ÄSPÖLABORATORIET

INTERNATIONAL COOPERATION REPORT 95-06

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

Issue Evaluation table

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December 1995

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ÄSPÖ TASK FORCE ON MODELLING OF GROUNDWATER FLOW AND TRANSPORT OF SOLUTES

ISSUE EVALUATION TABLE

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ABSTRACT

An "Issue Evaluation Table" has been compiled by the delegates of the Task Force on modelling of groundwater flow and transport of solutes and the associated modelling teams. The table aims at reflecting our current understanding of the key issues related to performance of the geological barrier, availability of reliable data, how they can be or are being addressed by different organizations or at different underground laboratories. One of the major aims has been to produce a document which is condensed, informative, but not necessarily complete. The following issues are addressed: 1) radionuclide retention processes, 2) influence of heterogeneity on radionuclide transport predictions, 3) long term stability of the geologic environment, 4) modelling aspects, and 5) geosphere changes due to repository presence.

ISSUE EVALUATION TABLE

Version 4

Olle Olsson

BACKGROUND

The idea of putting together a table in order to identify what experiments are planned at Äspö and other underground laboratories was raised by Masahiro Uchida, PNC, at the Modelling Task Force meeting in April 1994. A draft "Planning Table" was compiled by Uchida shortly after the meeting. The "Planning Table" has then been reviewed and revised after discussions between Masahiro Uchida (PNC), Anna Littleboy (Nirex), Anders Ström (SKB), and internally within SKB. These discussions resulted in a revised structure of the table and also a change in name.

The revised table was discussed at the Task Force meeting at Kuhmo on December 1st, 1994. The table was scrutinized by 4 different groups each focussing on a different part of the table. Based on the recommendations from the various groups a new version of the table was produced which has later been updated in accord with review comments received, mainly from Paul Marschall (NAGRA).

The table is named "Issue Evaluation Table" in order to reflect that it intends to provide a basis for identification and evaluation of key issues in performance assessment of a deep geological repository. The full name of the table is "Key issues in representation of the geosphere as a basis for input to Performance Assessment". The table aims at reflecting our current understanding of the key issues related to performance of the geological barrier, their importance, how they can be or are being addressed by different organizations or at different underground laboratories. Hopefully, the table should provide some structure to the many different issues related to the geosphere which are discussed in performance assessment of deep geological repositories.

TABLE OBJECTIVES

The objectives of the table are:

- to provide a summary of key issues which are or could be of concern in performance assessment,
- to provide a basis for prioritization of experimental work to be performed at Äspö,
- to list key issues as a basis for identifying issues which could be of interest to resolve in joint projects at Äspö HRL or elsewhere, and
- to provide information on projects in progress at Äspö or elsewhere relating to the various issues.

It should be noted that SKB has used a preliminary version of the table as a basis for prioritization of future work which has been defined in the Research Development and Demonstration Plan 1995 which was submitted to the Swedish authorities in September 1995.

One of the major aims have been to produce a document which is condensed and still informative, but not necessarily complete. It is hoped that this can be a living document which is updated as new knowledge is gained and new projects to resolve remaining issues are started.

TABLE CONTENTS AND STRUCTURE

The table has been compiled by the delegates of the Task Force on modelling of groundwater flow and transport of solutes and the associated modelling teams. The contents and the structure of the table is of course reflected by the persons who have been engaged in producing the table and providing comments on its contents. It should be recognized that the individuals engaged in the Task Force work are mainly modelers and experimentalists. This document has not been submitted for extensive review outside the Task Force group and the views of experts on performance assessment may not be fully included in the current version.

In identifying issues that should be included in the table we have aimed at identifying such processes and/or conditions which may affect the performance of a deep geological repository for radioactive waste. In this work the SKB concept on direct disposal of spent nuclear fuel, KBS-3 (also described in SKB-91), has been a starting point. During the work we have tried to include issues which are relevant also to other disposal concepts and different geological media to provide a document which is of general interest. We have also tried to formulate the issues in a generic fashion to avoid defining issues which are closely related to specific model formulations or codes.

In structuring the table an attempt has been made to structure it according to the basic components of model descriptions in general and descriptions of radionuclide transport in particular. Following the thinking outlined in SKB TR

94-08 (The structure of conceptual models with application to the Äspö HRL Project by Olsson et al.) the issues in performance assessment can be divided into three basic categories: processes, validity of conceptual models, and input data. For each category there is a set of general issues or questions as indicated below:

- Processes; Have all relevant processes been identified? is our understanding of each process adequate? what is the relative significance of different processes under different circumstances (scenarios)?
- Conceptual models; What is an appropriate conceptualization in terms of structure, material properties, and boundary conditions? is the degree of simplification appropriate for the purpose? what is the influence of conceptual uncertainty?
- Data; can sufficient and representative data be obtained on geometry, material properties, and boundary conditions? how do we relate model parameters to measurable entities? to what extent can material properties be correlated to structural features (e.g. fracture zones) at a site? how reliable is the structural model?

In the table we have tried to address these general issues more specifically. The table is basically structured as follows:

1 Radionuclide retention processes

This section attempts to identify the key issues related to various processes that influence radionuclide transport.

2 Influence of heterogeneity on radionuclide transport predictions

This section addresses a number of issues related to the selection of appropriate conceptual models with respect to structure and associated material properties and how to get data to these models.

3 Long term stability of geologic environment

This section lists issues related to the reliability of long term predictions in an evolving environment.

4 Modelling aspects

In this section we have tried to compile issues specifically related to the selection and applicability of predictive models.

5 Geosphere changes due to repository presence

Issues related to the changes induced on the geosphere through construction and operation of the repository.

The first page of the table lists the headings of the columns and the type of information that is included for each issue. The issues are defined in the first column of the table, sometimes additional specifications or clarifications of the issues are provided in the Comments column. The issue of data availability and reliability for a process or a geometric scale is raised in the third column. The lack of data could prompt development of technology to obtain more data for a specific parameter.

The table includes a column for putting a priority on each listed issue. This column is left blank because the priority given to each issue depends on the repository concept and the host rock chosen. In general, this is different for the organizations participating in the Äspö Hard Rock Laboratory and hence there is no common ground for putting priorities on the issues listed. However, prioritization of issues should be of addressed by each organization separately.

ABBREVIATIONS USED

TRUE	Tracer Retention Understanding Experiments; A series of tracer tests in detailed and block scales to be performed at Äspö HRL. Description in SKB Äspö PR 25-94-24. The letters A, B, and C refer to the different stages of TRUE.
LPT2	Large scale pumping test at Äspö (completed). Experimental results used to test models for flow and transport (Task 1 for Äspö Task Force on modelling of groundwater flow and solute transport)
HYDRIS	SKB study aimed at evaluating different hydraulic test schemes and conceptual models used to compute hydraulic parameters (desk study).
2-phase	Degassing of groundwater and two-phase flow, Äspö HRL Project. Objective: to show if degassing of groundwater at low pressures has significant effects on measurements of hydraulic properties in boreholes and drifts, understanding of two-phase flow, to get a measure of time scales required for resaturation of repository.
PVC	Pore Volume Characterization, project carried out at Äspö HRL (completed, reported in PR 25-94-30). Mapping of fracture apertures by grout injection.
CTH-L	SKB project to study fracture intersection properties in laboratory.
ZEDEX	ANDRA-UK Nirex-SKB Project conducted at Äspö HRL. Objective: to study properties, extent, and origin of EDZ.
DOABLE	Working name for SKB:s plan to construct a prototype repository at Äspö.

CHEMLAB	Tool used in Radionuclide retention project to be performed at Äspö HRL. Objective: to determine material properties (chemical constants) under natural conditions.
REX	Detailed scale redox experiment to be performed at Äspö HRL.

Experiments performed at the Grimsel Test Site

FRI	Fracture Zone Investigation
MI	Migration experiment
EX/CP	Excavation experiment/Connected Porosity test
BK	Fracture System Flow Test
EDZ	Excavation Disturbed Zone experiment
TPF	Two Phase Flow test
BOS	Borehole sealing

Experiments performed by PNC

LABROCK	Laboratory experiment which uses 50 cm cube rock block including single fracture.
NETBLOCK	Laboratory experiment which uses 1 m cube rock block including fracture network/fracture intersection (due to start April 97).
GEOFRONT	Laboratory experiment which looks at the evolution of high pH plume within atmospheric control column.
KT1	Kamaishi Task 1: Age determination and geological observations of fracture filling materials.
KT2-1	Kamaishi Task 2-1: Study of REDOX change around a drift.
KT2-2	Kamaishi Task 2-2: EDZ experiment.
KT3-1	Kamaishi Task 3-1: Detailed scale matrix diffusion and sorption experiment.

KT3-2	Kamaishi Task 3-2: Block scale fracture network flow and non-sorbing tracer experiment.
KT5	Kamaishi Task 5: Head and geochemistry change due to earthquakes.

Key issues in representation of the geosphere as a basis for input to PA

#	Generic or process issues	Relevance for input to PA	Availability of reliable data	Feasibility of -experiments (EX) -test of model concepts (MC)	Priority	Project	Comments Remarks -conceptual or data issue
	Definition of key issues which need to be addressed in PA. List of issues related to theoretical concepts, physical processes, or parameters.	Brief description of relevance to PA and/or hypothesis used in PA which could be questioned. Uncertainties expected to be related to PA	Assess whether reliable data exists or it is feasible to derive defensible values for parameters for the issue in question	List useful methodology for resolving issue qualitatively or quantitatively Assess if it will be feasible to prove or disprove possible hypothesis or to test (alternative) model concepts	5= high 0= low	List experiments addressing the issue and responsible organization	Classify if issue is mainly conceptual or related to lack of reliable data Briefly state status of issue

#	Generic or process issues	Relevance for input to PA	Availability of reliable data	Feasibility of -experiments (EX) -test of model concepts (MC)	Priority	Project	Comments Remarks -conceptual or data issue
1	**RADIONUCLIDE RETENTION PROCESSES**						
1.1	**Diffusion into stagnant pores and matrix**						
1.1.1	Efficiency of matrix diffusion as a retardation mechanism	Major retardation mechanism in PA, depends on several parameters see 1.1.2-1.1.4	- Yes, indirect data for moderate and high effective diffusivity, questionable for low diffusivities - Natural analogues provide evidence of mechanism	EX: Yes, by long time experiments, breakthrough tails in tracer tests MC: Yes, by reliable data		TRUE detailed B Chemlab Grimsel: MI,EX/CP TVO: gas diffusion exp, lab exp on surface diffusion and anion exclusion	Data issue Existence of mechanism well established More important for weakly sorbing radionuclides
1.1.2	Matrix diffusion depth (connected porosity)	Determines upper limit for retention in long term perspective	- Yes, from natural analogues - Questionable value of lab data	EX: Yes, by long time experiments followed by resin impregnation and excavation MC: Yes, by reliable data		TRUE detailed B Grimsel: MI, EX/CP PNC: lab exp, natural analog study	Data issue Porosity adjacent to fracture might not be constant
1.1.3	Fracture area available for matrix diffusion and surface sorption (pore structure)	Determines magnitude of retention due to matrix diffusion and sorption	- No, further investigations required	EX: Yes, by the use of tracers with different K_d, different D_e, thermal transport, resin impregnation, detailed flow measurements? MC: Yes		TRUE detailed B TRUE block Grimsel: EX/CP, MI TVO: lab exp on rock blocks PNC: LABROCK, KT3-1	Conceptual issue Data issue Dependance of available surface on boundary conditions? Scale effects? When and how can data be obtained from site characterization work?

#	Generic or process issues	Relevance for input to PA	Availability of reliable data	Feasibility of -experiments (EX) -test of model concepts (MC)	Priority	Project	Comments Remarks -conceptual or data issue
1.1.4	Diffusion into stagnant areas and dead end pores within conductive fracture plane (pore structure)	Limited contribution to retention in long term perspective	- Limited, due to strong correlation with matrix diffusion	EX: Yes, by the use of tracers with different diffusivities, resin impregnation and excavation MC: Limited, due to strong correlation with matrix diffusion		TRUE detailed Grimsel: EX/CP, MI PNC: LABROCK, NETBLOCK	Conceptual issue Data issue Affects interpretation of experiments
1.2	**Sorption**						
1.2.1	Fracture area available for surface sorption						See 1.1.3
1.2.2	Magnitude of K_d for nuclides, dependence on mineral composition and gw chemistry. Possibility of extrapolation of lab data to field conditions	Determines magnitude of retardation. Reliability of data for site scale modelling.	- Yes, mostly lab data (limited on dependance of mineral composition and gw chemistry),	EX: Yes, by lab data and comparison with in-situ data (tracer tests followed by fracture excavation) In-situ distribution of trace elements MC:		TRUE detailed CHEMLAB In-situ K_d project Grimsel: MI TVO: Lab exp PNC: Lab exp	Data issue Scale effect in K_d values? Relation of K_d to geology, fracture minerals, and gw composition, can this be related to structural features at a site?
1.2.3	Linearity and reversibility of sorption mechanisms	Recommendation of sorption model for PA	- Limited, lab data	EX: Yes, Lab tests		Tracer development at CTH NAGRA: Lab tests PNC: Lab exp	Conceptual issue Is linear sorption model sufficient for PA? Can complex sorption processes be modelled? (with sufficient reliability for PA?)
1.2.4	Sorption on fracture debris (flakes, gouge, coatings)	Possible additional retention in short term. Need for assessment of relevance for PA	- Limited, lab data	EX: Possibly, difficult to separate from other effects		(TRUE detailed C) Grimsel: EX/CP +lab tests PNC: Lab exp	Conceptual issue Affects experiments, long term importance limited

#	Generic or process issues	Relevance for input to PA	Availability of reliable data	Feasibility of -experiments (EX) -test of model concepts (MC)	Pri-ority	Project	Comments Remarks -conceptual or data issue
1.2.5	Sorption kinetics	Recommendation of sorption model for PA	- Qualitative data available from lab tests	EX: Yes, Lab tests			Conceptual issue Data issue Not relevant for geosphere transport
1.2.6	Sorption/Cation Exchange Capacity	Recommendation of sorption model for PA	- Yes	EX: Yes, by equilibration test MC: Yes		Grimsel: MI PNC: Lab exp	
1.2.7	Available rock for sorption (wall rock, infill)	Important for retention if matrix diffusion is limited	- Yes, Natural analogs	EX: Yes, tracer experiments followed by resin impregnation and excavation MC: Yes, by interpretation of b.c. curves		TRUE B PNC: KT3-1	Data issue

#	Generic or process issues	Relevance for input to PA	Availability of reliable data	Feasibility of -experiments (EX) -test of model concepts (MC)	Pri-ority	Project	Comments Remarks -conceptual or data issue
1.3	**Solubility and speciation of radionuclides**						
1.3.1	Solubility limits at source term	Influence on long-term predictions	-Yes, for current situation. Groundwater sampling and data base on solubilities	EX: Yes MC: Yes		CHEMLAB General geochemistry work, natural analogues TVO: speciation experiments PNC: Lab exp, natural analog study	Data issue Temperature and salinity dependence? Influence of stability of groundwater chemistry (possible changes in long term)?
1.3.2	Changes in solubility with time resulting in precipitation or dissolution	Possible retention mechanism (precipitation)	- Yes, for current situation. Groundwater sampling	EX: not evaluated MC: not evaluated		Äspö Geochemistry modelling PNC: Lab exp	Related for example to location and stability of fresh/saline water boundary, geology, heterogeneity
1.3.3	Solution kinetics for radionuclides and rock/fracture minerals	Possible deviation from equilibrium models	- Qualitative data from lab K_d tests	EX: Yes, lab tests		PNC: Lab exp	Data issue

#	Generic or process issues	Relevance for input to PA	Availability of reliable data	Feasibility of -experiments (EX) -test of model concepts (MC)	Pri-ority	Project	Comments Remarks -conceptual or data issue
1.4	**Other processes**						
1.4.1	Radionuclide transport in gas phase (geogas or waste generated gas)	Evaluation of additional transport mechanism	- Yes, for lab experiments - Limited for in-situ conditions	EX: Yes for lab tests Limited, under in-situ conditions (gas injection tests) MC: Yes		Grimsel: TPF	Conceptual and data issue 2-phase flow properties of fractured rock not well known
1.4.2	Rapid transport by colloids attached to gas bubbles	Faster transport than dissolved species	- Limited	EX: Yes (Lab tests)			Conceptual and data issue Process not well understood
1.4.3	Effect of microbes	Possible influence on long term predictions (changes in chemical conditions, transport mechanism)	- Limited, Some data on amount of bacteria in groundwater	EX: Questionable MC: Yes, with reliable data		TRUE (microbial studies included) CHEMLAB	Conceptual issue Microbes introduced by repository construction Could alter geochemical conditions
1.4.4	Effect of colloids	Possible reduction of retardation times	- Yes, natural analogues	EX: Yes, colloid tracer tests MC: Yes		CHEMLAB	Limited transport capacity due to low colloid contents in natural gw
1.4.5	High pH plume	Effect on sorption, matrix diffusion and flow system	- Yes, natural analogues, high pH injection experiments	EX: Yes, high pH injection experiments MC: ?		PNC: GEOFRONT	

#	Generic or process issues	Relevance for input to PA	Availability of reliable data	Feasibility of -experiments (EX) -test of model concepts (MC)	Pri-ority	Project	Comments Remarks -conceptual or data issue
2	**INFLUENCE OF HETEROGENEITY ON RADIONUCLIDE TRANSPORT PREDICTIONS**						
2.1	**Flow path heterogeneity detailed scale**						
2.1.1	Dispersion due to fracture scale heterogeneities (roughness)	Representation of dispersion in models	- Limited	EX: Yes, by resin injection, difficult (expensive) for larger volumes MC: Questionable		TRUE detailed PVC TVO: lab exp on rock blocks PNC: LABROCK, NETBLOCK	Conceptual issue Can dispersion within channels be neglected (e.g. in CN model)?
2.1.2	What percentage of fracture surface is open to flow? Ratio of flow porosity to total porosity (flow velocity, volume of stagnant pools relative to flowing volume)	Recommendation of models for advective transport	- Limited	EX: Yes (Resin impregnation, tracer testing) MC: Yes		TRUE detailed Grimsel: BK, EX TVO : lab exp on rock blocks PNC: LABROCK, NETBLOCK	Conceptual issue Data issue
2.1.3	Importance of fracture intersections as preferential pathways relative to flow within fractures	Possible reduction of residence times	- Limited	EX: Yes (Lab testing, Resin impregnation)		TRUE detail & block CTH-L PNC: NETBLOCK, Prof. Watanabe	Conceptual issue If intersections are important how can we find and quantify them?
2.1.4	Mixing at fracture intersections	Influence on residence times	- No			PNC: NETBLOCK	Conceptual issue

#	Generic or process issues	Relevance for input to PA	Availability of reliable data	Feasibility of -experiments (EX) -test of model concepts (MC)	Pri-ority	Project	Comments Remarks -conceptual or data issue
2.2	**Flow path heterogeneity block scale**						
2.2.1	Existence (frequency) of fast flow paths	Transport times and flow rates	- Limited, has to be investigated (Tritium contents in gw can provide evidence on existence)	EX: Yes, by interference testing during drilling, cross-hole hydraulic testing Difficult to assess fraction found MC: Questionable		CRIEPI: Gw flow meas at Rokkasyo TVO:Lab exp on rock blocks PNC: KT3-2	Conceptual issue Data issue Can fast flow paths be identified and avoided near canisters? Little reliable data on frequency and properties of fast pathways
2.2.2	Connectivity of fracture network	Transport times and flow rates	- Yes, but has to be further investigated	EX: Yes, by cross-hole hydraulic and tracer testing Dense drilling? Geophysical methods? Geochemistry? MC: Yes, by Fracture Network Modelling		TRUE block scale Grimsel: BK Äspö Geochemistry modelling TVO:Lab exp on rock blocks PNC: KT3-2, NETBLOCK	Data issue
2.2.3	Influence of "flow barrier"	Reduce gradient within surrounded block. Possible retardation.	Yes, known from pressure distribution, but has to be further investigated	EX: Yes, by pressure interference tests and pressure monitoring MC: Yes, DFN with "anti-fracture"		PNC: KT3-2	Data issue (feasibility to identify at site characterization with small number of boreholes)
2.2.4	Flux distribution within fracture network	Transport times and flow rates	- Yes, but has to be further investigated	EX: Yes, by flux measurements MC: Yes, hydraulic cross-hole testing can provide test of DFN and CN models		TRUE block scale PNC: KT3-2, NETBLOCK	Conceptual issue Data issue Can fracture (core) data be used to infer hydraulic properties?

#	Generic or process issues	Relevance for input to PA	Availability of reliable data	Feasibility of -experiments (EX) -test of model concepts (MC)	Pri-ority	Project	Comments Remarks -conceptual or data issue
2.2.5	Relation of flow and transport properties of fractures to fracture genesis and stress state	Use of site specific and (more?) realistic models	- Limited	EX: Yes, by tracer tests in well defined geologic setting		Fracture Classification and Characterization TRUE Grimsel: FRI	Data issue Can preferential pathways be defined on a geological basis? Weighing of fracture sets in models
2.2.6	The disturbed zone (EDZ) as a preferential pathway?	The role of EDZ for tunnel sealing Potential fast transport path along tunnels	- Limited	EX: Yes, by hydraulic and tracer tests and flow measurements near drifts		ZEDEX DOABLE? (2-phase) Grimsel: EDZ TVO Research Tunnel exp PNC: KT2-2	Conceptual issue Data issue No reliable experiments so far, desaturation reduces permeability, difficult to investigate under saturated conditions
2.2.7	Evolution of fractures (healing, clogging, reactivation)	Influence on long term prediction	- No	EX: limited, e.g. by geological studies, natural analogues		Fracture Classification and Characterization Äspö Geochemistry modelling CRIEPI: Lab tests on fracture sealing PNC: KT1	Conceptual issue

#	Generic or process issues	Relevance for input to PA	Availability of reliable data	Feasibility of -experiments (EX) -test of model concepts (MC)	Priority	Project	Comments Remarks -conceptual or data issue
2.3	**Site scale heterogeneities**						
2.3.1	Identification of "major" zones (which require separation distance)	Determination of repository layout	- Yes, from site characterization	EX: Yes, by integrated geologic, geophysical, and hydrologic investigations		TVO: Site investigations	Conceptual issue Related to repository concept Criteria and procedure for classification needs to be specified
2.3.2	Effect of major fracture zones on site scale flow and transport	Determination of repository layout	- Yes, from site characterization	EX: Yes, by large scale pumping tests MC: Yes, by e.g. MTF Task 3		LPT2 Tunnel drawdown TVO: Site investigations	Data issue
2.3.3	Separation distance required to major zones	Repository layout Critical path length Specification of criteria		MC: Yes, but related to chosen PA model		TRUE block scale TVO: Site investigations	Conceptual issue Depends on repository concept and site specific PA
2.3.4	Boundary conditions to flow model	Validity of data input to PA	- Limited for recharge and flow through model boundaries - Yes for head	EX: Yes, by large scale pumping tests MC: Yes, by e.g. MTF Task 3		LPT2 Tunnel drawdown Hydrochemistry CRIEPI: Geochemistry Rokkasyo	Conceptual issue Data issue Validity of "standard" assumptions? (e.g model boundaries at water divides)
2.3.5	Identification of recharge and discharge area	Post closure scenarios; Groundwater flow regime	- Yes, by head monitoring, recharge is determined indirectly	EX: Yes, e.g. MTF Task 3		LPT2 Tunnel drawdown Grimsel: MI	Data issue Necessity/possibility to identify discharge areas?
2.3.6	Effect of fresh/ saline water boundary on flow and transport	Possible safety barrier	- Limited	EX: Yes, by measurement of flow velocities MC: ?		Hydrochemistry (VTT modelling) TVO site investigations at Olkiluoto	Depends on geology, topography Stability of interface in long term?

#	Generic or process issues	Relevance for input to PA	Availability of reliable data	Feasibility of -experiments (EX) -test of model concepts (MC)	Priority	Project	Comments Remarks -conceptual or data issue
2.4	**Heterogeneity at all scales and coupling between scales**						
2.4.1	REV for conductivity, dispersivity, K_d, FWS for different conceptual models? Is there an REV?	Determination of effective parameters	- Limited, can testing be made at the appropriate scale?	EX: Yes, by tracer tests MC: Yes by prediction-validation exercises		TRUE detail & block Grimsel: MI PNC: Kamaishi Macropermeability Test	Conceptual issue Data issue Experiment issue Do models and data provide realistic descriptions of the system? How are characterization data transformed to "effective parameters"?
2.4.2	Relation of hydraulic and transport parameters	Relevance of hydraulic data for prediction of transport Characterization strategy for repository sites	- Yes, hydraulic and tracer test data	EX: Yes, by hydraulic and tracer tests at same location MC: Yes, by prediction-validation exercises		TRUE block LPT2 TVO: Lab exp on rock blocks PNC: LABROCK, NETBLOCK	Conceptual issue Usefulness of relationship between porosity and storativity
2.4.3	Scale effects in hydraulic testing, influence of borehole diameter and test section length	Determination of effective parameters Characterization strategy for repository sites	- Yes, in-situ hydraulic tests	EX: Yes, by hydraulic testing MC: Yes, by prediction-validation exercises; Comparison of different testing techniques		HYDRIS	Data issue Conceptual issue Fracture heterogeneity is of borehole diameter scale Use of small-scale borehole measurements as parameters in large scale prediction models?
2.4.4	Procedures for up-scaling small-scale hydraulic measurements (to block conductivities)	Determination of effective parameters Characterization strategy for repository sites	- Yes, in-situ single hole and cross-hole tests at different scales	EX/MC: Yes, by comparison of model simulations with large scale field tests		LPT2 MTF Task 3	Conceptual issue

#	Generic or process issues	Relevance for input to PA	Availability of reliable data	Feasibility of -experiments (EX) -test of model concepts (MC)	Pri-ority	Project	Comments Remarks -conceptual or data issue
3	**LONG TERM STABILITY OF GEOLOGIC ENVIRONMENT**						
3.1	Hydraulic boundary conditions, long term stability	Need for time dependent site models in PA incorporating e.g. climatic changes? Driving force for groundwater movement	- Limited, only indirect data available e.g (neotectonic activity, erosion/ sedimentation data, historic data on climatic changes)	EX: No MC: Reasonable bounding calculations can be made		Äspö Geochemical modelling CRIEPI: Regional geochemistry Rokkasyo	Changes of land surface are also considered Recharge/discharge areas may change
3.2	Change of hydraulic properties, flow paths, and flow regimes in long term perspective	Need for time dependent site models in PA? Changes in flow paths	- Limited, only indirect data from e.g. geologic/ mineralogic characterization in boreholes and tunnels, borehole tests.	EX: Limited, data from genetic/hydraulic classification of water conducting features (WCF) and studies of differences in properties between recharge and discharge areas and with depth could be useful MC: Reasonable bounding calculations can be made		Regional scale geochemistry CRIEPI: Regional geochemistry Rokkasyo PNC: Prof. Watanabe, KT5	Not much data even in perspective of a few years!?
3.3	Chemistry, long term stability (effects on -solubility and speciation -retention/sorption -canister and buffer stability)	Influence on long term predictions Need for time dependent site models in PA?	- Limited, indirect data sources only, e.g. fracture mineralogy, isotopic geochemistry, gw samples	EX: ? MC: Limited, use of indirect evidence of long residence times		Regional scale geochemistry CRIEPI: Regional geochemistry Rokkasyo TVO site investigations (GEOCHEM work) PNC: KT5	Conceptually feasible Practicability highly questionable Past as an indication of future can be questioned

#	Generic or process issues	Relevance for input to PA	Availability of reliable data	Feasibility of -experiments (EX) -test of model concepts (MC)	Pri-ority	Project	Comments Remarks -conceptual or data issue
3.4	Mechanical stability, long term	Possibility of damage to engineered barriers Possible changes in flow paths	- Limited, Indirect data on neotectonic activity	EX: No MC: ?			

#	Generic or process issues	Relevance for input to PA	Availability of reliable data	Feasibility of -experiments (EX) -test of model concepts (MC)	Priority	Project	Comments Remarks -conceptual or data issue
4	**MODELLING ASPECTS**						
4.1	Procedure used for abstraction of characterization data into structural site model	Reliability of structural model for a site	- Yes, plenty of site characterization data from many sites	EX: Yes, by verification by drilling or excavation MC: Yes, by prediction-validation exercises		Site characterization projects, (Äspö, Stripa, URL, etc) TVO site investigations CRIEPI Site char Rokkasyo PNC: Regional Flow Model	Conceptual issue Interaction geologists-modelers required Model reliability depends on investigation methods, availability of surface data, and no. of boreholes
4.2	Discrimination between different conceptual models for flow and transport in fractured rocks	Conceptual model uncertainty	- Yes	EX/MC: Comparison of model predictions to experimental data		Äspö Task Force	Conceptual issue Central issue Maybe not important, but visualization is important
4.3	Use of hydraulic conductivity, storativity, and head data in conditioning hydraulic simulation models	Improve realism/ reliability in model output	- Yes	EX/MC: Comparison of model predictions to experimental data		LPT2 Tunnel drawdown TRUE Block CRIEPI Site char and gw flow meas at Rokkasyo PNC: FracMan	Conceptual issue Implications for site characterization strategy

#	Generic or process issues	Relevance for input to PA	Availability of reliable data	Feasibility of -experiments (EX) -test of model concepts (MC)	Pri-ority	Project	Comments Remarks -conceptual or data issue
4.4	Are AD transport models good enough for PA purposes?	Adequacy of simplified models	- Yes	EX: Yes, by tracer experiments MC: Yes		TRUE Grimsel: MI CRIEPI: Regional scale geochemistry at Rokkasyo PNC: Kamaishi Tracer exp ('93), LABROCK, NETBLOCK	Conceptual issue
4.5	Coupling of near field and far field models in PA	Near field source term in far field models	- ?	EX: - MC: ?			Conceptual issue
4.6	How to include other types of data in hydraulic simulation models	Model improvement, wider data base	- Yes	EX: Yes MC: Yes, by prediction-validation exercises		Äspö Task Force	Conceptual issue Procedure adopted and data included probably site specific

#	Generic or process issues	Relevance for input to PA	Availability of reliable data	Feasibility of -experiments (EX) -test of model concepts (MC)	Pri-ority	Project	Comments Remarks -conceptual or data issue
5	**GEOSPHERE CHANGES DUE TO REPOSITORY PRESENCE**						
5.1	Changes in flow and transport properties due to heating (from canister)	Induced change of the flow system in near (and far?) field	- Yes, several in-situ experiments	EX: Yes, by in-situ heater experiments and lab studies MC: Yes		Heater experiments at Stripa, Grimsel, URL Äspö Prototype re-pository?	Conceptual issue Coupled models
5.2	Changes in flow prop-erties and chemical conditions due to repository operation (open repository)	Need to maintain favorable conditions for long term safety Possibly irreversible adverse effects	- Limited	EX: Yes MC: Yes		2-phase REX Block Scale Redox exp PNC: KT2-1	Conceptual issue Data issue Observations in old mines may be of use
5.3	Time for establish-ment of chemical equilibrium after repository closure	Effect of repository operation (air, buff-er) on the geosphere and long term safety	- No	EX: Yes, by in-situ tests in existing underground labora-tories MC: ?		REX	Conceptual and data issue Observations in old mines may be of use
5.4	Long term stability of excavations	Potential damage to engineered barriers (buffer, backfill)	- Limited	EX: Yes, by observations in old mines			Rheologic properties of rock important

List of International Cooperation Reports

ICR 93-01
Flowmeter measurement in borehole KAS 16
P Rouhiainen
June 1993
Supported by TVO, Finland

ICR 93-02
Development of ROCK-CAD model for Äspö Hard Rock Laboratory site
Pauli Saksa, Juha Lindh,
Eero Heikkinen
Fintact KY, Helsinki, Finland
December 1993
Supported by TVO, Finland

ICR 93-03
Scoping calculations for the Matrix Diffusion Experiment
Lars Birgersson[1], Hans Widén[1],
Thomas Ågren[1], Ivars Neretnieks[2],
Luis Moreno[2]
1 Kemakta Konsult AB, Stockholm, Sweden
2 Royal Institute of Technology, Stockholm, Sweden
November 1993
Supported by SKB, Sweden

ICR 93-04
Scoping calculations for the Multiple Well Tracer Experiment - efficient design for identifying transport processes
Rune Nordqvist, Erik Gustafsson,
Peter Andersson
Geosigma AB, Uppsala, Sweden
December 1993
Supported by SKB, Sweden

ICR 94-01
Scoping calculations for the Multiple Well Tracer Experiment using a variable aperture model
Luis Moreno, Ivars Neretnieks
Dept. of Chemical Engineering and Technology,
Royal Institute of Technology, Stockholm, Sweden
January 1994
Supported by SKB, Sweden

ICR 94-02
Äspö Hard Rock Laboratory. Test plan for ZEDEX - Zone of Excavation Disturbance EXperiment. Release 1.0
February 1994
Supported by ANDRA, NIREX, SKB

ICR 94-03
The Multiple Well Tracer Experiment - Scoping calculations
Urban Svensson
Computer-Aided Fluid Engineering
March 1994
Supported by SKB, Sweden

ICR 94-04
Design constraints and process discrimination for the Detailed Scale Tracer Experiments at Äspö - Multiple Well Tracer Experiment and Matrix Diffusion Experiment
Jan-Olof Selroos[1], Anders Winberg[2],
Vladimir Cvetkovic[2]
1 Water Resources Eng., KTH
2 Conterra AB
April 1994
Supported by SKB, Sweden

ICR 94-05
Analysis of LPT2 using the Channel Network model
Björn Gylling[1], Luis Moreno[1], Ivars Neretnieks[1],
Lars Birgersson[2]
1 Department of Chemical Engineering and Technology, Royal Institute of Technology, Stockholm, Sweden
2 Kemakta Konsult AB, Stockholm, Sweden
April 1994
Supported by SKB, Sweden

ICR 94-06
SKB/DOE Hard Rock Laboratory Studies Task 3. Geochemical investigations using stable and radiogenic isotopic methods
Bill Wallin[1], Zell Peterman[2]
1 Geokema AB, Lidingö, Sweden
2 U.S. Geological Survey, Denver, Colorado, USA
January 1994
Supported by SKB and U.S.DOE

ICR 94-07

Analyses of LPT2 in the Äspö HRL with continuous anisotropic heterogeneous model

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September 1994

Supported by PNC, Japan

ICR 94-08

Application of three-dimensional smeared fracture model to the groundwater flow and the solute migration of LPT-2 experiment

T Igarashi, Y Tanaka, M Kawanishi

Abiko Research Laboratory, Central Research Institute of Electric Power Industry, Abiko, Japan

October 1994

Supported by CRIEPI, Japan

ICR 94-09

Discrete-fracture modelling of the Äspö LPT-2, large-scale pumping and tracer test

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March 1994

Supported by PNC, Japan

ICR 94-10

Äspö Hard Rock Laboratory
International workshop on the use of tunnel boring machines for deep repositories
Äspö, June 13-14 1994

Göran Bäckblom (ed.)

Swedish Nuclear Fuel and Waste Management Co.

October 1994

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ICR 94-11

Data analysis and modelling of the LPT2 Pumping and Tracer Transport Test at Äspö.
Tracer experiment

Aimo Hautojärvi

VTT Energy

November 1994

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ICR 94-12
Modelling the LPT2 Pumping and Tracer Test at Äspö. Pumping test
Veikko Taivassalo, Lasse Koskinen,
Mikko Laitinen, Jari Löfman, Ferenc Mészáros
VTT Energy
November 1994
Supported by TVO, Finland

ICR 94-13
Proceedings of The Äspö International Geochemistry Workshop, June 2-3, 1994, Äspö Hard Rock Laboratory
Peter Wikberg (chairman), Steven Banwart (proc. ed.)
December 1994
Supported by SKB, TVO, Nirex, ANDRA, CRIEPI

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Hydrodynamic modelling of the Äspö HRL. Discrete fracture model
D Billaux[1], F Guérin[2], J Wendling[2]
1 ITASCA
2 ANTEA
November 1994
Supported by ANDRA, France

ICR 94-15
Hydrodynamic modelling of the Äspö Hard Rock Laboratory. ROCKFLOW code
M L Noyer, E Fillion
ANTEA
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Supported by ANDRA, France

ICR 94-16
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Y Barthelemy, J Schwartz, K Sebti
ANTEA
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Jari Löfman, Veikko Taivassalo
VTT Energy, Espoo, Finland
June 1995
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Definition and characterisation of the N-S fracture system - tunnel sections 1/600m to 2/400m.
Relationships to grouted sections - some remarks -
W Kickmaier
June 1993
Supported by NAGRA, Switzerland

ICR 95-03
Groundwater degassing and two-phase flow:
Pilot hole test report
Jil T Geller[1], Jerker Jarsjö[2]
1 Earth Sciences Division, Lawrence Berkeley National Laboratory, USA
2 Water Resources Engineering, Royal Institute of Technology, Sweden
August 1995
Supported by U.S .DOE, USA and SKB, Sweden

ICR 95-04
Difference flow measurements at the Äspö HRL, May 1995
Pekka Rouhiainen
PRG-Tec Oy
September 1995
Supported by TVO, Finland

ICR 95-05
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
Gunnar Gustafson[1], Anders Ström[2]
1 Chalmers University of Technology
2 Swedish Nuclear Fuel and Waste Management Company
October 1995

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