four canisters with heaters, in the inner section, will be installed mid 2001. This part of the tunnel will be backfilled and sealed with a concrete plug at the end of 2001. The remaining two canisters with heaters, in the outer section, will be installed early 2002 the and that part of the tunnel will be backfilled and sealed with a concrete plug mid 2002.

The design, manufacturing and testing of the equipment for handling and deposition of the buffer material and canisters for the CRT and the Prototype Repository was completed during 2000. The equipment, mainly a mobile gantry crane and a small canister deposition machine, was used for the installation of buffer material and canister with heaters for the CRT in September 2000. After some modification the same equipment will be used for the handling of buffer material and canisters for the six deposition holes in the Prototype Repository.

Scope for 2001

The modification of the gantry crane and the small deposition machine as well as the purchase of a specially designed 50 tons trailer will be completed early 2001.

The development work of the equipment needed in the future deep repository will continue during 2001 and onwards based on experiences from the ongoing work with the demonstration deposition machine now installed at Äspö. The whole system of different machines and equipment needed is expected to be identify and developed to a feasibility stage as part of the ongoing design studies of the deep repository

3.3 The Prototype Repository

Background

Many aspects of the repository concept (KBS-3) have been tested in a number of in situ and laboratory tests. Models have been developed that are able to describe and predict the behaviour of both individual components of the repository, and the entire system. However, processes have not been studied in the complete sequence, as they will occur in connection during repository construction and operation. There is a need to test and demonstrate the execution and function of the deposition sequence with state-of-the-art technology and in full-scale and to demonstrate that it is possible to understand and qualify the processes that take place in the engineered barriers and the surrounding host rock. It is envisaged that this technology can be tested, developed and demonstrated in the Prototype Repository.

The execution of the Äspö Prototype Repository is a dress rehearsal of the actions needed to construct a deep repository from detailed characterisation to resaturation of deposition holes and backfilling of tunnels. The Prototype Repository will provide a demonstration of the integrated function of the repository and provide a full-scale reference for test of predictive models concerning individual components as well as the complete repository system. The Prototype should demonstrate that the important processes that take place in the engineered barriers and the host rock are sufficiently well understood.

Objectives

The main objectives for the Prototype Repository are:

- To test and demonstrate the integrated function of the deep repository components under realistic conditions in full-scale and to compare results with models and assumptions.
- To develop, test and demonstrate appropriate engineering standards and qualify assurance methods.
- To simulate appropriate parts of the repository design and construction processes.

The Prototype Repository is set up to simulate a part of the KBS-3 type repository under what can be described as normal conditions, which is essentially the same as the reference scenario described in SR-97 /SKB, 2000/. The Prototype Repository will differ from a real repository in that the canisters will contain electrical heaters to simulate heat generation instead of spent nuclear fuel.

The evolution of the Prototype Repository should be followed for a long time, possibly up to 20 years. This is made to provide long term experience on repository performance to be used in the evaluation that will be made after the initial operation stage of the real deep repository.

Experimental concept

The Prototype Repository should, to the extent possible, simulate the real deep repository system, regarding geometry, materials, and rock environment. This calls for testing in full-scale and at relevant depth. The test arrangement should be such that artificial disturbance of boundary conditions or processes governing the behaviour of the engineered barriers and the interaction with the surrounding rock are kept to a minimum.

Important limitations with respect to the possibilities to simulate a repository situation are:

- The test site area is given and the location in conjunction with certain conditional criteria is therefore limited.
- No spent fuel, or any other form of nuclear waste, will be used. Canisters equipped with electrical heaters will be used to simulate encapsulated spent fuel.
- The Prototype Repository cannot demonstrate long-term safety, since the experiment considered will be extended in time at most tens of years.
- The Prototype cannot demonstrate final handling and installations of components in the deep repository due to practical considerations, such as installation of instruments etc.

In the deep repository, localisation of the repository, deposition tunnels and final canister positions is planned to be determined by a step-by-step characterisation system followed by a detailing of the repository layout. The site of the Prototype Repository is given, and the rock mass has been characterised

The test location chosen is the innermost section of the TBM tunnel at 450 m depth. The layout involves six deposition holes with a centre distance of 6 m (Figure 3-1). The distance is evaluated considering the thermal diffusivity of the rock mass and the fact that maximum acceptable surface temperature of the canister is 90°C. The distance between the plugs and the nearest deposition holes are 9 m. Canisters with dimension and weight according to the current plans for the deep repository and with heaters to simulate the thermal energy output from the waste will be positioned in the holes and surrounded by bentonite buffer material (Figure 3-2). The tunnel will be backfilled with a mixture of bentonite and crushed rock (30/70).

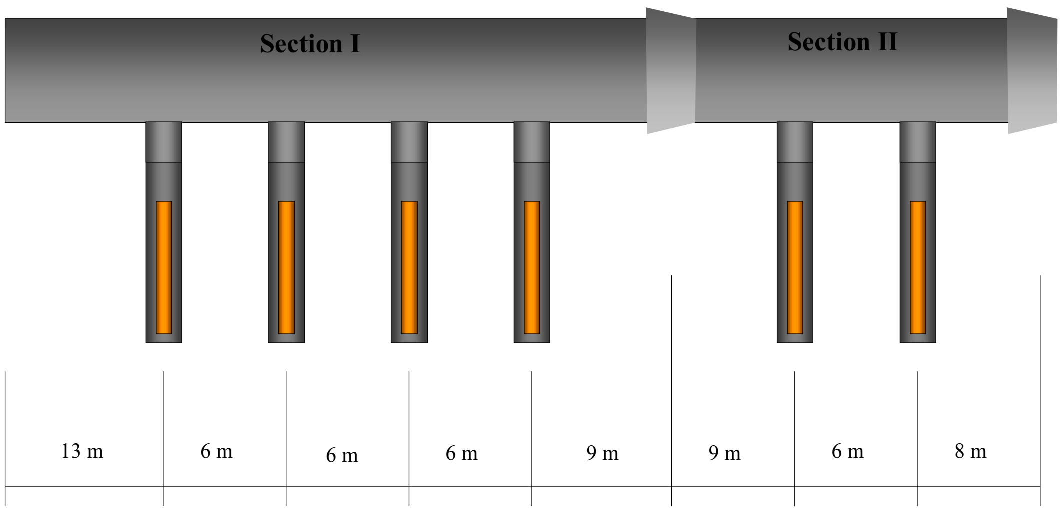


Figure 3-1 *Schematic view of the layout of the Prototype Repository (not to scale)*

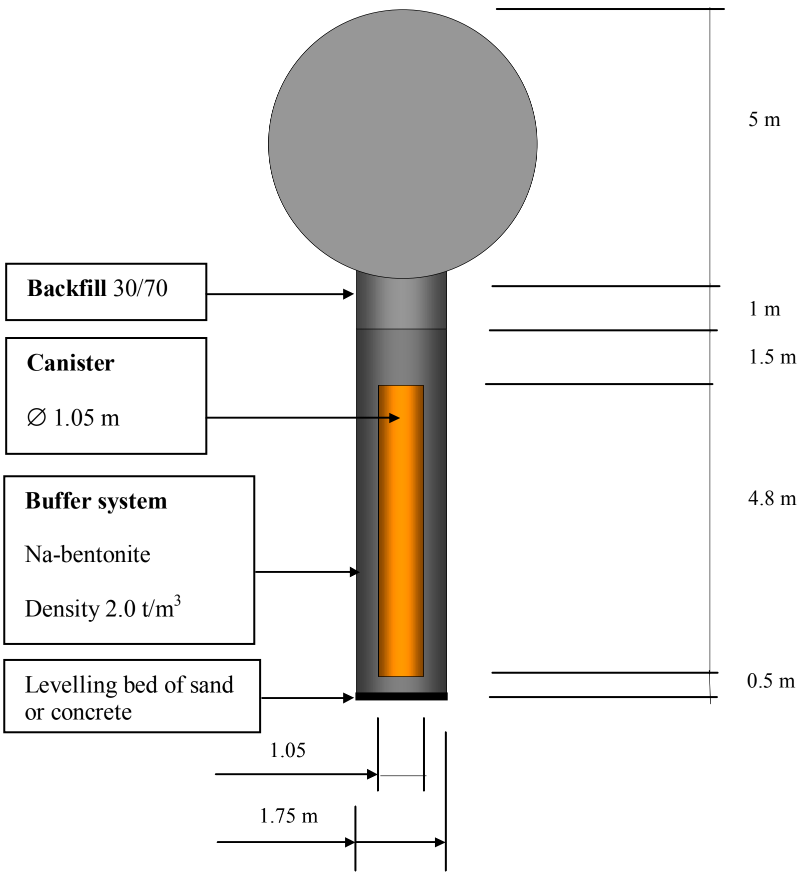


Figure 3-2 *Schematic layout of the deposition holes (not to scale)*

A massive concrete plug designed to withstand full water- and swelling pressures will separate the test area from the open tunnel system. A second plug will be placed such that it divides the test into two sections, comprising four and two canister holes. This layout will in practice provide two more or less independent test sections.

Operation time for the experiment is envisaged to be at least 10 years, possible up to 20 years. Decision as to when to stop and de-commission the test will be influenced by several factors, including performance of monitoring instrumentation, results successively gained, and also the overall progress of the deep repository project. It is envisaged that the outer test section will be de-commissioned after approximately five years to obtain interim data on buffer and backfill performance through sampling.

Instrumentation will be used to monitor processes and properties in the canister, buffer material, backfill and the near-field rock. The intention to minimise disturbance will however add restrictions to the monitoring possible.

Processes that will be studied include:

- Water uptake in buffer and backfill
- Temperature distribution in canisters, buffer, backfill and rock

- Displacements of canisters
- Swelling pressure and displacement in buffer and backfill
- Stresses and displacements in the near field rock
- Water pressure build up and pressure distribution in rock
- Gas pressure in buffer and backfill
- Chemical processes in rock, buffer and backfill
- Bacterial growth and migration in buffer and backfill

Scope for 2001

During year 2000 the application for EC funding of the Prototype Repository Test was granted and the work conducted during year 2001 will be made as part of the EC project. Besides SKB the group consists of:

- POSIVA, Finland
- ENRESA, Spain
- AITEMIN, Spain (associated with ENRESA)
- CIMNE, Spain (associated with ENRESA)
- GRS, Germany
- BGR, Germany
- UWC (University of Wales)
- JNC, Japan
- VBB VIAK, Sweden (assistant to SKB)
- Clay Technology, Sweden (assistant to SKB)
- Geodevelopment AB, Sweden (assistant to SKB)

Minor additional parts of the characterisation work will be carried through and the reporting of the results from all the characterisation work carried out will be completed and reported in one characterisation summary report.

Remaining rock work prior to installation of bentonite blocks and canisters are lining of the already bored lead-throughs to the adjacent G-tunnel for cables and tubes from all instruments, gas and water sampling unit, and heaters in the canisters. In addition instruments and bentonite-based packers in rock in the inner section are installed and the bottom of the deposition holes levelled-off.

The canister are being manufactured and the remaining bentonite blocks are fabricated. After installation of the cables and tubes in the lead-throughs, which can be installed prior to installation of bentonite blocks and canisters, the actual installation starts in hole number 2, counted from the front of the tunnel. Then hole number 4 is installed, then hole number 3 and finally hole number 1. This order is due to the fact that hole number 1 has a high water inflow, quite higher than the other holes. Holes number 2 and 4 are very sparsely instrumented while hole number 3 is intensely instrumented and so is the rock around this hole as well

Backfilling is made in the same way and with the same equipment as in the Backfill and Plug Test in one sequence, whereafter the plug between Section I and Section II is cast. The installation is planned to take place in a high tempo and the plug is scheduled to be cast before the end of the year 2001. Section II is installed during year 2002.

3.4 Backfill and Plug Test

Background

The *Backfill and Plug Test* is a test of different backfill materials and emplacement methods and a test of a full-scale plug. It is a test of the hydraulic and mechanical function of the backfill materials and their interaction with the near field rock. It is also a test of the hydraulic and mechanic functions of a plug and will be the basis for the design of temporary plugs in a repository. The test is partly a preparation for the *Prototype Repository*.

Objectives

The main objectives of the test are:

- To develop techniques and test techniques and materials for backfilling tunnels.
- To develop and test techniques for temporary plugging of deposition tunnels and to test the mechanical and hydraulic function of such a plug.
- To test the integrated mechanical and hydraulic function of the backfill and near field rock in a tunnel excavated by drill and blast.

Experimental concept

Figure 3-3 shows an overview of the test. The test region, which is located in the old part of the ZEDEX drift, can be divided into the following three test parts:

1. The *inner part* filled with backfill containing 30% bentonite (sections A1-A5 and B1).
2. The *outer part* filled with backfill without bentonite (sections B2-B4).
3. The *plug*.

The backfill sections have been applied layer wise and compacted with vibrating plates that were developed and built for this purpose. It was concluded from preparatory tests that inclined compaction should be used in the entire cross section from the floor to the roof and that the inclination should be about 35 degrees.

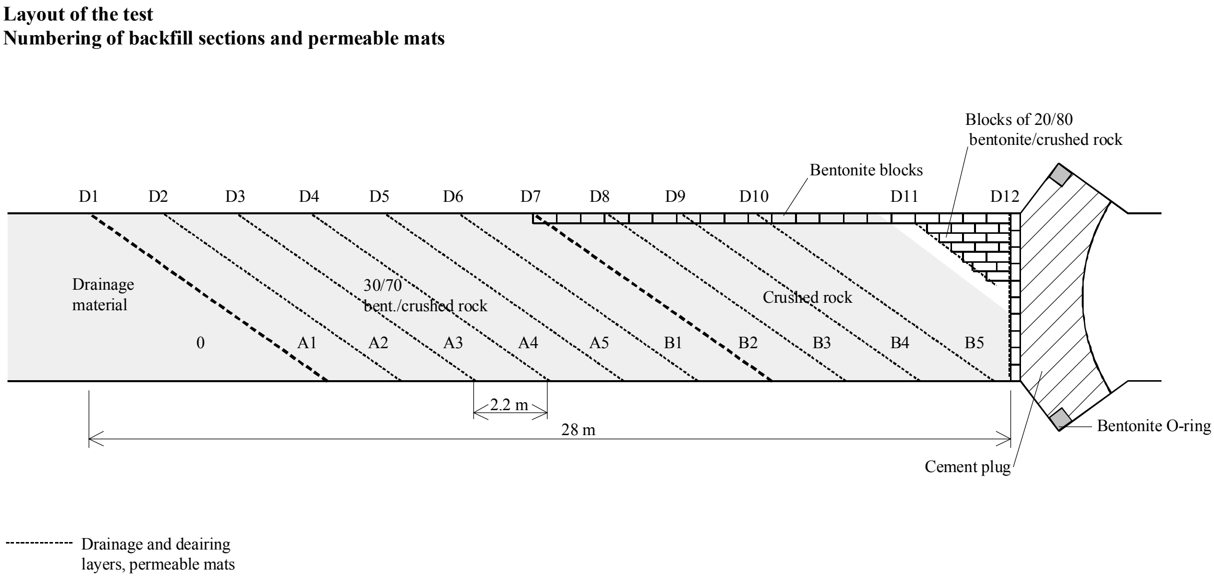


Figure 3-3 *An overview of the Backfill and Plug Test*

The inner test part has been filled with a mixture of bentonite and crushed rock with a bentonite content of 30%. The composition has been based on results from laboratory tests and field compaction tests. The outer part has been filled with crushed rock with no bentonite additive. Since the crushed rock has no swelling potential but may instead settle with time, a slot of a few dm was left between the backfill and the roof and filled with a row of highly compacted blocks with 100% bentonite content, in order to ensure a good contact between the backfill and the rock. The remaining irregularities between these blocks and the roof were filled with bentonite pellets.

The two parts are about 14 meter long and split by drainage layers of permeable mats in order to apply hydraulic gradients between the layers and to study the flow of water in the backfill and nearfield rock. They are also used for the water saturation of the backfill by applying water pressure. The mats have been installed in both backfill parts with the individual distance 2.2 m. Each mat section was split in three units in order to be able to separate the flow close to the roof from the flow close to the floor and also in order to separate the flow close to the rock surface from the flow in the central part of the backfill.

The outer section ends with a wall made of prefabricated bars for temporary support of the backfill before the plug was cast. Since in situ compaction of the backfill cannot be made in the upper corner, this triangle was instead filled with blocks of bentonite/sand mixture with 20% bentonite content.

The backfill and rock have been instrumented with piezometers, total pressure cells, thermocouples, moisture gauges, and gauges for measuring the local hydraulic conductivity. The axial conductivity of the backfill and the near field rock will be tested after water saturation by applying a water pressure gradient along the tunnel between the mats and measuring the water flow. All cables from the instruments are enclosed in Tecalan tubes in order to prevent leakage through the cables. The cables have been led through the rock to the data collection room in boreholes drilled between the test tunnel and the neighbouring Demo-tunnel.

The *plug* is designed to resist water and swelling pressures that can be developed. It is equipped with a filter on the inside and a 1.5 m deep triangular slot with an "O-ring" of highly compacted bentonite blocks at the inner rock contact.

The saturation was expected to take at least one year and the subsequent flow testing about one year. The flow testing in the backfill is planned to start after saturation, when steady state flow and pressure have been reached. The tests are planned to start by decreasing the pressure in the filters one by one starting with the outer filter and after equilibrium continue with the next filter.

Scope for 2001

During 1999 the experimental setup was finished and during 2000 the water saturation of the backfill has been going on and data collected from the transducers. In order to avoid piping and since the plug is not tight yet very low water pressure has been applied in the mats and the 30/70 backfill is at present only water saturated to about 1/3.

For 2001 the following main activities are planned:

- Supplementary laboratory tests for increasing the understanding and developing the models of water unsaturated backfill
- The interface between the plug and the rock surface will be grouted through three sets of pre-installed grouting tubes (in April)
- Test of the tightness of the plug a few months after grouting
- Continued wetting of the backfill with increased water pressure in the mats if possible
- Continuing data collection of measured water pressure, water flow, total pressure and degree of water saturation

3.5 Canister Retrieval Test

Background

The stepwise approach to safe deep disposal of spent nuclear fuel implies that if the evaluation of the deposition after the initial stage is not judged to give a satisfactory result the canisters may need to be retrieved and handled in another way. The evaluation can very well take place so long after deposition that the bentonite has swollen and applies a firm grip around the canister. The canister, however, is not designed with a mechanical strength that allows the canister to be just pulled out of the deposition hole. First the canister has to be made free from the grip of the bentonite before the canister can be taken up into the tunnel and enclosed in a radiation shielding before being transported away from the deposition area.

Objectives

The objectives of the retrieval test are

- to develop and test methodology and equipment for freeing of canister from the grip of the swollen bentonite,
- to show in a perceptible way that a free canister can be safely retrieved in an underground environment

The test set-up will in addition provide date on the saturation process of the bentonite buffer with defined hydraulic boundary conditions – water is added artificially to permeable mats that are attached on to the borehole walls.

Experimental concept

The Canister Retrieval Test is located in the main test area at the 420 m level, and is separated into three stages:

Stage I: Boring of deposition holes and installation of bentonite blocks and canisters with heaters. The holes are covered in the top with a lid of concrete and steel, which is anchored by cable bolts to the rock around the hole. The tunnel is maintained unfilled.

Stage II: Saturation of the bentonite and evolution of the thermal regime.

Stage III: Test of freeing the canister from the bentonite, docking the gripping device to the canister lid and lifting of the canister up to the tunnel floor and into the radiation shield on the deposition machine (reversed deposition sequence).

Two holes were bore but only one has been installed, the reason being that only one robust method is presently considered to be tested in full scale in the Äspö HRL.

Scope for 2001

The test set-up was completed in 2000 and the heaters turned on. During 2001 the saturation, which is scheduled to take 3-4 years, goes on while instrument readings are collected, quality controlled and stored in the SICADA data base. Six months reports on controlled data will be presented.

Data on termo-hydro-mechanical processes taking place in the buffer may be used for modelling exercisis aiming at calibrating coupled process codes for their later use in predicting the development of the Prototype Repository.

3.6 Long term tests of buffer material

Background

Bentonite clay has been proposed as buffer material in several concepts for HLW repositories. In the Swedish KBS-3 concept the demands on the bentonite buffer are to serve as a mechanical support for the canister, reduce the effects on the canister in case 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 KBS-3 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 the reference KBS-3 repository conditions and the testing periods have generally been dominated by initial processes, i.e. water uptake and temperature increase.

Objectives

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 KBS-3 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.

Experimental concept

The testing philosophy for all tests in the series (Table 3-1) is to place prefabricated units of clay blocks surrounding heated copper tubes in vertical boreholes (*Figure 3-4*). 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 3-1. Lay out 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	S	= standard conditions
T	= temperature	[K^+]	= potassium concentration
pH	= high pH from cement	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.

The five test parcels were installed during the autumn 1999 and the heating started in February 2000. The parcels are presently in a water saturation phase. The A0 parcel, which is artificially saturated at 3 levels, is close to full saturation.

Scope for 2001

Water pressure, total pressure, temperature and moisture in the 5 parcels are continuously measured and stored every hour. Further characterisation of the original bentonite material in the parcels will be made. Development of analyse technique are being made in order to improve the characterisation of field exposed parcel material.

Planning and preparation for the uptake of the A0 parcel will start in May and the drilling for retrieval is planned to begin in October. Subsequent analyses of the bentonite material will start immediate after uptake and go on for the rest of the year.

Previously planned gas tests are likely not possible to carry through during the year, mainly due to the instalaltion of the data acquision system of the Prototype Repository Test that takes place in the the G-tunnel. These tests will therefore be postponed to the year 2002.

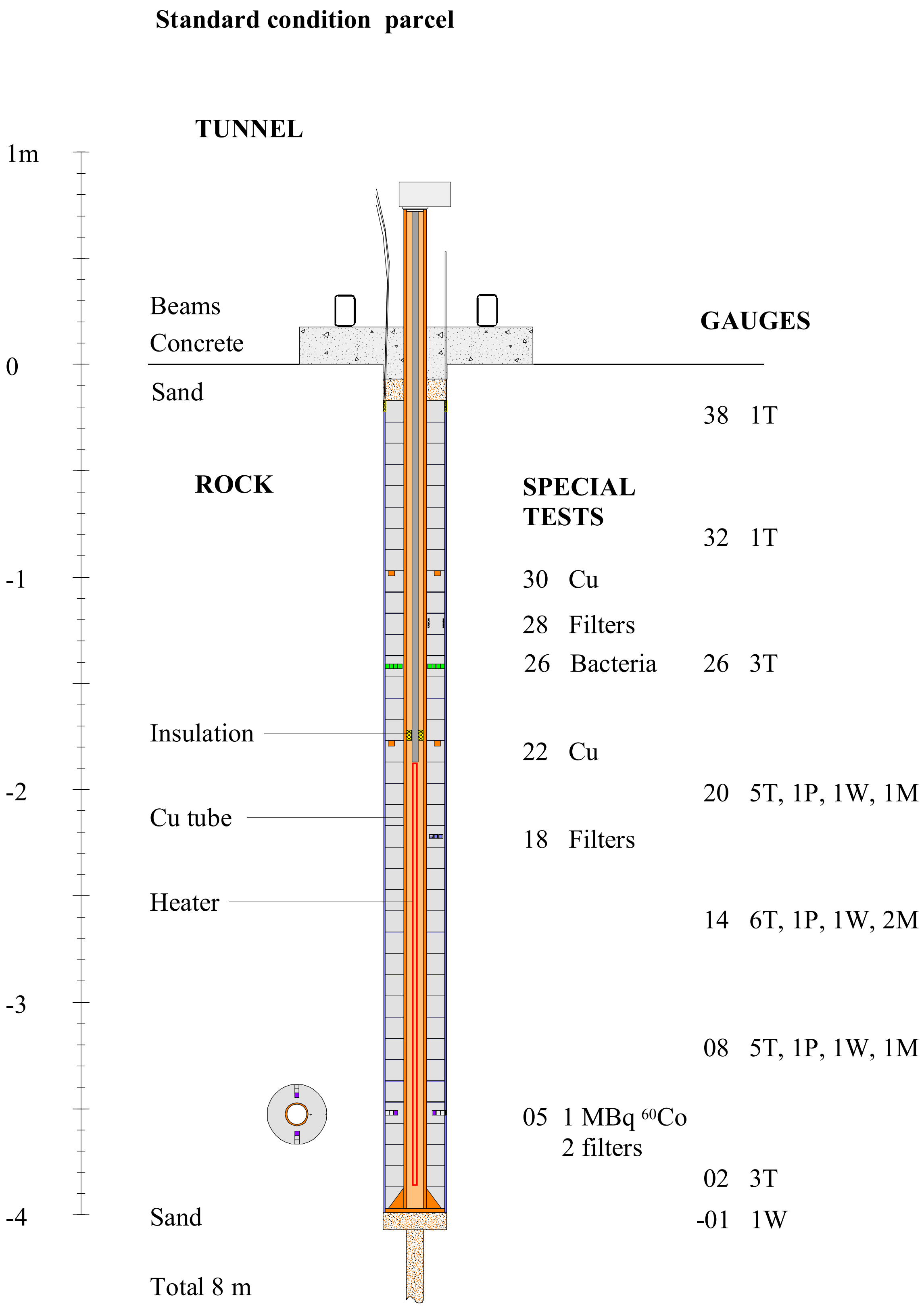


Figure 3-4 *Principle parcel layout. Numbers show bentonite block notation and the number of gauges at each level. T indicate thermocouples, W indicate water pressure gauges, P indicate total pressure gauges, and M indicates moisture gauges.*

4 Äspö facility operation

4.1 Plant operation

Background

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

Scope for 2001

A major rock and reinforcement program is to be completed in the beginning of this year, which will ensure safe and reliable rock conditions.

A project based on increased fire safety is in progress. Additional fire alarm and a new warning system are to be installed. One firewall and rescue chambers are built. Safety-related education and fire fighting training is to be held in co-operation with the local firebrigade

An automatic registration and object-monitoring system is to be installed with the objective of increasing personnel safety underground.

A plant supervision system was taken into operation in 2000. This has considerably increased the possibility to run the facility in a safe and economic way. In 2001 several systems are to be monitored and if possible optimised. The long-term goal (2003) is to reach 99% availability in the underground-related systems.

A program for exchanging underground lighting is currently in progress and exchange of corroded and damaged non-stainless steel components underground is to continue.

A large number of instructions are to be formalised and system handbooks to be prepared and completed as a part of the ISO 9001 and 14001 certification,.

The need for more office space has become urgent due to growing staff. In order to meet this need, on a short-term basis, a number of temporary office barracks will be placed in the Äspö village. In order to meet the need on a long-term basis a project is initiated on acquiring permits for building permanent additional office space. organisation.

The road to Äspö is considerably worn and will be coated with a layer of tarmac. Also the new parking space in the Äspö village will be coated with tarmac at the same time.

4.2 Data management and data systems

Background

Management of investigation data is a highly demanding and critical task in SKB´s 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,
- accessability,
- data security and
- efficiency (system integration and user friendly applications).

The parameter data needed in a safety assessment have been reported in Andersson et al /1998/. A set of major data systems has been developed and implemented in order to support and control the management of all investigation data sets and the corresponding parameters. Below the current plans for SKB's Site Characterisation Database (SICADA), SKB's Rock Visualisation System (RVS) and SKB's Geographical Information System are presented. Other important tools are also improved and adapted continuously, without being specially mentioned in this planning report.

Objectives

SICADA

SICADA is and will be one of SKB’s most strategic database systems. The database should efficiently serve planned investigations activities at the future candidate sites as well as the experiments at Äspö HRL. The database should be user-friendly and always guarantee a high degree of quality, traceability and accessability. SICADA is to be held modern and also adapted and improved in parallel with the planning and execution of the site investigation programme.

RVS

A three dimensional geoscientifical model is built by progressive collection, processing and interpretation of site data. All site data will be stored in SICADA. Furthermore all geological and geophysical maps will be available in SKB's GIS database.

It is important to have the possibility to test interactively in 3D different possible connections between observations in boreholes, tunnels and on the ground surface. By effectively visualising the rock model, based on available site data in SICADA, it is also possible to optimise new investigation efforts. Later, during the design of the deep repository, the geoscientifical model will be the basis for adaptation of the tunnel layout to the different rock characteristics at the site

GIS

Geographical Information Systems are used to visualise any attribute distribution in a geographical area of any scale. By superimposing different sets of data the situation of a piece of land becomes easy to analyse. This advantage has been used extensively in the feasibility studies performed by SKB. GIS will also be used during the site investigation planning and execution.

System concept

SICADA

Data model

The central data table in the system is the activity_history table. Each data row in this table has a unique activity identifier. This identifier uniquely connects measured data with only one activity in the activity-history table.The activity identifiers is located in the first column of the tables. Normally the activity identifier is hidden, but it is always present in the background and is handled automatically by the system.

Activity identification numbers were introduced in order to make it possible to link an arbitrary number of investigation data tables to a certain activity. Hence, activity identification numbers are present in all investigation data tables in the whole system.

All data rows in the activity history table also have a time stamp and a user identification code to show and control when data were inserted into the table and who made it.

Data structure

A hierarchical data structure was implemented in the former GEOTAB system in order to make it easy to find and retrieve any investigation data. This data structure is also available in the SICADA system. The hierarchy comprises four levels:

- Science (Level 1)
- Subject (Level 2)
- Method (Level 3)
- Activity (Level 4)

At present time the SICADA data structure contains the sciences (Science, level 1): *Engineering*, *Geology*, *Geophysics*, *Geotechnics*, *Hydrochemistry*, *Hydrology*, *Meteorology* and *Rock mechanics.* An excerpt of the the hierarchical data structure of the SICADA system is illustrated in Figure 4-1.

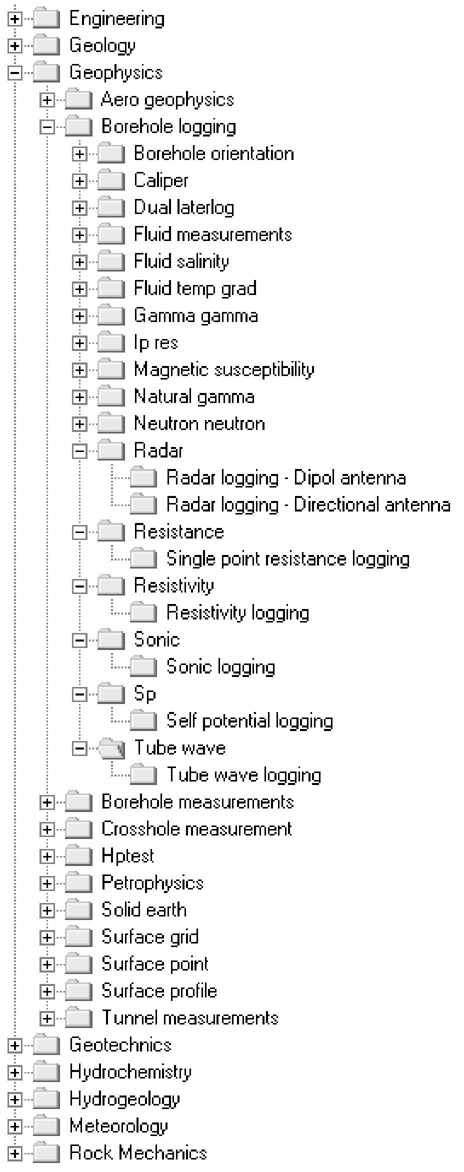


Figure 4-1 *The hierarchical data structure of the SICADA system, with all of level 1 (Sciences) shown, but only an excerpt of subjects, methods and activities. Note, in most cases there is an one to one association between a certain method and an activity, but in some cases a whole group of activities are associated with only one method.*

RVS

RVS is an advanced visualisation and rock modelling system based on the CAD-system MicroStation/J. MicroStation/J is a modern and powerful 3D-modeling system developed by Bentley Systems Inc in USA, and is running on computers with the most common operating systems as Windows NT and UNIX.

The current version of RVS is designed as a single-user system, and the data exchange link between RVS and SICADA is based on a client/server technique.

There is also a local database, currently based on MS/Access 97, required on each RVS workstation. An open architecture based on the ODBC data exchange concept is used. Hence, by using ODBC, it will be easy to quit MS/Access 97 if another database system is needed in the future.

In the RVS, in contrast to standard MicroStation/J, the work is not based on design files (drawing files) and levels but on projects and objects. In order to work in an organised matter, and for practical reasons, it is for larger projects highly recommended to separate the visualisation work into three sub-projects:

- Data project (Containing visualisations of background data)
- Model project (Containing modelled objects)
- Construction project (Containing underground constructions)

Hence, data, model and construction can be handled separately, which is a great advantage, mainly regarding version handling, when data are updated continuously and much more often than the model. The project with background data is then attached as a background project to the model project.

For small projects, limited in time and extension, it could, however, be more efficient to gather all information in one project, but independent of how the total set of objects are managed they can be mixed arbitrary when displayed on the screen.

GIS

As a result of the feasibility studies a huge amount of GIS data has been set up and organised. Some of the information is stored in the ArcInfo database. The application ArcView is used to display and visualise geographical attribute data.

Scope for 2001

SICADA

- The SICADA system administration tool, GTADMIN, will be given a graphical user interface.
- The user applications SICADA/Diary and SICADA/Finder will be integrated to one application.
- Processes for management of investigation data are identified, documented and implemented during year 2001. This issue is a part of the planning of the site investigations.

SICADA has to be supplemented in order to fulfil the requirements of separating data stored for the European Commission project on the Prototype Repository from other data stored.

RVS

RVS version 2.3 will be released and implemented in January 2001. Short after this release the programming of RVS version 3.0 will start. This new version will support the new geometric modelling technique developed by the GEOFUNK project (Munier and Hermanson, 2001). To fulfil the actual requirements the new version of RVS will be based on MicroStation/V8, announced to be released in August 2001 by Bentley Systems Inc.

GIS

New efforts will be taken to implement GIS as a general tool in the process of creating illustrations based on geographical information.

All information received from the feasibilty studies performed will be structured and documented in more detail.

Different kinds of applications will be developed in order to support acquisition of field data. Applications for presentation of data available in the SICADA database will also be developed.

4.3 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. The system is called HMS (Hydro Monitoring System). Water levels and pressure heads are collected from surface and tunnel 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.

The system has evolved through time, expanding in purpuse and ambition. The monitoring of water levels started in 1987 while the computerized HMS was introduced in 1992. The number of boreholes included in the network has gradually increased. The tunnel excavation started in October 1990 and the first pressure measurements from tunnel drilled boreholes were included in the HMS in March 1992.

Construction of the Äspö HRL began in October 1990 and was completed during 1995. The tunnel excavation began to impact the groundwater head during the spring 1991.

Objectives

The scope of maintaining such a monitoring network has scientific as well as legal grounds:

- It is a necessary requirement in the scientific work to establish a baseline of the groundwater head and groundwater flow situations as part of the site characterization exercise. That is, a spatial and temporal distribution of groundwater head prevailing under natural conditions (i.e. prior to excavation).
- It is indispensable to have such a baseline for the various model validation exercises, which were implemented during the Construction Phase and the Operational Phase including the comparison of predicted head (prior to excavation) with actual head (post excavation)
- It was conditioned by the water rights court, when granting the permission to execute the construction works for the tunnel, that a monitoring program should be put in place and that the groundwater head conditions should continue to be monitored until the year 2004 at the above mentioned areas.

Experimental concept

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

Scope for 2001

The operation of the monitoring system will maintain the monitoring points from the previous year and no additional point are planned. The system will continue to support the experiments undertaken and meet the requirements stipulated by the water rights court.

4.4 Program for monitoring of groundwater chemistry

Background

During the construction phase of the Äspö HRL, different types of water samples were collected and analysed with the purpose of monitoring the groundwater chemistry and its evolution as the construction proceeded. 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 at a sufficient cover of the hydrochemical conditions with respect to time and space within the Äspö HRL. This program is designed to provide information for determining where, within the rock mass, the hydrochemical changes are taking place and at what time stationary conditions are established.

Planned work

The annual water sampling campaign is scheduled to take place in September (w. 138-w. 139).

4.5 Hydro monitoring system (HMS)

Background

The HMS collects data on-line of groundwater head, salinity and, in some boreholes, Eh and pH. The data are recorded by numerous transducers installed in boreholes on Äspö as well as in boreholes located in the tunnel, *Figure 4-2*.

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

As an effect of the excavated tunnel, the groundwater levels in the core drilled boreholes in the vicinity of the tunnel have been lowered up to 100 meters. Because of this the installations in the boreholes, e.g. the stand pipes (plastic tubes) in the open boreholes have been deformed. This makes it sometimes impossible to lover pressure transducers in the tubes or to lower manual probes for calibration purposes. Development and testing of new types of tubes is in progress. An evaluation of the groundwater monitoring system used at Äspö HRL is needed before a new similar system will be set up at candidate sites for the deep repository.

The measuring system, which is incorporated in the HMS, is located in the tunnel with substations at sections 690, 1190, 1645, 2162, 2511, 3007, 3107, 3385 and 3510 m. Groundwater inflow to the tunnel is measured at intervals in the tunnel by dams and weirs.

The inflow of water into the different shafts is collected with the aid of a weir and a Thomson measuring device for flow determination. At the ramp positions at 220 m, 340 m and 450 m, the measuring stations are installed for data sampling from the substations.

Scope for 2001

- The Prototype Repository will be instrumented and connected to the Measurement system during 2001.
- A new measuring station at ramp position –450 (G-Tunnel) will be installed to take care of data from the Prototype Repository.The system consist of nearly 1000 measurement channels.
- Also new measurement points in the tunnel will be instrumented and connected to the HMS- system.

The presentation system for the HMS will be installed during the spring and taken into full operation during the summer.

4.6 Underground measurement methods and methodology

4.6.1 Rock stress measurements by the overcoring method

Background

In situ stress measurements is a method for collecting a very important rock mechanical parameter – the load on an underground opening.

Two dominant methods are available: Hydraulic Fracturing and Overcoring. The Overcoring method has been used for measuring of the mechanical boundary conditions for some of the experiments at the Äspö HRL. There are, however, indications that the method may have been used beyond its capacity, i.e. the theoretical assumptions of elastic and homogeneous response may not be fulfilled in all tests. Alternative methods for calculation of the in situ stresses based on the recovered strains and anisotropic rock properties may be considered.

Objectives

A programme is initiated with the objectives to identify the possible limitations for the overcoring method and to control under what conditions anisotropic theory may apply.

Experimental concept

The work is planned to be based on existing data, but further laboratory testing of the mechanical properties of the cores.

4.6.2 Heat transport

Background

The layout of the repository, which is guided by the distance between the canisters, is primarily dependent on the ability of the rock to conduct heat from the canisters and out into the rock. The criterion is the maximum temperature allowed on the surface of the canister and a low thermal conductivity in the rock leads to a larger distance between the canisters than in case of a high thermal conductivity.

Objectives

The aim is to develop a thermal transport model for a rock block in a similar fashion as the models for geohydrology, geochemistry and rock mechanics.

Scope for 2001

- The theoretical basis is outlined and data needed for the model identified.
- If needed, in situ investigations are planned and executed.
- The model is compiled.

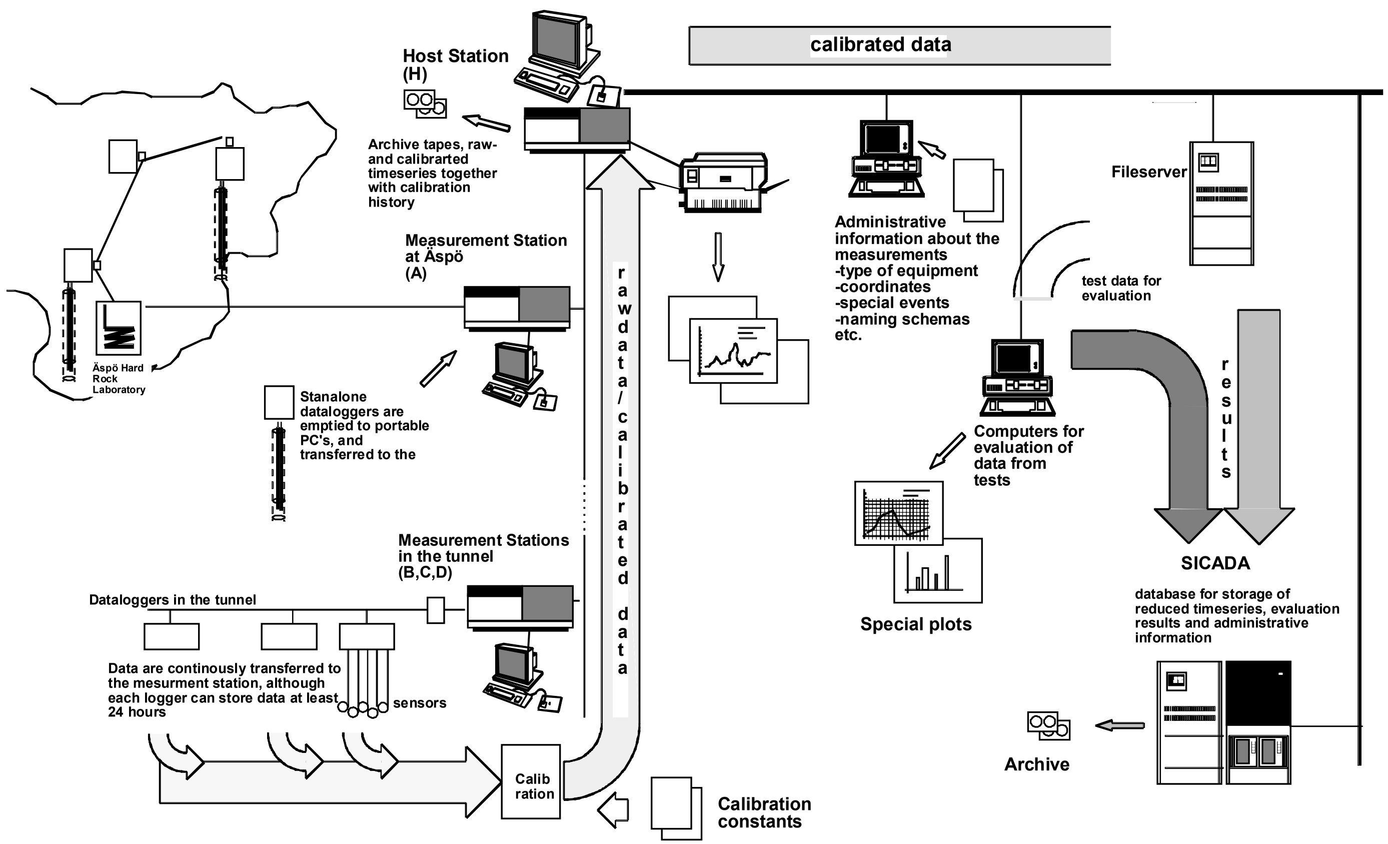


***Figure 4-2** Borehole system for groundwater monitoring*

5 International co-operation

5.1 Current international participation in the Äspö HRL

Nine organisations from eight countries are currently (March 2001) participating in the Äspö HRL.

The participation by JNC and Criepi is regulated by one agreement and the organisations are represented by one delegate in the International Joint Committee.

In each case the co-operation is based on a separate agreement between SKB and the organisation in question. Table 5-1 shows the scope of each organisation's 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 co-operation in the area of conceptual and numerical modelling of groundwater flow and solute transport in fractured rock.

ANDRA, Nirex, POSIVA, ENRESA, JNC and SKB are co-operating under a special multilateral agreement regarding the TRUE Block Scale experiment.

A Task Force on Engineered Barriers was initiated during 2000 after carefull analysis and discussion on topics to address. The final outcome was to start with one topic; saturation process of the bentonite buffer, using the experiments Canister Retrieval Test and Prototyp Repository. The main group addressing this question is the modelling group within the European Commission project on the Prototype Repository, and the participants in the Task Force are the organisations – ANDRA and GRS modelling team – that stand outside the European Commission project. The Task Force work is carried out in close co-operation with the modelling group of the European Commission project.

Cluster of Repository Projects - CROP

SCK-CEN, POSIVA, GRS, ENRESA, ANDRA, NAGRA, OPG (Ontario Power Generation), USDOE CBFO (Carlsbad Field Office) and SKB are co-operating in this European Commisssion project aiming at summarising experience gained in different rock laboratories. The project started in February 2000 and has a duration of 36 months. The first task is ” Design and construction of engineered barrier systems (EBS)”, which will take 12 months to complete. Each participant compiles a country annex and the co-ordinator (SKB) summarises the different country annexes in a main text. The second task is ” Instruments and experimental procedures”, which concerns experiments in the rock laboratories and which is studied in the same way as the first task with country annexies and a summary text. The second task starts mid 2002 and takes also12 months to complete.

Table 5-1. Scope of international co-operation for 2001

Organisation	Scope of participation
Agence Nationale pour la Gestion des Dechets 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
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.	Assistance in development of ”Task 6” reference cases for site characterization and performance assessment integration Reporting and evaluation of tracer and hydrogeochemical analyses in ”Task 4” and ”Task 5” Experimental design and analysis, conceptual model development, and simulation for ”TRUE Block Scale” and ”Two TRUE” Collaborate in ”Prototype Repository” with coupled Thermo-Hydro-Mechanical modeling

Organisation	Scope of participation
The Central Research Institute of the Electronic Power Industry**, CRIEPI,** Japan	Modeling and analyses for groundwater flow and radionuclide migration. Geochemical modeling and analyses under changing groundwater flow conditions. Modeling and analyses of coupling phenomena in the repository system. Validation of groundwater dating methods.
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
USDOE/**Sandia National Laboratories**, USA	Test of models describing the barrier function of the bedrock

5.2 Summary of work by participating organisations

5.2.1 POSIVA

Introduction

The Project Agreement between SKB and POSIVA covers the co-operation in the Äspö HRL. The work within the Joint Project comprises three main areas:

- Detailed investigation methods and their application for modelling the repository sites
- Test of models for description of the barrier function of the bed rock
- Demonstration of technology for and function of important parts of the repository system

According to a specific agreement Posiva is participating in TRUE Block Scale (TBS) experiment together with Nirex, ANDRA, SKB, ENRESA and PNC.

- At the moment Posiva is starting a new era, a stage of confirming site characterisation of the Olkiluoto site. It begins on 2001 and will continue until 2010. The main objective of this new stage is to go underground and confirm the results of the site characterisation made from the ground surface and to confirm the repository area. Consequently Posiva will start excavation of an underground characterisation facility within a few years. As a result of this an assignment of roles between the Olkiluoto underground facility, called ONKALO, and the Äspö HRL has been made:
- The site specific characterisation will be done at ONKALO
- Demonstration and testing of the repository concept is made in appropriate parts at Äspö HRL.

These directions guide Posiva's participation in research projects in the Äspö HRL.

The following comprises the work to be done during 2001 according to the Joint Project.

Detailed investigation methods and their application for modelling the repository sites

Applicability of different investigation methods for assessment of repository sites

Background

Posiva conducted an investigation programme in the Laxemar KLXO2 borehole with the technology used in the site characterisation programme in Finland. The function of Posiva Flog Log and the pressurised groundwater sampling equipment of Posiva were tested down to 1400 m depth. In addition a study on methodology for the Posiva Flog Log was conducted. The whole testing program has been reported.

Scope for 2001

Posiva participates in the final evaluation seminar that is held in February 2001.

Test of models describing the barrier functions of the bedrock

Task Force on Modelling of groundwater flow and transport of solutes

Background

Posiva has participated in the Task Force on modelling of groundwater flow and transport of solutes. The latest task, Task #5 that was also part of the Hydrochemical Stability project, has been modelled by three modelling groups from VTT, Finland. The final report of the task will be ready during the first half of 2001

Scope for 2001

Posiva participates in the planning of the next task, Task #6.

Tracer Retention Understanding Experiments (TRUE) - Block Scale

Background

TRUE Block Scale experiment was performed in a network of fractures with expected transport length of 10-50 m. Posiva participated in the TRUE Block Scale experiment in accordance to a specific co-operation agreement between ANDRA, Nirex, ENRESA, PNC (now JNC) and SKB

Scope for 2001

Posiva will participate in the planning of the continuation of the project, called "Two TRUE", together with SKB, ENRESA, ANDRA and JNC.

Hydrochemical Stability project

Background

Posiva and SKB initiated in 1997 a common project with the aim of investigating the hydrochemical stability of deep groundwater in crystalline bedrock. At present this project is carried out within the Äspö agreement between SKB and Posiva. It also covers the technical parts of the participation in the EC EQUIP (Evidences from Quaternary Infillings for Palaeohydrology) project and the modelling of Task 5 within the framework of the Äspö Task Force for modelling of groundwater flow and transport of solutes.

Scope for 2001

The final report of the Hydrochemical Stability project as well as the EQUIP report and Task #5 report will be finished during the first half of 2001.

Matrix Fluid Chemistry

Background

Posiva participates in a Matrix Fluid Chemistry experiment, which concerns a study of matrix fluids and groundwater from the rocks with low hydraulic conductivity. Kivitieto Oy from Finland participates in the intercomparative study on characterisation of fluid inclusions. The main method used by Kivitieto Oy for characterising the content of fluid inclusions has been laser ablation ICP-MS.

Scope for 2001

The fluid inclusion studies will be reported during the first half of 2001.

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

Prototype Repository

Background

At present SKB is building a replicaof a disposal tunnel at a depth of 450 m in the TBM tunnel in the Äspö HRL, the Prototype Repository. It includes 6 deposition holes in full scale divided into two sections. The Prototype Repository project has been incorporated into the European Commission´s 5th Framework Programme and became subject for funding.

Scope for 2001

Posiva participates in the assessment of the planning and installation of the test arrangements and structures, and in the preparation of tunnel groundwater sampling and analysis. In addition the ground water balance in the interface of bentonite and bedrock will be modelled in the near field of the Prototype Repository.

Long Term Test of Buffer Material (LOT)

Background

Posiva is participating in the LOT project. The LOT test series aims at validating models and hypotheses concerning long term processes in buffer material and related processes under conditions similar to those in a KBS-3 repository.

Scope for 2001

The research conducted in Finland pertains to the chemical processes occurring in bentonite and the chemical conditions developed in the pore water and the bentonite. The developed analysis, measuring and sample treatment methods will be utilised, when the first parcle will be retrieved. Decision on participation in research on the long term tests (5 years and 20 years) will be taken later on the basis of results obtained from the first test.

Characterisation of excavation disturbance around full-scale experimental deposition holes

Background

In a nuclear waste repository, rock in the excavation-disturbed zone adjacent to the walls of deposition holes for waste canisters is one potential pathway for the transport of corrosive agents and radionuclides. Rock characteristics in the excavation-disturbed zone also play a role in saturation of the bentonite buffer and in gas release.

Experimental concept

Characterisation of the excavation disturbance caused by boring of the experimental full-scale deposition holes in the Research Tunnel at Olkiluoto was carried out by using two novel methods; the ^{14}C-PMMA and the He-gas methods. The ^{14}C-PMMA method has been in continuous use during 2000 and the work has included development of both the measuring and interpretation techniques in order to study disturbance caused by boring with mini discs, a technique used in the Äspö HRL.

Scope for 2001

The final reporting of the work including the final analysis of the results of a wide variety of measurements is scheduled to be finished in 2001.

In situ failure test

Background

The stability of the deep repository is of great importance from both safety and constructability points of view. In order for the rock to become damaged, fracturing must occur. A significant component of progressive failure is fracture propagation. The development of computers and associated modelling programmes has made it possible to model the process of fracture propagation.

Experimental concept

The general objective of the in situ failure test is to assess the applicability of numerical modelling codes and methods to the study of rock failure and associated crack propagation in larger scale than laboratory scale. In the in situ failure experiment, a hole cored in one of the full-scale deposition holes will be broken by using an artificial stress field large enough to cause failure. After the failure test the observed patterns of failure and the results obtained from the computer model will be compared and evaluated.

Scope for 2001

The study is in progress and a preliminary field test followed by the final in situ failure test and the characterization of the failure shall be carried out during the summer of 2001. Samples shall be taken after the failure test from the failed rock sections and the microfracturing will be studied in laboratory using microscopical techniques. The observed failures will be compared with the results of numerical simulation carried out in 2000.

5.2.2 ANDRA

Background

L'Agence Nationale pour la Gestion des Déchets Radioactifs (ANDRA) provides since 1992 experimental and modelling support to the Äspö HRL with emphasis on site characterisation to complete research activities in France. SKB-ANDRA bilateral Agreement has been renewed in 2000 with an extension of scope to repository and engineered barriers systems.

ANDRA's recent contributions focused on:

- Modelling work within the Task 5 of the Äspö Task Force on groundwater flow and transport of solutes concentrated on hydro-chemical changes caused by the construction of the Äspö HRL
- TRUE Block Scale experiment with the design, performance and interpretation of non-sorbing tracer tests (3He and other dyes) and modelling efforts.
- Completing the REX experiment by comparing in situ results in the experimental fracture with laboratory work carried out by CEA on an excavated part of the fracture.

Objectives

Prime objectives of ANDRA were and still are to enhance the understanding of flow and transport in fractured granitic rock and to evaluate experimental and modelling approaches in view of site characterisation of a French site. This characterisation of undisturbed rock at a distance from the waste, the far-field.

In conjunction with SKB´s development of major experiments related to parts of the repository system, new objectives appear concerning the near-field, and ANDRA is in enhancing the understanding and modelling of the engineered barrier systems behaviour. An additional topic is comparing the functions of repository systems for either spent fuel or reprocessed vitrified HLW.

Scope for 2001

- Participation in modelling in Task 6 of the Äspö Task Force, with the aim of bridging approach and modelling of characterisation and long-term safety.
- Contribution through ITASCA to the modelling of the TRUE Block Scale evaluation and reporting stage, as well as supporting the elaboration of a TRUE BS continuation test plan.
- Participation in the new Task Force on EBS (Engineered Barrier Systems) with modelling of the THM behaviour in the Canister Retrieval Test (controlled saturation).

In addition, ANDRA intends to exploit ways of a wider the involvement with SKB in both the siting process and demonstration of the repository system.

5.2.3 JNC/CRIEPI

Background

JNC and CRIEPI have been active participants in the Äspö HRL project since 1992 and conducted significant research on groundwater, transport, and engineering aspects of radioactive waste repository development. JNC and CRIEPI research has focused on development and application of experimental and numerical methods for groundwater flow and solute transport. Areas of focus for experimental methods have been development and evaluation of methods for site characterization, fracture activity dating, groundwater dating, groundwater flow velocity/direction measurement, redox experiments, and coupled process experiments. Numerical method developments have included discrete fracture network (DFN), channel network (CN), smeared-fracture/continuum, and coupled thermo-hydro-mechanical (THM) approaches.

Scope for 2001

Task Force on Groundwater Flow and Transport of Solutes

JNC and CRIEPI will continue to participate in the Äspö Task Force on Groundwater Flow and Transport of Solutes.

During 2001, JNC will play an active role in defining and executing Task 6, ”Performance Assessment Modelling Using Site Characterization Data (PASC)”. This task is an extension of solute transport experiments carried out in ”Task 4” and ”TRUE Block Scale”, with the objective of providing theoretical support for integration of site characterization and performance assessment activities and techniques. JNC has been asked to take a leading role in this task during 2001, assisting in the development of the specification of a series of conceptual and numerical modelling exercises integrating site characterization and performance assessment techniques with real experimental data and reference cases.

CRIEPI will conclude its computational works in ”Task 4E” and ”Task 4F” and summarize them in an ICR-report. In ”Task 5”, CRIEPI will apply the original code FEGM/FERM to the site scale groundwater flow and solute transport under disturbed groundwater condition caused by the tunnelling. CRIEPI will probably also participate in ”Task 6” and start the computational work for the project.

JNC and CRIEPI will also work to complete the evaluation and reporting of Task 4 on sorbing tracer experiments, and Task 5 on coupled hydrogeological-geochemical modelling during 2001.

TRUE Block Scale Project/ Two TRUE

JNC will participate in the final stages of the ”TRUE Block Scale Project”, and the initial stages of the ”Two TRUE” experiment during 2001. These two experiments involve hydrogeological characterization and testing of a fracture network at the southwestern part of the ÄspöHRL. JNC has participated in the ”TRUE Block Scale Project” since 1998 within a variety of areas, loke experimental design and interpretation, geological and hydrogeological analysis, and numerical modelling using discrete fracture network and channel network codes.

Prototype Repository

JNC and CRIEPI will continue to participate in the Prototype Repository through JNC, who will participate in Work Packages WP3h and WP3i, and collaborate in WP2.

During 2001, JNC will carry out coupled THM analysis in WP3h and perform preliminary 2 dimensional analysis as well as investigate the feasibility of coupled THMC processes in WP3i.

In WP2 JNC will comment on durability of sensors used in the Prototype Repository, on buffer properties and the emplacement method. Laboratory tests will be carried out by using sensors for measurements of water content in the buffer, e.g. TDR, and the data will be presented.

CRIEPI has been developing the THM model, which can simulate the various interactive phenomena expected in an engineered barrier system , and intends to verify the developed model using data from in situ experiments conducted in Äspö HRL, such as LOT. The model will be used for analyses in the Prototype Repository or Task Force on Engineered Barrier Systems.

Groundwater Dating

CRIEPI has been estimating groundwater residence times by measuring the dissolved He content and ^{36}Cl concentration in 16 groundwater samples collected at the Äspö site in 1999, and intends to present the last groundwater sampling need for the investigation of changes and stability of groundwater environment under the strongly disturbed conditions caused by the tunnelling.

General

JNC's and CRIEPI's technical specialist Mr. Junichi Goto will represent the two organisations at the Äspö HRL.

5.2.4 BMWi

Background and objectives

In addition to the research carried out in Germany for final disposal in salt formations, the purpose of the co-operation in the Äspö HRL programme is to increase the knowledge on other potential host rock formations for radioactive waste repositories. The work addresses groundwater flow and radionuclide transport, two-phase flow and transport processes, and development and testing of instrumentation and methods for detailed underground rock characterization. Six research institutes are performing the work on behalf of BMWi: BGR, FZK, FZR, GRS, Uni Stuttgart, and TU-Clausthal.

Scope for 2001

Two-phase flow

From 1996 to 2000, a programme was carried out addressing two-phase flow and transport processes in saturated fractured rock. In 2000, the investigation phase was concluded. In the coming year, the final report will be written and published.

In co-operation with KTH a project is being performed to further improve the numerical tools for calculating gas-water flow in fractured and porous media. The aims are to further develop the methods to describe two-phase flow processes in single fractures and to develop up-scaling methods for transferring the constitutive relations from microscale to macroscale. Furthermore, data from the Äspö HRL are used to generate geostatistical models. In 2001, different up-scaling techniques for determining aperture distributions in single fractures will be compared. Geostatistical models will be tested for their suitability to generate aperture distributions on different scales.In addition, the scale of a REV is planned to be identified by using renormalisation methods. With this information, parameters and constitutive relations on a larger scale can be obtained and used as input for a 3D-model of a fracture matrix system on a mesoscale. These activities aim at studying the influence of main flow paths on gas migration.

EBS performance

In the Prototype Repository electrical resistivity measurements will be conducted in boreholes and in a backfilled tunnel sections in order to investigate time-dependent changes of water saturation in the buffer, buffer and near-field rock (EDZ). In these investigations advantage is taken of the dependence of the electrical resistivity in rocks on fluid content, porosity, and fluid resistivity. In order to correlate the resistivity of the backfill with the fluid content, the field measurements will be accompanied by laboratory tests. The measuring equipment was ordered late 2000 and delivery of the first components to Äspö HRL is expected in early 2001. The installation of pressure-watertight connection cables will start in March/April 2001. The installation of the first electrode array in Section I of the test field will be performed in October 2001. In order to enable interpretation of the resistivitiy measurement data in terms of water content, calibration measurements started in the GRS laboratory in Braunschweig in 2000. These investigations will be terminated around mid 2001.

An additional contribution to the Prototype Repository consists of THM modelling aimed to determine transport parameters within the repository. For this purpose, available finite element computer programmes are used and developed further and expanded by integrating other available programmes in the system.

A project was initiated aiming at modelling resaturation processes in the bentonite buffer. A simple one-dimensional code will be developed in 2001. It will allow a sensitivity analysis with regard to effects like variable temperature or state of swelling by incorporating the related mathematical formulations into the code. Discussion of the conceptual models and the measured data of the Canister Retrieval Test will be used to verify the model. Supporting laboratory experiments in order to investigate the applicability of the diffusion approach will start in 2001.

Radionuclide transport and retention

Model calculations in the Task Force on Modelling of Groundwater Flow and Transport of Solutes will be concluded. In the past, a large-scale numerical model of a fracture system with more than ten intersecting fractures was developed. This model was used to simulate the transport of substances dissolved in water and the mixing of these substances in the flow field. The aim was to determine the influence of the tunnel excavation on the flow regime. In 2001, the results will be summarized in a final report.

In another project, transport and retention of typical elements in micro-fractured rock around larger fractures are studied. The objectives are to determine distribution and characteristics for altered fracture zones in terms of volume and internal surface. The retention capacity of specific minerals in these micro-fractured systems is determined by laboratory studies. Based on these studies, the bulk retention capacitiy of altered rock will be calculated. In 2001, following inspection of typical fracture zones in the HRL tunnel and of existing drill cores, sampling of representative core sections will be carried out and the cores will be prepared for X-Ray and NMR tomography.

Actinide migration

In 2000, actinide migration experiments in the laboratory and in the CHEMLAB probe were performed. The cores used in these experiments will be analyzed with respect to the flow path and to the interactions between dissolved actinides and solid phases. Analysis of the flow path will be performed by destructive and non-destructive investigations, such as X-Ray computer tomography. Destructive investigations are performed as follows: In the flow path a fluorescent epoxy resin is injected, and the core is cut perpendicular to the cylinder axis in thin slices. Scanning of the slices will show geometry, orientation and properties of the flow path. Additional information of the flow path will be obtained by 3D visualization.

Investigations of the distribution of actinides and the sorption behaviour along the flow path are carried out by different methods. The abraded material gained by cutting the slices is solubilized chemically and the actinide concentration measured by ICP-MS. The actinide concentration in the solid material of the slices will be analyzed by means of coupled laser ablation ICP-MS techniques.

A new CHEMLAB experiment will be started as soon as possible. This requires tests of the CHEMLAB probe itself and equilibration of the core under Äspö groundwater conditions. The duration of this experiment is scheduled to be about 3 month. If additional drill cores can be provided, further experiments will cover also migration experiments with uranium and technetium. Actinide migration in the cores will be modelled by a 2D transport process in connection with adequate sorption models.

Stability and mobility of colloids

Groundwaters present in Äspö will be analyzed with respect to their background colloid concentrations. The in situ measurements will be performed by means of the mobile LIBD (Laser Induced Breakdown Detection) device developed by FZK/INE. Application of LIBD requires a specific detection cell which can be operated under a representative hydrostatic pressures of about 3 MPa. The detection cell is under construction. After completion, it will be tested and the complete system will be calibrated. Measurement of colloid concentrations at Äspö with the mobile LIBD device is planned for late summer 2001.

Microbial activities

A project is being initiated addressing (i) the interaction of actinides with relevant bacteria found in Äspö groundwater, (ii) quantification of actinide bonding on microorganisms in dependence of the chemical conditions in the groundwater, and (iii) characterization of the actinide complexes/compounds formed by interaction with microbes. Laboratory sudies will be conducted in FZR laboratories and presumably start in 2001.

5.2.5 ENRESA

Backfill and Plug Test

Objectives

The purpose of ENRESA's contribution is:

- To develop and test a dynamic pore water pressure sensor, based on the piezocone principle, for the direct measurement of permeability in saturated backfill.
- To model a particular section of the backfill, including the hydration process and the hydraulic tests to be performed.

The dynamic pore pressure sensors and the measurement system required to control the sensors and to perform the pulse tests, were installed in 1999. The sensors were installed in Section A4 of the backfill (see Figure 3-1), and preferably in the areas where a higher density gradient may be expected (i.e. rock proximity), in order to measure hydraulic conductivity after saturation. In this way, a map of local permeability values will be obtained and compared with the global value estimated by backanalysis from the flow test under saturated conditions.

Once saturation is reached, a pulse pore water pressure will be applied, and the corresponding dissipation time will be measured. There is a relation between soil permeability and the shape of this dissipation curve. The details of this relationship are presented in the next section.

Regarding the modelling work, the hydration of the backfill and the flow experiments under saturated conditions will be simulated. An in house programme ("CODE_BRIGHT") will be used for modelling purposes. This is a Finite Element Code that efficiently solves Thermo-Hydro-Mechanical problems involving swelling clay barriers.

A preliminary simulation of the hydration process has been modelled, and as expected, the time required for saturation is very sensitive to the parameters governing the flow equations. Due to the scattering in the laboratory experiments, the reliability of the values adopted for those parameters has been considered to be too low for making good predictions. Therefore, additional laboratory tests are deemed needed and expected to be performed during 2001.

In addition, gradients of salt concentration in the water of the backfill and in the hydration water have complicated the modelling work. An attemt is being made to incorporate such effects in the simulations. In addition, some of the laboratory tests to be performed will focus on the understanding of the coupling between hydraulic properties and water salt concentration. The effect of this coupling has been highlighted after realising that in Äspö water with different salt concentration is being mixed in the backfill.

Experimental concept

The dynamic pore pressure sensors

The dynamic pore pressure (DPP) sensor is a specially constructed hydraulic piezometer, with a cylindrical ceramic filter of 60 microns pore size, and with a miniature pressure sensor inside. Figure 5-1 shows the DPP sensor configuration. Each piezometer has two metallic capillary tubes for water input and output, and an electrical cable for the pressure transducer signal.

The DPP sensors work in the same way as the "piezocone" testing method: a controlled positive pressure pulse is applied to the sensors, and the evolution of the pressure drop in the sensor body, which is controlled by the local permeability of the surrounding material, is analysed.

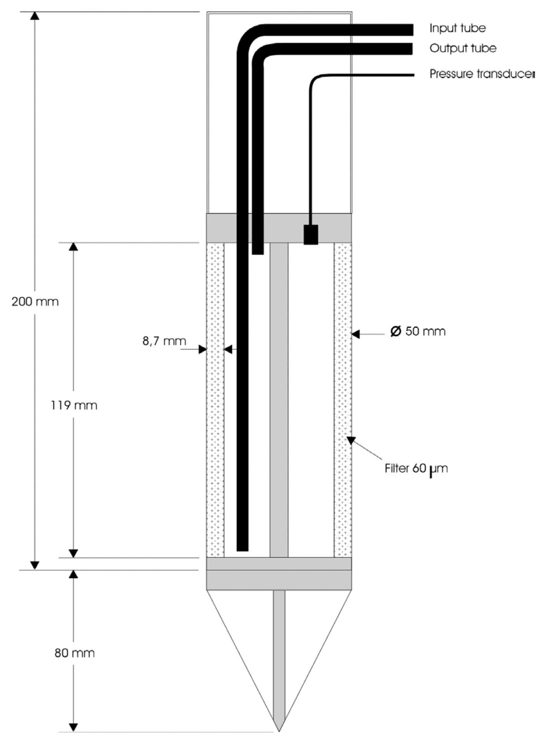


Figure 5-1 *DPP sensor configuration*

According to the initial calculations made by UPC (Barcelona University), the compressibility of the water existing in the measuring circuit is a very sensible parameter, provided that the mechanical components (tanks, pipes...) are sufficiently rigid. As the expected range of the permeability to be measured may be very wide (from 10^{-8} to 10^{-11} m/s), the system has been designed so that the internal volume of the measuring circuit can easily be modified. Also the possibility of measuring the volume (flow) of water transfer to the backfill during the pulse test has been included in the system design, for the case of very permeable media.

Additional equipment and system description

The complete system comprises a number of DPP sensors (13 units), and a common measuring system, which is located outside the backfill area.

The measuring and control system performs the following three basic functions:

- Flushing and de-airing of the hydraulic circuit of each DPP sensor.
- Generation of pressure pulse and control.
- Recording of the pressure variation at the DPP sensors.

The hydraulic/electric control system scheme is shown in Figure 5-2. The two hydraulic tubes for all the DPP sensors are connected to electric valves in a circuit-switching panel, so that only one sensor circuit is connected to the measuring system at any one time.

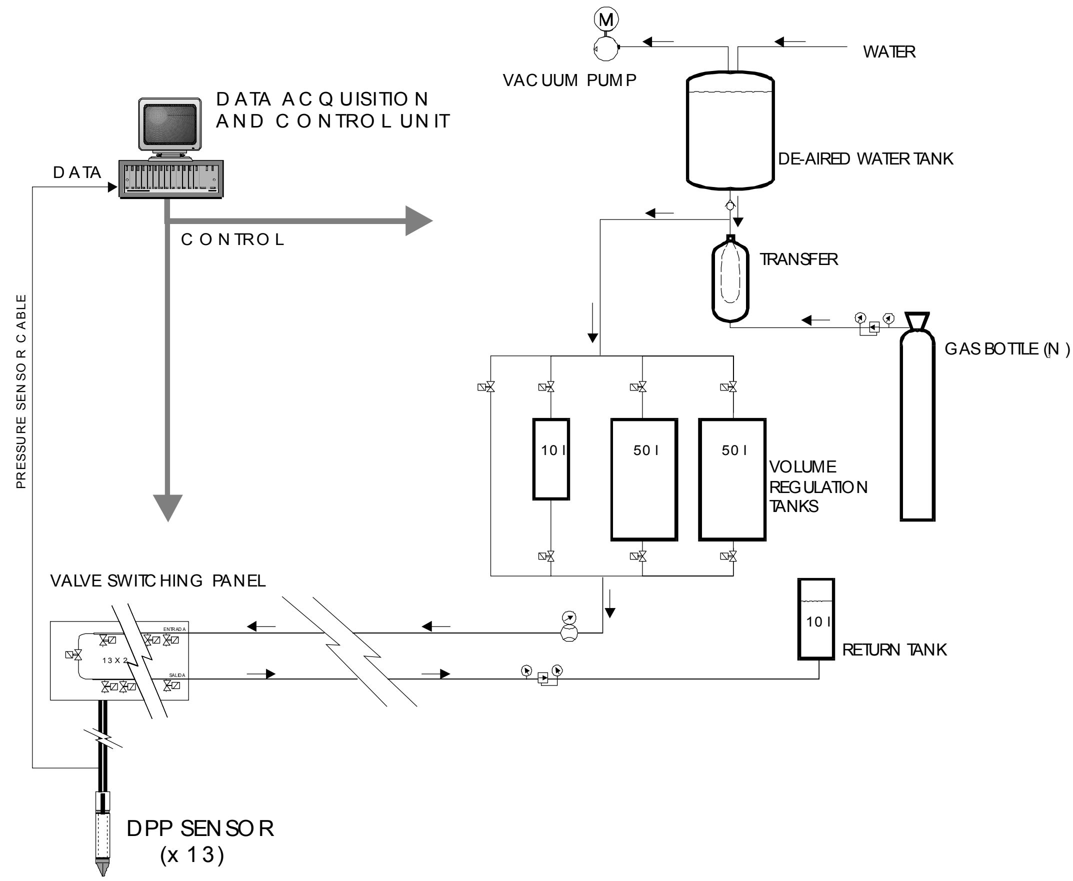


Figure 5-2 *Control system scheme*

The data acquisition and control unit (DAC) controls the switching panel, which actuate the appropriate valves in the system, according to manually input commands. Electrical signals from all the DPP sensors are permanently connected to the DAC unit for automatic data recording and storage. The system layout is shown in Figure 5-3.

In principle, the entire measurement sequence is carried out manually, although some of the operations are automated (specially valves control) to simplify the process, making it more accurate and repetitive, and to avoid malfunction.

Measurement principle

The basis of the "in situ" tests is the analysis of the dissipation of the development of the pore water pressure with time, after a sudden increase of the pressure in the sensor. Water from the cylindrical ceramic filter will flow out to the soil surrounding the sensor according to the permeability and the compressibility of the soil. From a practical point of view, the interpretation of these tests is sometimes difficult, and main efforts have been devoted to develop a systematic procedure to perform the interpretation of these pulse tests.

The mathematical formulation of the problem is described in the hydrogeological and geotechnical literature (Cooper et al, 1967 and Gibson, 1963). According to the analytical solution, the equalisation ratio of the water pressure depends mainly on the combined non-dimensional variable $\mu T = (FKt / f\gamma_w)$. F is the intake factor of the piezometer, K is the backfill permeability, t is time, f is the system flexibility and γ_w is the water density. System flexibility is due to the equipment itself (piezometer, tubes, etc), and also to the water compressibility.

A back-analysis procedure to identify backfill permeability from pore pressure records has been developed and tested in the laboratory, where a calibration cell has been built to test the functions of the sensor ant to reproduce the pulse test under controlled conditions.

Scope for 2001

The sensors and the whole measuring system were installed during March 1999, see sensors installation positions in Figure 5-4.Today, the system is working properly and sensor data are recorded to see the evolution of the pressure in the backfill.

Some laboratory characterisation regarding salt effects on backfill behaviour is going to be performed, but it is not fully defined yet. The modelling of the test will depend on the hydration process, and whether the backfill becomes saturated in 2001 or not.

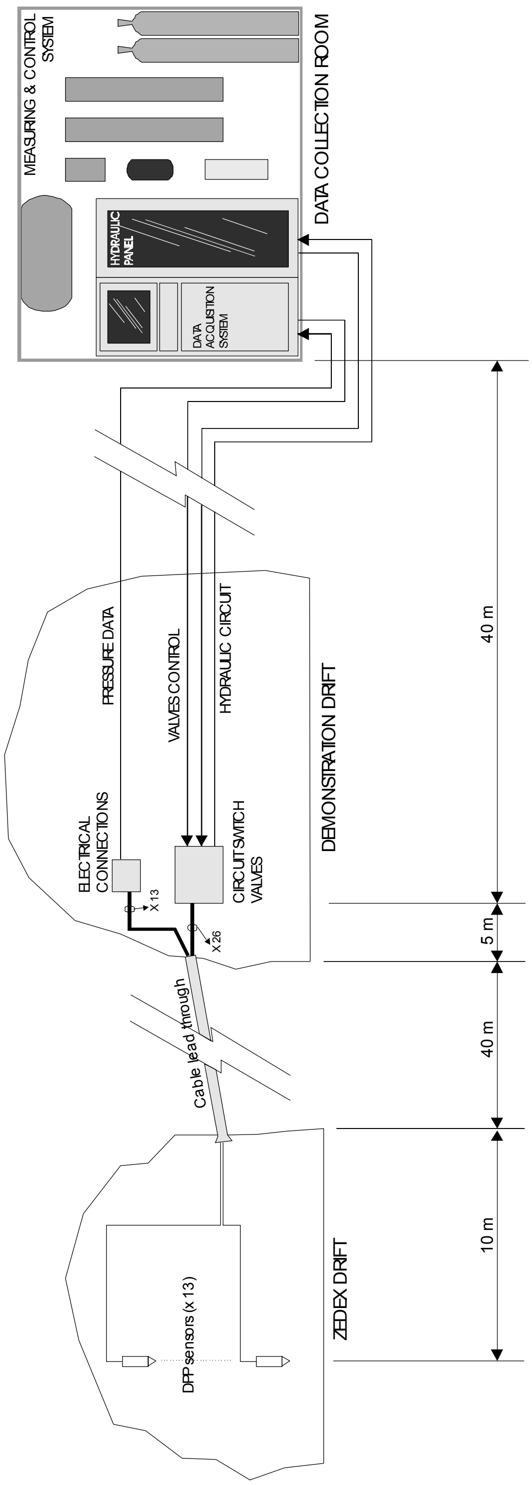


Figure 5-3 *System layout.*

.

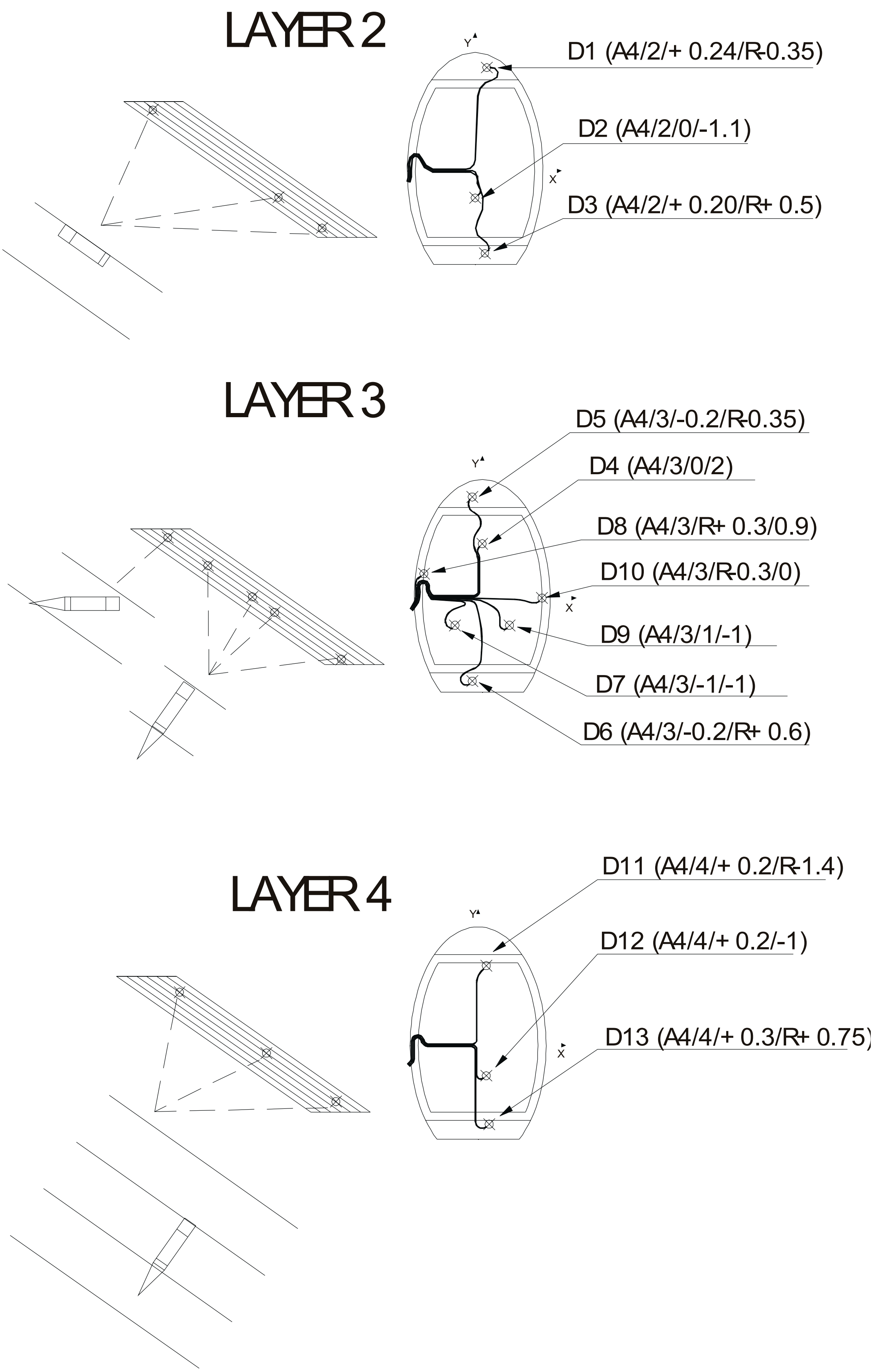


Figure 5-4 *Sensors location in A4 section, the location of A4 is shown in Figure 5-1.*

.

Prototype Repository

Objectives

The purpose of ENRESA's contribution is:

– To apply a system for tracking any movements of the canisters along the duration of the experiment, including tilting, and vertical and horizontal displacements.

– To perform THM and THMC modelling of the experiment

As an additional goal, the instrumentation of this part of the project has an innovative component due to the application of fibre optics based sensors. This will require the development of new custom-made sensors, which are not available for the harsh environment prevailing in the bentonite buffer.

The canister displacement system will be installed in deposition hole No. 3 in Section I and No. 6. in Section II (see Figure 5-5).

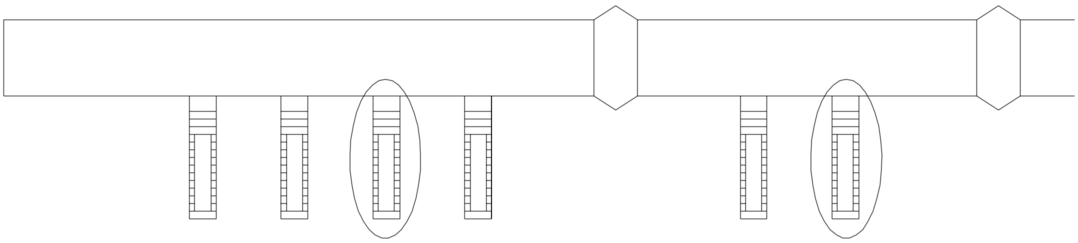


Figure 5-5 *Deposition holes for canister displacement measure*

Regarding the modelling work, ENRESA will contribute with several analyses in a step by step approach. Initially, a T or TM analysis will be performed, in order to check the mesh and to compare the result with other analyses being performed by other groups. Then, a THM simulation of one canister, focusing on the behaviour of the bentonite, will be conducted. Finally, the chemical aspects involved in the bentonite buffer will be addressed in a preliminary simulation.

The code CODE_BRIGHT will be used for the simulations. It is an in-house finite element code which has been used previously in other similar works, and which in detail considers the constitutive models that describe the stress – strain behaviour of bentonite barriers. A chemical version of the code is being developed, and some preliminary analyses have already been performed.

Experimental concept

Layout

For each deposition hole, six displacement sensors are foreseen; three in the top part and three in the bottom part of the canister, as shown in Figure 5-6.

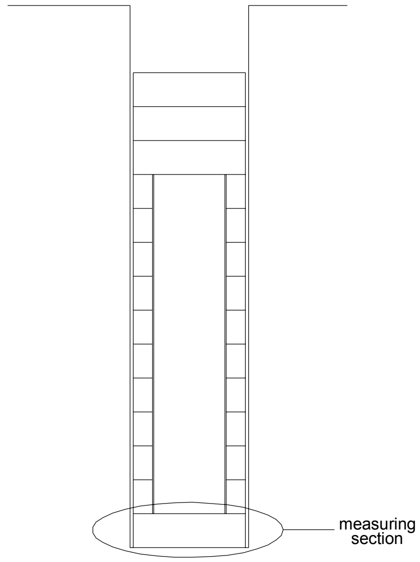


***Figure 5-6** Layout of measuring section in the bottom part*

The three at the top are placed horizontally just below the lid and attached to the cylinder, in a 120º radial disposition. The sensors will always be in a horizontal position, so that the horizontal displacement of the canister can be measured.

The other three displacement sensors will be vertically placed in the bottom in holes drilled into the bentonite block. These three sensors will determine the vertical displacement of the canister, as well as any possible tilt. The points where the sensors are attached to the canister will be located on the same120º radial disposition as the horizontal sensors at the top.

Sensors description

The displacement sensors to be installed are based on fibre optics. They comprise no electronics inside, but a Thin Film Fizeau Interferometer, that receives a broadband white light and returns a wavelength modulated light. Hence, it is assured that no electromagnetic interference will affect the readings.

The selected sensor is the FOD 25 from Roctest (Canada). Because of the harsh working conditions for the sensors, a rugged version will be specially constructed in Incoloy 825 by the manufacturer, assuring water tightness and corrosion resistance. The dimensions of the sensor are fairly small, which helps to keep the disturbance in the whole system low.

The fiber optical cables will be sheathed with Incoloy 825 tube along their length in the buffer, and with polyamide tube along their length in the backfill.

Supervision and data management

A local recording system will be installed on site to gather the data. It will comprise a 16 channel DMI signal conditioner from Roctest connected to a commercial SCADA running in a PC with a modem. (see Figure 5-7). One reading will be collected every hour from every sensor, and the mean value will be stored every day in a local database.

The supervision and data management will be carried out from a remote monitoring system located in the main offices of AITEMIN in Madrid. This system will be connected periodically with the local one via modem for data transmission. It will comprise the same SCADA running in a PC. A master database will be built up from the data gathered.

Reports will be generated periodically including graphical representation of the evolution of the displacements.

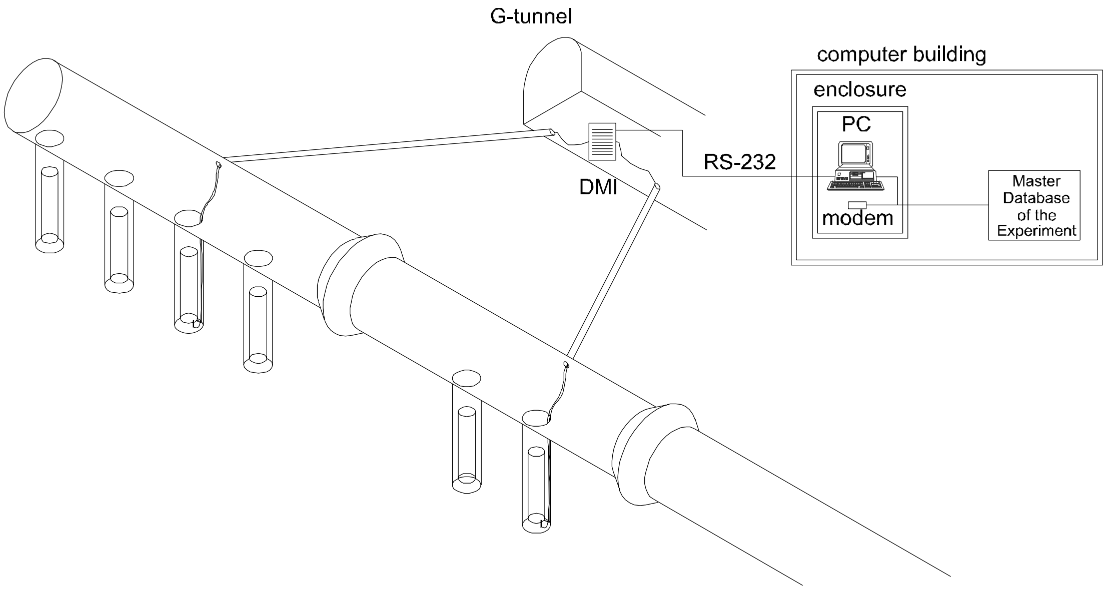


Figure 5-7 *Cabling and local monitoring system (Äspö)*

Scope for 2001

During 2001 the sensors are purchased, assembled and the ones for hole No.3 in Section I installed. Monitoring and data acquisition systems are taken into operation. T and TM simplified modelling is made and THM modelling initiated. Installation in hole No.6 is made in year 2002 following the installation plan for the whole Prototype Repository.

References

Andersson, P., Ludvigsson, J-E., Wass, E. And Holmqvist, M. 2000a : TRUE Block Scale Project, Tracer Test Stage, Phase A Interference, dilution tests and tracer tests.
Äspö HRL International Progress Report, IPR-00-28.

Andersson, P., Wass, E., Holmqvist, M. 2000b : TRUE Block Scale Project, Tracer Test Stage, Tracer tests, Phase B.
Äspö HRL International Progress Report, IPR-00-29.

Cooper, Bredehoeft, Papadopoulos, 1967, Water Resources Research, 3:263-297;

Cvetkovic, V., Cheng, H. And Selroos, J-O. 2000 : First TRUE Stage, Evaluation of tracer retention understanding experiments (first stage) at Äspö.
Äspö HRL International Cooperation Report, ICR-00-01

Elert , M. in prep : TR-01-XX

Elert, M. 1999 : Evaluation of modelling of the TRUE-1 radially converging and dipole tests with conservative tracers. The Äspö Task Force on Modelling of Groundwater Flow and Transport of Solutes. Tasks 4C and 4D
SKB Technical Report, TR-99-04.

Munier and Hermanson, 2001, in prep. GEOFUNK project

Gibson, 1963, Geotechnique, 13:1-11

Gustafson G, Ström A, 1995. The Äspö Task Force on Modelling of Groundwater Flow and Transport of Solutes. Evaluation report on Task No 1, the LPT2 large scale field experiments.
SKB International Cooperation Report, ICR 95-05.

Gustafson G, Ström A, Vira J, 1997. The Äspö Task Force on Modelling of Groundwater Flow and Transport of Solutes. Evaluation report on Task No 3, the Äspö tunnel drawdown experiment.
SKB International Cooperation Report, ICR 97-06.

Haveman, S.H., Pedersen, K. and Routsalainen, P. (1999) Distribution and metabolic diversity of microorganisms in deep igneous rock aquifers of Finland.
Geomicrobiol. J. 16, 277-294.

Hermanson, J. and Doe, T. 2000 : TRUE Block Scale Project, March'00 Structural and Hydraulic model based on borehole data from KI0025F03.
SKB HRL International Progress Report, IPR-00-34.

Kertsting A, Efurd D, Finnegan D, Rokop D, Smith D, Thopmson J, 1999.
Migration of plutonium in the ground water at the Nevada Test Site. Nature

Laaksoharju M, Degueldre C, Skårman C, 1995. Studies of colloids and their importance for repository performance assessment.
SKB Technical Report, TR 95-24

Motamedi, M. (1999) Thesis. 1, pp 1-45 Göteborg University, Göteborg.

Pedersen K (1996) Investigations of subterranean bacteria in deep crystalline bedrock and their importance for the disposal of nuclear waste.
Can J Microbiol 42: 382-391

Pedersen K (1999) Subterranean microorganisms and radioactive disposal in Sweden.
Engineering Geology 52: 163-176

Pedersen K, Karlsson F (1995) Investigations of subterranean microorganisms - Their importance for performance assessment of radioactive waste disposal.
SKB Technical Report, TR 95-10

Pedersen K, Motamedi M, Karnland O, Sandén T (2000a) Cultivability of microorganisms introduced into a compacted bentonite clay buffer under high-level radioactive waste repository conditions.
Engineering Geology 58: 149-161

Pedersen K, Motamedi M, Karnland O, Sandén T, Sandén (2000b) Mixing and sulphate-reducing activity of bacteria in swelling compacted bentonite clay under high-level radioactive waste repository conditions.
Journal of Applied Microbiology 89: 1038-1047

Pedersen, K. (1997). Investigations of subterranean microorganisms and their importance for performance assessment of radioactive waste disposal. Results and conclusions achieved during the period 1995 to 1997
SKB Technical Report , TR 97-22

Pedersen, K. (1999) Subterranean microorganisms and radioactive disposal in Sweden.
Engineering Geology 52, 163-176.

Rhén I (ed), Gustafson G, Stanfors R, Wikberg P, 1997b. Äspö HRL - Geoscientific evaluation 1997/5. Models based on site characterization 1986-1995.
SKB Technical Report, TR 97-06.

Rhén I, Forsmark T,1999. High Permeability Features (HPF).
SKB HRL International Progress Report, IPR-00-02

Allard B, Karlsson F, Neretnieks I, 1991. Concentrations of particulate matter and humic substances in deep groundwaters and estimated effects on the adsorption and transport of radionuclides
SKB Technical Report, TR 91-50

Svensson U, 1997a. A regional analysis of groundwater flow and salinity distribution in the Äspö area.
SKB Technical Report, TR 97-09.

Svensson U, 1997b. A site scale analysis of groundwater flow and salinity distribution in the Äspö area.
SKB Technical Report, TR 97-17.

Svensson U, 1999a. A laboratory scale analysis of groundwater flow and salinity distribution in the Äspö area.
SKB Technical Report, TR-99-24.

Svensson U, 1999b. Representation of fracture networks as grid cell conductivities.
SKB Technical Report, TR-99-25.

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

Winberg, A. (ed) 2000. TRUE Block Scale Project – Final Report of the Detailed Characterisation Stage – Compilation of premises and outline of programme for tracer tests in the block scale.
SKB HRL International Cooperation Report, ICR-00-01

Winberg, A. (in prep): Proceedings from the 4th International Äspö Seminar – Results and conclusions of the First TRUE Stage.
SKB Technical Report, TR-01-XX

Winberg, A., Andersson, P., Hermanson, J., Byegård, J., Cvetkovic, V. and Birgersson, L. 2000. Final report of the first stage of the tracer retention understanding experiments. Swedish Nuclear Fuel and Waste Management Company,
SKB Technical Report, TR-00-07

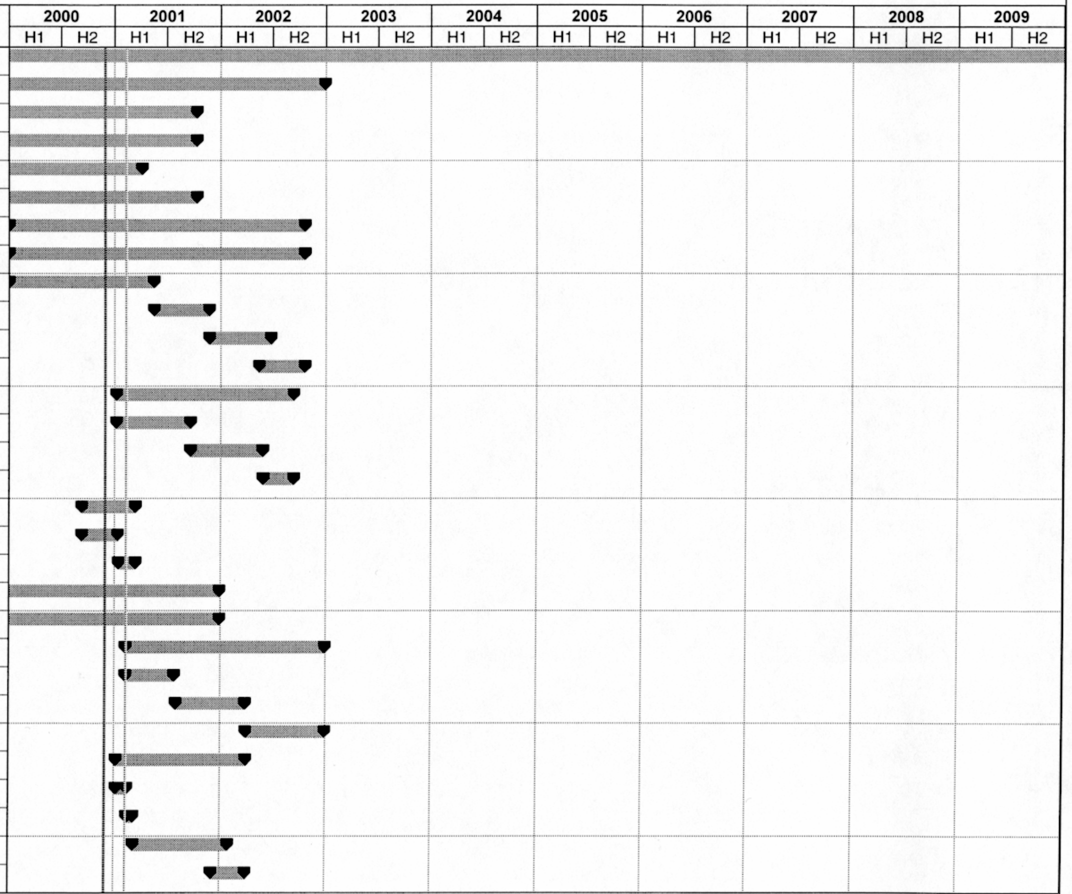
Appendix A – Schedules

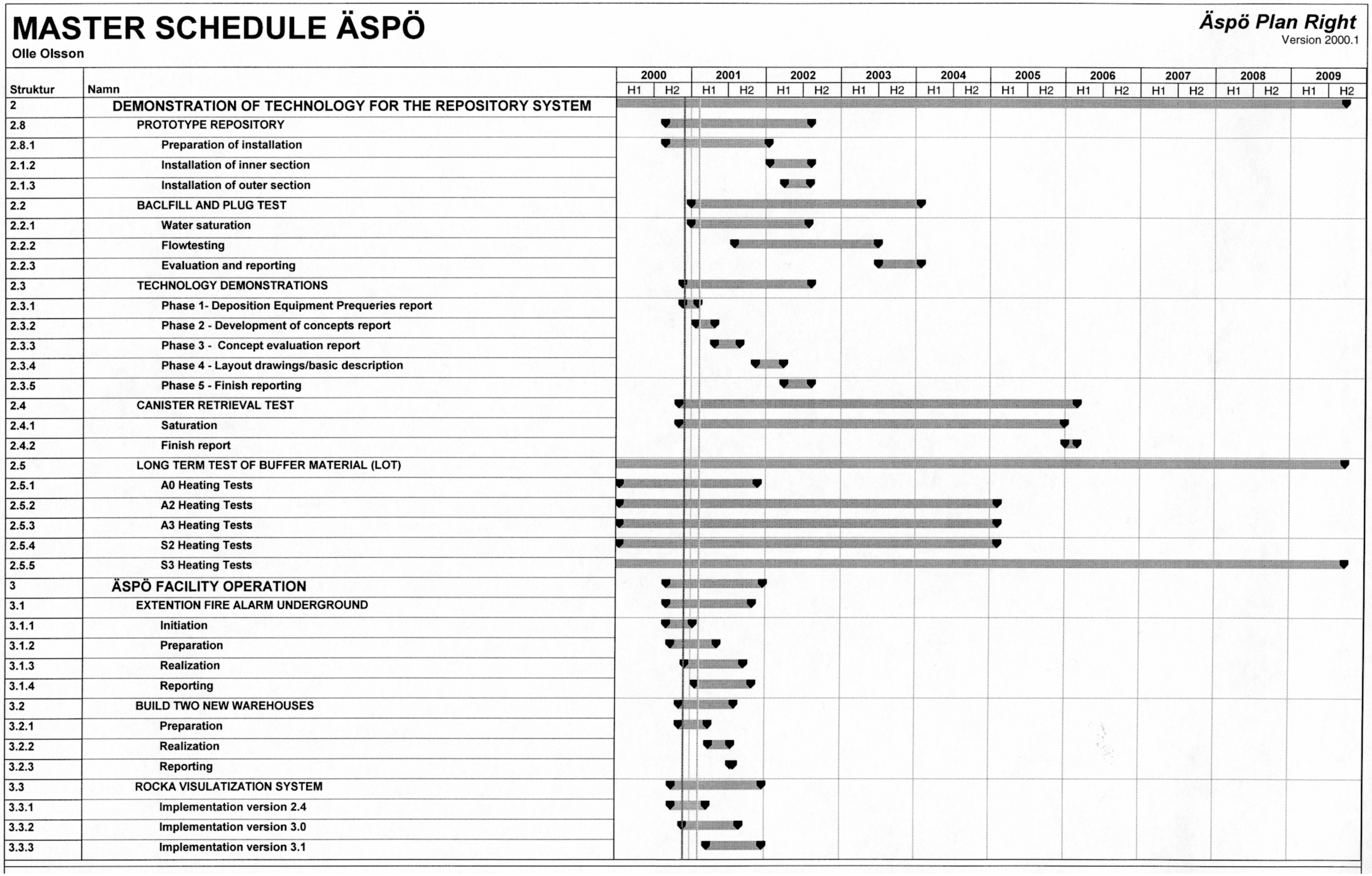
MASTER SCHEDULE ÄSPÖ

Olle Olsson

Äspö Plan Right
Version 2000.1

Struktur	Namn
0	MASTER SCHEDULE ÄSPÖ
1	TEST OF MODELS OF THE BARRIER FUNCTION OF THE HOST ROCK
1.1	TRACER RETENTION UNDERSTANDING EXPERIMENTS
1.1.1	TRUE Blocks Scale
1.1.1.1	Tracer test stage
1.1.1.2	Evaluation and reporting stage
1.2	RADIONUCLIDE RETENTION
1.2.1	Actinideexperiment
1.2.1.1	Preparations
1.2.1.2	Field experiments II
1.2.1.3	Field experiments III
1.2.1.4	Reporting
1.2.2	Radiolysisexperiment
1.2.2.1	Realization indirect radiolysis
1.2.2.2	Realization direct radiolysis
1.2.2.3	Reporting
1.3	LONGTERM STABILITY/HYDROCHEMICAL STABILITY
1.3.1	Realization
1.3.2	Reporting
1.4	MATRIX FLUID CHEMISTRY
1.4.1	Water sampling and analysis
1.5	COLLOIDS
1.5.1	Laboratory tests
1.5.2	Field tests
1.5.3	Reporting
1.6	MICROBE
1.6.1	Initiation
1.6.2	Preparation
1.6.3	Realization
1.6.4	Reporting




MASTER SCHEDULE ÄSPÖ
Olle Olsson
Äspö Plan Right
Version 2000.1
Struktur
Namn
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009
H1 H2
2 DEMONSTRATION OF TECHNOLOGY FOR THE REPOSITORY SYSTEM
2.8 PROTOTYPE REPOSITORY
2.8.1 Preparation of installation
2.1.2 Installation of inner section
2.1.3 Installation of outer section
2.2 BACLFILL AND PLUG TEST
2.2.1 Water saturation
2.2.2 Flowtesting
2.2.3 Evaluation and reporting
2.3 TECHNOLOGY DEMONSTRATIONS
2.3.1 Phase 1- Deposition Equipment Prequeries report
2.3.2 Phase 2 - Development of concepts report
2.3.3 Phase 3 - Concept evaluation report
2.3.4 Phase 4 - Layout drawings/basic description
2.3.5 Phase 5 - Finish reporting
2.4 CANISTER RETRIEVAL TEST
2.4.1 Saturation
2.4.2 Finish report
2.5 LONG TERM TEST OF BUFFER MATERIAL (LOT)
2.5.1 A0 Heating Tests
2.5.2 A2 Heating Tests
2.5.3 A3 Heating Tests
2.5.4 S2 Heating Tests
2.5.5 S3 Heating Tests
3 ÄSPÖ FACILITY OPERATION
3.1 EXTENTION FIRE ALARM UNDERGROUND
3.1.1 Initiation
3.1.2 Preparation
3.1.3 Realization
3.1.4 Reporting
3.2 BUILD TWO NEW WAREHOUSES
3.2.1 Preparation
3.2.2 Realization
3.2.3 Reporting
3.3 ROCKA VISULATIZATION SYSTEM
3.3.1 Implementation version 2.4
3.3.2 Implementation version 3.0
3.3.3 Implementation version 3.1