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USE OF SITE SPECIFIC DATA FROM ÄSPÖ - PRELIMINARY RESULTS FROM THE ON-GOING SAFETY ANALYSIS SR 97

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Abstract

This paper discusses an on-going safety assessment study of the Swedish Nuclear Fuel and Waste Management Company (SKB) as well as the use of field data from Äspö for obtaining input parameters for flow and radionuclide transport modelling in the geosphere. In the on-going Safety Assessment study SR 97, three individual sites in Sweden are used for exemplifying site specific conditions on overall repository performance. Thus, models capable of reproducing site specific characteristics are utilised. This is primarily obtained by implementing the geologic structural models in suitable conceptual models for groundwater flow on both regional and local (site) scales. The models for flow incorporate observed and/or inferred water conducting features as well as other site-specific characteristics necessary for realistic descriptions of flow at the sites. The flow modelling thus aims at realism; the results obtained for present day conditions should not in any serious aspect conflict with observations (e.g., flow, pressure, mixing) at the site. Agreement between observed and modelled entities provides confidence in that a sound understanding of the site is obtained. Äspö is one of the three sites providing site-specific conditions in SR 97.

Transport is subsequently modelled using a streamtube approach where the "travel times", for non-sorbing species, and discharge locations of a set of one-dimensional streamtubes are obtained from particle tracking in the flow model. The resulting distribution of "travel times" in a single model realisation reflects the spatial variability and spatial extent of the repository, whereas the ensemble travel time distribution (over several realisations) for a given canister location reflects the uncertainty in travel time. The actual transport paths used in the transport modelling are thus dependent on site specific information such as e.g. existence of water conductive features. Other input parameters to the transport model are based on more generic and/or conservative arguments. However, the goal in a safety assessment context is to establish confidence in the modelling approach while showing compliance with regulatory standards rather than it is to convey perfect realism in every detail of all models used.

In general all data entered into the final assessment models have undergone several steps of modelling and interpretation. Hydraulic tests are interpreted by well test analysis. The information is analysed statistically, is upscaled and introduced into a stochastic continuum model. This latter modelling is used to derive migration paths and travel times. Variant cases may originate from ambiguities in data, but can only be formed by applying expert judgement. Also the matrix data is based on an expert selection where, as a minimum, the representativity of the data has been assessed. All final parameter selection also undergoes internal peer review. This implies that expert judgement is a necessary ingredient in parameter selection.

This paper is limited in the sense that SR 97 is an on-going safety analysis project. This means that integration, conclusions, feedback to site characterization and similar issues are still remaining. Thus, this paper will provide glimpses from the on-going project related to Äspö and the far field.

Introduction

At the present time SKB is involved in producing a new safety assessment study called SR 97 (Safety Report 97) for a deep repository for spent nuclear fuel. SR 97, which is part of a series of activities scrutinizing all pertinent aspects of deep-rock nuclear waste disposal, is primarily aimed at analyzing the long-term safety of a deep-rock repository in Sweden. New features of SR 97 as compared to previous analyses is that more emphasis is placed on the canister integrity and on systematic treatment of data uncertainties in radionuclide transport analyses. Furthermore, three separate locations in Sweden are analyzed in order to illustrate the site-specific conditions. The safety report, which is to be delivered early 1999, is a site-specific application of SR 95 /SKB, 1995/ which was a framework indicating how a complete safety assessment study should be performed.

Site specific conditions and model parameters related to the nearfield and engineered barriers are not specifically discussed.

Compilation of site specific information

The three hypothetical sites are named Aberg, Beberg and Ceberg, each of which is based on data from previous site characterisation studies conducted by SKB. These are:

- Aberg, which is based on the Äspö Hard Rock Laboratory in southern Sweden;
- Beberg, which is based on investigations at Finnsjön, in central Sweden; and
- Ceberg, which is based on investigations at Gideå, in northern Sweden.

Äspö is the most recently and thoroughly investigated site in the SKB program and is also the site of the intensive investigations associated with the Äspö Hard Rock Laboratory (HRL). Beberg is based on Finnsjön, perhaps the second-most thoroughly investigated site in the SKB program. Finnsjön was also the subject of SKB 91, a previous PA modelling study. The last site, Ceberg, is based on data taken from Gideå, one of the oldest SKB site characterisation studies. Although a great deal of data exists for Gideå, it is the least thoroughly investigated site of the three sites.

The actual flow and radionuclide modelling work for different scenarios in SR 97 is preceded by compilation of existing site specific data. For each discipline such as hydrogeology, hydrochemistry etc. a compilation is conducted of existing data and descriptions are made for each of three sites for use in modelling. Each compilation is intended to provide modelling teams with parameter values and uncertainties for inputs to numerical models on the regional and site scales. Specifically, for hydrogeology the compilation report /Walker, 1997/:

- reviews the investigations at the sites and existing reports,
- summarises the current knowledge of conditions and uncertainties regarding the hydrogeology of the sites,
- updates the data and analyses in order to correct known errors and inconsistencies, and
- provides estimates of the block-scale parameters for use in modelling of the sites at the regional and site scales.

Its primary objective is to provide consistent data sets so that the results of modelling will be as comparable as possible. One limitation of comparing modelling studies for alternative sites is that the site characterisation studies and analyses of data are frequently conducted at different times for different goals. Although the bias and error of site investigations are never fully known, a consistent analysis of the data and presentation of conceptual models will at least help confine the differences to the sites themselves.

Geosphere modelling and parameters

SKB has traditionally in performance assessment studies used fairly sophisticated models for the description of spatial variability in primarily hydraulic properties. Stochastic continuum models on both regional and local scales have dominated in the performed safety assessment studies such as SKB 91 /SKB, 1992/. Discrete models have also been adopted, but mainly in more research oriented projects.

For SR 97, the flow modelling aims at realism; the results obtained for present day conditions should not in any serious aspect conflict with observations (e.g., flow, pressure, mixing) at the site. Agreement between observed and modelled entities provides confidence in that a sound understanding of the site is obtained. Transport is subsequently modelled using a streamtube approach where the "travel times", for non-sorbing species, and discharge locations of a set of one-dimensional streamtubes are obtained from particle tracking in the flow model. The resulting distribution of "travel times" in a single model realisation reflects the spatial variability and spatial extent of the repository, whereas the ensemble travel time distribution (over several realisations) for a given canister location reflects the uncertainty in travel time. The actual transport paths used in the transport modelling are thus dependent on site specific information such as e.g. existence of water conductive features. Other input parameters to the transport model are based on more generic and/or conservative arguments. The specific one-dimensional transport code used, FARF31, incorporates advection and dispersion along the migration path, matrix diffusion combined with sorption and chain decay. The direct input parameters to FARF31 are the travel time t_w, the flow wetted surface per volume of water a_w, and the "Peclet-number" describing the relation between advective velocity times migration length and dispersivity as well as nuclide specific K_d-values and diffusivities of the rock matrix. In reality both the flow and the specific surface area vary along the migration path and it can be shown that proper equivalent parameters can only he obtained by integrating the quotient between the flow wetted surface per volume of rock and the Darcy velocity along the migration path. However, in SR 97 the approach is simplified by assuming flow wetted surface and porosity to be constant in space. Thereby, the groundwater flow input to migration modelling can be described in terms of the travel time distribution only.

The set of one-dimensional migration paths and travel times are obtained from three-dimensional flow modelling. The underlying conceptual model of the rock assumed is one of a rock domain described as a spatially varying stochastic continuum intersected by conductor domains (fracture zones), also modelled as porous media, but of hydraulic properties distinct from the rock domain. The approach further assumes a nested approach using a site scale model, with relatively much detail in conductive structures and adoption of a stochastic continuum model embedded in a regional scale model with less geometrical detail and with equivalent, i e non-stochastic, hydraulic parameters. The fractures zones are inferred from a geological structure model resulting from a joint interpretation of topography and surface and bore hole geophysical data. The majority of available information on the rock hydraulic conductivity is in the form of small scale (a few m), bore hole hydraulic tests. Data belonging to designated conductor domains are treated separately from data representing the rest of rock mass, thereby allowing for assignment of different hydraulic properties to these two classes. The data are treated as geostatistical samples and resulting geostatistical properties are estimated and upscaled to the model discretization scale. There is no specific assessment of dispersion along migration paths; dispersivities are selected in a pragmatic way. The main dispersion in the system is handled by the difference between different migration paths.

Estimates of the flow wetted surface along migration paths is obtained by underestimating the conductive fracture frequency and noting that there is at least one conductive fracture in a flowing test section. This procedure is strictly valid only if the flow is evenly distributed between all paths, whereas in the general case it is necessary to integrate the flow width along the migration path. The approach is selected partially out of lack of more detailed information and partially due to limitations in present modelling tools. For the assessment this means that the potential errors need to be handled in the uncertainty evaluation.

A sub-project within SR 97 is the so called Alternative Modelling Project (AMP) aimed at quantifying conceptual model uncertainty. The specific objectives of AMP are thus to *illustrate rock barrier performance* using different conceptual models and to *assess model robustness* in terms of relevant far-field performance measures. Three different conceptual models of the spatially variable geosphere are used. These are a stochastic continuum model, a discrete fracture network model, and a channel network model. The different conceptualizations of the rock mass are illustrated in Figure 1. The stochastic continuum model used is HYDRASTAR; a code developed and extensively used within SKB /Walker et al, 1996/. HYDRASTAR is also used for the main modelling of SR 97 mentioned above.

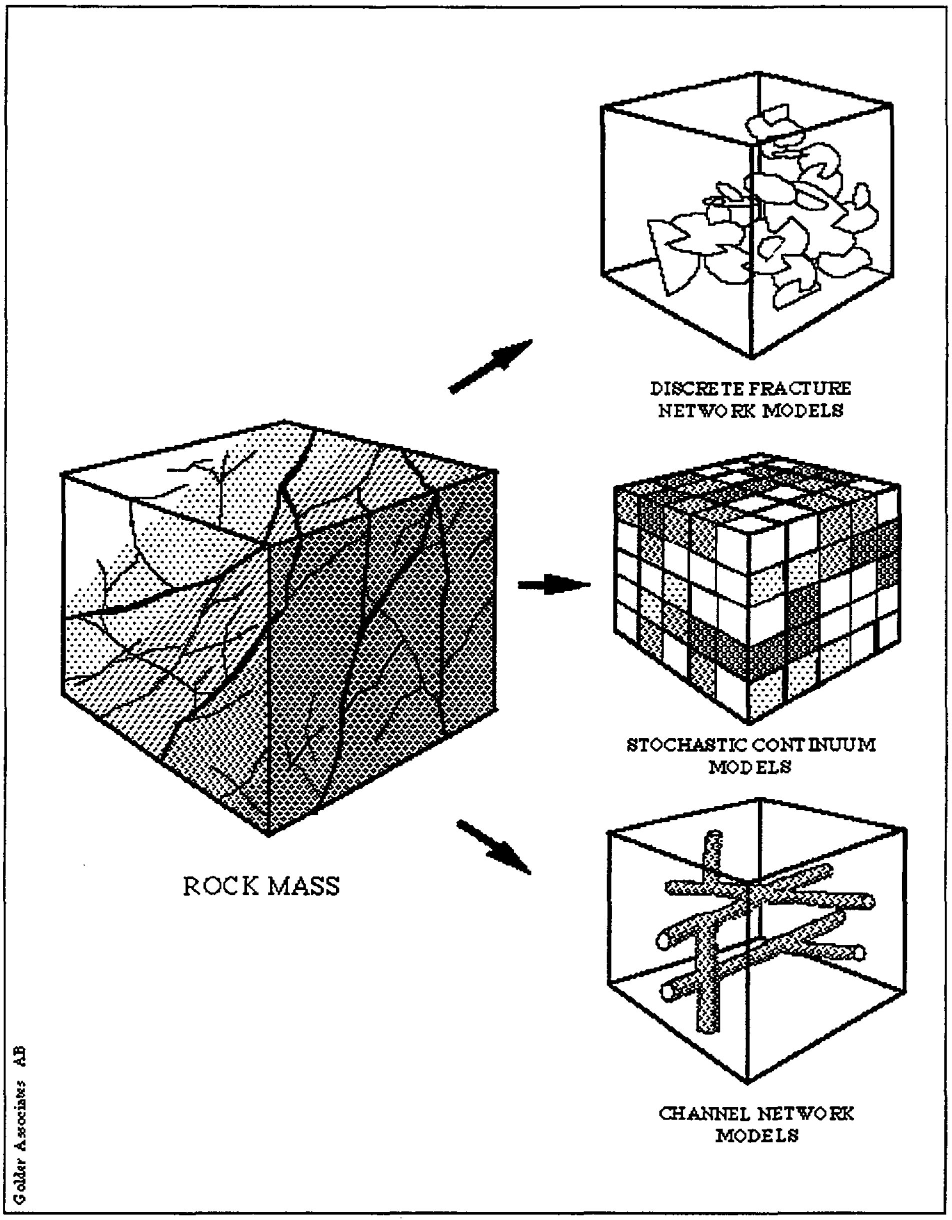

Figure 1. Illustration of different conceptual models used for flow and transport modelling.

The choice of these three models in the AMP exercise is primarily based on the fact that all models have successfully been used in previous analysis of field-scale flow and transport experiments in Sweden. Thus, it is of interest to evaluate if models that all explain field data will result in significant differences when applied in PA applications.

In order to enable conditions which permit a quantitative comparison between the different conceptual models, it was early recognized that a clear project strategy and modelling specifications had to be defined. In the first phase of the project it was decided to emphasize on conceptual differences in flow related descriptions. It is believed that the analysis within AMP will be simplified by only comparing transport related parameters for use in FARF31 and COMP23 rather than comparing final results from individual transport codes. However, in future stages of AMP transport may be simulated directly by all three models.

It was also decided to use site-specific data from the Äspö Hard Rock Laboratory within AMP to the greatest possible extent. The site-specific data used pertains to discrete zones with known transmissivity and conductivity statistics for the rock mass in between. Since parts of the geological data only is known in a statistical sense, multiple realizations of the spatially variable rock domain is to be employed. Furthermore, the boundary conditions used were obtained from a regional model for Äspö, and the canister locations coincide with parts of a hypothetical repository placed at Äspö within the SR 97 safety assessment study. A strong emphasis in AMP has been put on the definition of output entities to be calculated and subsequent performance measures for comparison of the output. A number of performance measures quantifying various aspects of the output have been formulated.

The evaluation of AMP is still on-going and no final results are available at the present moment. However, a few preliminary findings and conclusions may be reported. Our experience is that even though strict modelling specifications are defined, it is hard to safeguard that the different conceptual models actually address identically the same problem. This is primarily due to the fact that not every single aspect of the problem can be defined in the specifications, thus leaving room for individual judgment and decisions, which may be biased by the possibilities offered by the conceptual model utilized. Furthermore, the results obtained so far indicate that it may be hard to quantitatively compare e.g. absolute values of the travel times resulting from different models due to the different assumptions invoked. Rather, the span of travel times and corresponding uncertainties are more relevant for comparison.

Discussion and conclusions

This paper is limited in the sense that SR 97 is an on-going safety analysis project. This means that integration, conclusions, feedback to site characterization and similar issues are still remaining and so the paper cannot be very conclusive.

All data entered into the final assessment models have undergone several steps of modelling and interpretation. Furthermore, expert judgement is used in selecting structural models and variant cases for the flow modelling. Also the matrix data is based on expert selection; as a minimum the representativity of the data has been assessed.

The general approach to deal with parameters unlikely to be measurable is to try to simplify and apply conservative parameter values. The difficulty with the approach taken is that the conservatism can be criticised, but also that the resulting performance may be too pessimistic. The way to deal with this problem is on one hand to make sure that the parameter is not crucial to repository performance and on the other hand to search information indicating that indeed present parameter values are too extreme.

The results obtained in the alternative modelling project may have some consequences on SR 97 in general and on future safety assessments specifically. The main reason for applying different models is to address conceptual model uncertainty. A stronger confidence in the results is foreseen as a consequence of the use of multiple conceptualizations. It is emphasized that in the future, spatial variability in other than hydraulic parameters (e.g., parameters affecting radionuclide retention) may also be incorporated in PA analyses. Both theoretical model development and experimental work (at the Äspö Hard Rock Laboratory) are presently being performed in order to address such issues.

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