



Strålsäkerhets
myndigheten

Swedish Radiation Safety Authority

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Technical Note

2012:24

Initial Review of SR-Site
Main Report

SSM perspektiv

Bakgrund

Strålsäkerhetsmyndigheten (SSM) granskar Svensk Kärnbränslehantering AB:s (SKB) ansökningar enligt lagen (1984:3) om kärnteknisk verksamhet om uppförande, innehav och drift av ett slutförvar för använt kärnbränsle och av en inkapslingsanläggning. Som en del i granskningen ger SSM konsulter uppdrag för att inhämta information i avgränsade frågor. I SSM:s Technical note-serie rapporteras resultaten från dessa konsultuppdrag.

Projektets syfte

Syftet med projektet är att ta fram synpunkter på SKB:s säkerhetsanalys SR-Site för den långsiktiga strålsäkerheten hos det planerade slutförvaret i Forsmark. Synpunkterna ska baseras på en granskning av huvudrapporten för SR-Site. I granskningsuppdraget ingår att:

- belysa den övergripande kvaliteten på SKB:s redovisning,
- identifiera behov av kompletterande information från SKB och
- ta fram förslag på kritiska frågor som behöver granskas mer i detalj i nästa fas av SSM:s tillståndsprövning.

Slutrapporten från konsultprojektet (denna Technical Note) är ett av flera externa underlag som SSM kommer att beakta i sin egen granskning av SKB:s säkerhetsredovisningar, tillsammans med andra konsultrapporter, remissvar från en nationell remiss och en internationell expertgranskning av OECD:s kärnenergibyrå (NEA).

Författarens sammanfattning

Strålsäkerhetsmyndigheten (SSM) genomför f.n. en tillståndsprövning av Svensk Kärnbränslehantering AB:s (SKB) tillståndsansökan för ett slutförvar för använt kärnbränsle. SKB:s ansökan innehåller en redovisning av den långsiktiga strålsäkerheten för det föreslagna slutförvaret. SKB:s säkerhetsredovisning är känd som SR-Site.

Den här rapporten beskriver observationer från ett konsultprojekt som ingår i SSM:s inledande granskning av tillståndsansökan. Projektet genomfördes på uppdrag av SSM av TerraSalus Limited.

Konsultprojektet omfattade en översiktlig granskning av SR-Site huvudrapporten, som omfattar närmare 900 sidor med information, med syfte att ta fram rekommendationer till SSM avseende områden som kräver en mer detaljerad granskning samt att identifiera behov av förtydliganden eller kompletterande information från SKB.

SKB har vidtagit olika åtgärder för att demonstrera att SR-Site-säkerhetsanalysen är så komplett och heltäckande som möjligt. SKB har tillämpat metoder för säkerhetsanalys som är fullständiga i den meningen att de täcker in alla analyssteg som man kan förvänta sig.

SR-Site anger att (i) buffererosion och kopparkorrosion som leder till kapselbrott, och (ii) kapselbrott på grund av skjuvrörelser (t.ex. beroende

på jordskalv) i geologiska sprickor som skär deponeringshål är de viktigaste processerna och scenarierna som påverkar slutförvarets säkerhet.

En nyckelslutsats från den här granskningen är att det utifrån enbart en granskning av huvudrapporten SR-Site inte är möjligt att förstå eller i detalj spåra hur SKB har kommit fram till sina uppskattningar av antalet deponeringshål där buffererosion och kapselbrott kan förekomma. Detta har att göra med tydligheten och detaljeringsgraden på den information som ges i SKB:s beskrivningar av sin grundvattenflödesmodellering och hur deras grundvattenflödesmodeller hanterar de hypotetiska positionerna av deponeringshål som ingår i analyserna. Detaljeringsgraden i informationen om säkerhetsanalysen som redovisas i SR-Site huvudrapporten är inte tillräcklig för att ett oberoende säkerhetsanalys-team skulle kunna spåra eller belägga resultaten – detta skulle kräva en detaljerad granskning av underliggande information.

SKB har använt etablerade metoder för att identifiera och utvärdera osäkerheter. SR-Site ger flera starka argument till varför det är nödvändigt att påbörja undersökningarna under jord på den föreslagna slutförvarsplatsen för att i någon större omfattning kunna reducera några av de återstående kritiska osäkerheterna ytterligare.

Granskningen av SR-site huvudrapporten har givit en förståelse för det föreslagna slutförvarssystemet och har gjort det möjligt att ta fram förslag på viktiga frågor som behöver granskas mer i detalj. Ytterligare information kan behövas från SKB inom flera områden, inklusive tillämpningen av Bästa Möjliga Teknik.

Projektinformation

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Diarienummer ramavtal: SSM2011-4248

Diarienummer avrop: SSM2012-648

Aktivitetsnummer: 3030007-4036

SSM perspective

Background

The Swedish Radiation Safety Authority (SSM) reviews the Swedish Nuclear Fuel Company's (SKB) applications under the Act on Nuclear Activities (SFS 1984:3) for the construction and operation of a repository for spent nuclear fuel and for an encapsulation facility. As part of the review, SSM commissions consultants to carry out work in order to obtain information on specific issues. The results from the consultants' tasks are reported in SSM's Technical Note series.

Objectives of the project

The objective of the project is to provide review comments on SKB's post-closure safety report, SR-Site, for the proposed repository at Forsmark. The review comments shall be based on a review of the main report for SR-Site. The review assignment comprises the following tasks:

- to evaluate the overall quality of SKB's reporting
- to identify need for complementary information from SKB, and
- to propose critical issues that need to be addressed in more detail in the next phase of SSM's licensing review.

The final report from this consultant project (this Technical Note) is one of several documents with external review comments that SSM will consider in its own review of SKB's safety reports, together with other consultant reports, review comments from a national consultation, and an international peer review organized by OECD's Nuclear Energy Agency (NEA).

Summary by the author

The Swedish Radiation Safety Authority (SSM) is reviewing a license application, which has been submitted by Svensk Kärnbränslehantering AB (SKB), for a repository for the final disposal of spent nuclear fuel. SKB's Application includes an assessment of the long-term safety of the proposed repository. The assessment is known as SR-Site.

This technical note records the findings from a project that forms part of SSM's initial phase of the license application review. The project was undertaken on behalf of SSM by TerraSalus Limited.

The project involved a broad review of the SR-Site main report, which comprises almost 900 pages of information, with the aims of identifying recommendations on areas in which SSM may conduct more detailed review and identifying the need for clarification or complementary information from SKB.

SKB has taken various steps to demonstrate that the SR-Site safety assessment is as complete and comprehensive as possible. SKB has applied a safety assessment methodology that is complete in the sense that it includes all of the expected assessment steps.

SR-Site suggests that (i) buffer erosion and copper corrosion leading to canister failure, and (ii) canister failure due to shear movement (e.g. due to earthquakes) on geological fractures intersecting waste deposition holes are the most important processes and scenarios affecting disposal system safety.

A key finding of this review is that on the basis of reviewing just the SR-Site main report it is not possible to understand in detail or trace how SKB has arrived at its estimates of the number of waste deposition holes in which buffer erosion and canister failure might occur. This relates to the clarity and level of detailed information provided in SKB's descriptions of its groundwater flow modelling and how the groundwater flow models relate to the hypothetical locations of the waste deposition holes considered in the analysis. The level of detail provided on the safety assessment in the SR-Site main report would not allow the results to be traced or confirmed by an independent assessment team – this would require detailed review of supporting information.

SKB has applied good practice in identifying and assessing uncertainties. It is considered that SR-Site main report makes several strong arguments to the effect that it would be necessary to begin underground investigations at the proposed repository site in order to make significant further progress in reducing some of the remaining key uncertainties.

Review of the SR-Site main report has provided an understanding of the proposed disposal system and allowed suggestions to be made on which may be the most important topics for more detailed review. Additional information might be sought from SKB in several areas, including on the topic of Best Available Technology.

Project information

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1. Introduction

The Swedish Radiation Safety Authority (SSM) is undertaking a formal review of a License Application, which has been submitted by Svensk Kärnbränslehantering AB (SKB) for construction, possession and operation of a spent nuclear fuel repository in Forsmark. SKB's Application includes an assessment of the long-term safety of the proposed repository known as SR-Site.

This technical note records the findings from a project that has been undertaken by TerraSalus Limited on behalf of SSM as part of its initial phase of review of the License Application.

The overall goal of SSM's Initial Review Phase is to conduct a broad-ranging examination of SR-Site and its supporting references and, in particular, to identify the need for complementary information and clarifications to be provided by SKB and possible focuses for more in-depth review by SSM.

The project described in this technical note involved a broad initial review of SKB's SR-Site main report (SKB 2011, TR-11-01), which comprises almost 900 pages of information.

After the Initial Review Phase has been completed, SSM will determine if the quality and comprehensiveness of SR-Site is sufficiently good to warrant a further phase of in-depth review of the Licence Application - the 'Main Review Phase'. It is envisaged that the Main Review Phase will focus on uncertain and/or safety critical issues that require more comprehensive review.

The remainder of this technical note is structured as follows:

- Section 2 presents the main review findings. Section 2 is divided into subsections based on SSM's general guidelines and questions for the Initial Review Phase.
- Section 3 makes recommendations to SSM.
- Appendix 1 identifies the SKB reports that were reviewed or examined.
- Appendix 2 provides a list of suggested essential questions to SKB for clarifications, complementary information, complementary data, etc.
- Appendix 3 provides a list of suggested topics requiring substantial additional work on the part of SSM and SSM's external experts during the Main Review Phase.

2. Main review findings

This section addresses the topics and review questions contained in SSM's General Guidelines for the Initial Review Phase. The topics identified in the General Guidelines are addressed by the subsections that follow. Each subsection begins with one or more review questions from SSM's General Guidelines.

2.1. Completeness of the safety assessment

This section addresses the completeness of the safety assessment and considers the following review question:

- *Are there any obviously missing pieces of information in the SR-Site and its supporting references within the area covered by the specific review assignment?*

2.1.1. Documentation and information

Assessing the '*completeness*' of a safety assessment, such as SR-Site, is not a straightforward task. SR-Site is presented in many reports containing hundreds of cited references¹ - this is not unusual for such an assessment, but in this case there does not appear to be a clearly defined limit to the extent of the information that is considered to comprise the SR-Site safety assessment.

Some of the reports cited by SKB were produced in support of previous projects and the extent to which the information contained in such older reports is considered by SKB to be part of SR-Site and the Licence Application is not always clear.

For example, Neretnieks (1986), which presents simplifications and analytical solutions for modelling solute transport, using '*equivalent flow*' and '*transport resistance*' parameters, is referred to in SKB 2010, TR-10-66. SKB 2010, TR-10-66 describes an analysis of copper canister corrosion that is central to the SR-Site safety assessment. It is not clear why it is necessary for SKB 2010, TR-10-66 to refer to the 1986 paper by Neretnieks, particularly when a much more recent report is available (SKB 2010, TR-10-42) that had as one of its aims, assessing the range of validity of the approach proposed by Neretnieks (1986). In this example it is, therefore, not clear whether some or all of the analysis contained in the 1986 paper by Neretnieks is regarded as current or valid and whether it is part of the SR-Site safety assessment.

SSM should consider asking SKB to identify clearly the reports and information that comprise the SR-Site safety assessment (and which by implication are part of the Licence Application), as opposed to other information that may be cited by SR-Site as providing background information or additional support, but which is not formally part of SR-Site or the Licence Application.

¹ It is noted that this initial review project has not had the scope to review all of the information provided by SKB.

2.1.2. Safety assessment methodology

A very positive aspect of the SR-Site safety assessment described in SKB 2011, TR-11-01 is that it has been produced and described in accordance with a well-documented assessment methodology (SKB 2011, TR-11-01, Section 2 - see Figure 2.1). SKB's safety assessment methodology can be recognised as being consistent with international best practice for such long-term safety assessments (e.g. Röhlig *et al.* 2012). This helps to build confidence in the completeness of the assessment because, at a high level, SKB's methodology can be seen to include all of the main steps that might be expected.

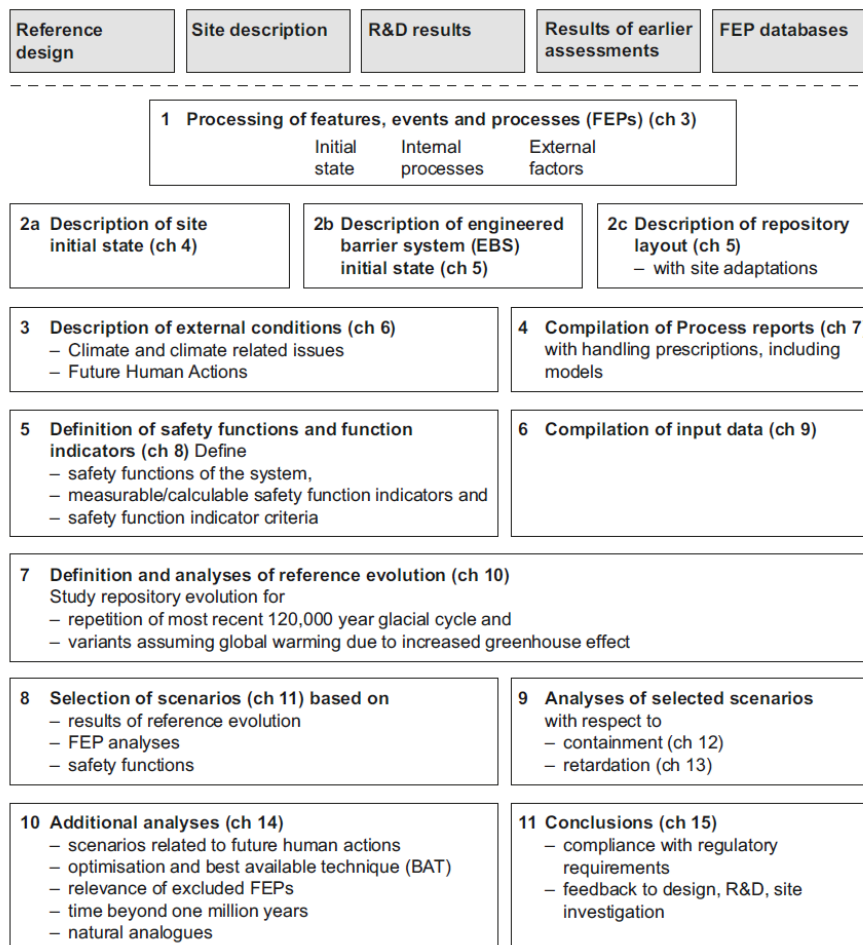


Figure 2.1: Outline of the eleven main steps of the SR-Site safety assessment. The boxes at the top above the dashed line are inputs to the assessment (SKB 2011, TR-11-01, page 66).

More specific observations on SKB's assessment methodology include:

- In addressing the safety of the proposed KBS-3 repository SKB has identified a number of 'safety principles' (SKB 2011, TR-11-01 Section 2.2.1, pages 16 and 60), including one that states, '*Engineered barriers shall be made of naturally-occurring materials that are stable in the long term in the repository environment.*' It is not clear that this 'principle' is a necessary condition for safe disposal of radioactive waste.

For example, the majority of designs for geological disposal systems include significant amounts of cement-based materials (NEA 2012) that could not be described as naturally-occurring.

- SKB has taken steps, particularly through the identification and analysis of *Features, Events, and Processes* (FEPs) to demonstrate that the SR Site assessment is as comprehensive as possible. The SR-Site FEP Catalogue is described in Section 3.3 of the SR-Site main report (SKB 2011, TR-11-01), from which it is apparent that the FEP catalogue is distributed amongst several *'Production reports'* (SKB 2010, TR-10-14; TR-10-15; TR-10-16; TR-10-17) and *'Process reports'* (SKB 2010, TR-10-46; TR-10-47; TR-10-48), as well as the Climate report (SKB 2010, TR-10-49), the Biosphere synthesis report (SKB 2010, TR-10-09) and supporting ecosystem reports, and the FHA (future human actions) report (SKB 2010, TR-10-53). Brief examination of some of these reports shows that they clearly address in a systematic way a wide range of radiological, thermal, hydraulic, mechanical, chemical, biological and other types of FEPs – this gives some confidence that the assessment is comprehensive in this sense (i.e. virtually all conceivable FEPs have been considered). It is odd, however, that Section 3.3 of the SR Site main report (SKB 2011, TR-11-01) does not explicitly refer to the FEP report (SKB 2010, TR-10-45), and the relationship between the FEP report and the other reports identified in this paragraph (e.g. the Process reports) is not clear. The text on page 288 of SKB 2011, TR-11-01 confirms that the justifications for the exclusion of FEPs are provided in the Process reports, making the role of the FEP report unclear.

Based on review of SKB 2011, TR-11-01, particularly Sections 10 to 13 and 14.4, FEPs that may need further consideration include:

- Homogenisation of bentonite materials (see also TerraSalus 2012).
- The mechanical effects of corrosion products formed during corrosion of the cast iron insert following the entry of water to the canister. This FEP may not have been considered.
- The release and transport of radionuclides (e.g. uranium and thorium) that may be irreversibly sorbed on, or only slowly desorbed from, colloids (see SKB 2011, TR-11-01, pages 665 and 678).
- The inventory and release of radionuclides from potential future spent fuels with higher burn-ups (see SKB 2011, TR-11-01, page 773).
- The SR-Site safety assessment is predicated on the assumed *'initial state'* of the system. For example, SKB states *'The initial state of the system is a fundamental input to the assessment and needs thorough substantiation'* (SKB 2011, TR-11-01, page 23). SKB defines the initial state as the state at the time of deposition / installation for the engineered barrier system, and the natural, undisturbed state at the time of beginning of excavation of the repository for the geosphere and biosphere (SKB 2011, TR-11-01, pages 19, 65 and Section 5). These definitions are clear and comprehensible, but with these definitions the initial state precedes the time

at which the repository and its components will be providing their safety functions. For example, the initial state is not defined as the time when the buffer becomes fully saturated with water and is, therefore, able to provide its main safety function of restricting water flow around the canister. It seems important to consider how sensitive the assessment is to the assumptions made regarding the initial state, and what tolerance there is for deviations in assumed conditions at the initial state. For example, the statement on page 30 of SKB 2011, TR-11-01 that the density of the backfill is sufficient in all the cases analysed in the reference evolution leaves open the question of what would happen if the desired backfill density was not achieved? It is recognised that SKB has conducted assessments of six buffer states (SKB 2011, TR-11-01, page 565), but all of these analyses consider buffer density as an average parameter defined on the scale of an entire deposition hole. SKB's analysis, thus, relies on buffer homogenisation being effective enough to remove or make negligible any smaller scale discontinuities and heterogeneities introduced during construction, operation and re-saturation. SSM may wish to ask SKB for additional analyses of the sensitivity of the safety assessment to FEPs that could cause deviations from the assumed initial state of the system, generally, and of the buffer in particular.

- SKB's assessment approach (see SKB 2011, TR-11-01 Figures S-7 and 2-2) does not emphasise the important steps of conceptual model development and model documentation. Models of processes are mentioned in Step 4 '*Compilation of process reports*' (see Figure 2.1) and in SKB 2011, TR-11-01, Section 2.5.4 '*Description of processes*', but examination of the Process reports reveals that the '*Handling in the safety assessment SR-Site*' sections they contain often refer to yet further reports at lower levels in SKB's documentation scheme. For example, the Buffer, backfill and closure process report (SKB 2010, TR-10-47) refers to an underlying report by Åkesson *et al.* (2010a, b) for details of buffer homogenisation modelling. This observation is not necessarily a criticism of SKB's work, but coupled with the fact that many processes and FEPs are modelled, it does suggest that reviewing and assessing SKB's modelling work for SR-Site is likely to be a significant review task involving examination of several layers of documentation. Section 2.4 below provides suggestions regarding priorities for detailed review of key areas.
- With regards to the *selection and analysis of scenarios*, it is necessary to consider whether the set of identified scenarios is sufficiently complete for the purposes of the assessment, and to assess in more detail whether the scenarios have been analysed properly. SKB has identified scenarios by considering how the barrier safety functions might cease to be fulfilled as a result of the action or occurrence of certain FEPs or combinations of FEPs. Further scenarios have been identified to address future human intrusion, hypothetical engineered barrier failures, and design variants (e.g. Table 11-1 of SKB 2011, TR-11-01). SKB's approach to scenario identification seems well-structured, and to have been applied in a very thorough and systematic in order not to miss any possible routes to safety function failure. However, there may be some gaps, for example a scenario to make a realistic evaluation of the consequences of poor tunnel plug performance (SKB 2011, TR-11-01, page 318).

SKB uses expert judgement to classify identified scenarios as the ‘*main scenario*’, ‘*less probable scenarios*’ or ‘*residual scenarios*’ and excludes residual scenarios from its evaluation of risk. In some instances, the assignment of scenarios to these categories may be debateable, for example:

- It is not clear that SKB is correct to classify the ‘*Buffer Advection Fracture Case*’ described on page 573 of SKB 2011, TR-11-01, in which the buffer has a conductive fracture and has lost its sealing properties, as a residual scenario (SKB 2011, TR-11-01 page 581). It could be argued that the Fracture Case ought to be included in the evaluation of risk.
- The Buffer Freezing scenario (SKB 2011, TR-11-01, Section 12.3), which SKB classifies as a residual scenario effectively on the basis that future glaciations will not be more severe than those in the past, might need to be represented as a less probable scenario if glaciations with greater maximum extent were to be considered.
- In relation to Human Intrusion scenarios, SKB 2011, TR-11-01 page 77 notes that ‘*human actions that disturb the immediate environment of the repository, e.g. the local groundwater flow field, are... .. excluded from the risk summation*’. SSM will need to consider whether it is appropriate for SKB not to evaluate the effects of reasonable non-intrusive human actions (e.g., drawdown associated with water abstraction).

In summary, SKB has taken various steps to demonstrate that the SR-Site safety assessment is as complete and comprehensive as possible, and has developed and applied a safety assessment methodology that is complete in the sense that, at a high level, it includes all of the expected assessment steps. However, based on review of the SR-Site main report, various questions have been identified on the details of how SKB’s methodology has been implemented and there may be a few gaps in the information. Particular issues relate to:

- The clarity of SKB’s description of its modelling of groundwater flow around the repository and how this may lead to canister corrosion.
- The amount of detail provided on SKB’s risk assessment.
- The information provided by SKB on Best Available Technology (BAT).

2.2. Scientific soundness and quality of the SR-Site

This section addresses the scientific soundness and quality of the safety assessment and considers the following review questions:

- *Are key scientific conclusions adequately supported and justified? Are the necessary references provided and are they sufficiently specific?*
- *Are there any alternative results or alternative scientific explanations published in the open scientific literature related to the assignment area*

which have not been addressed or mentioned by SKB? If so, please provide those references.

It is noted that SR-Site is based on the results of a long running programme of scientific research and development work, and that a scientific approach has been taken to developing SR-Site. Based on this initial review of SKB 2011, TR-11-01 alone, however, it is not really possible to reach conclusions on the scientific soundness of the conclusions of SR-Site as a whole. Quality and referencing are discussed briefly in Section 2.7.

2.3. Adequacy of safety functions

This section addresses safety functions and considers the following review question:

- *Has SKB defined any safety function(s) that is [are] closely related to a specific review assignment? If so are safety functions and their associated safety function indicators and criteria adequately explained and justified in the SR-Site?*

This review question is really applicable to initial review projects examining specific parts of the safety assessment or considering specific issues, rather than undertaking a broad review of the SR-Site main report. Nevertheless some observations can be made on safety functions.

Within SR-Site SKB has, at the highest level, defined ‘*safety functions*’ in terms of *containment* and *retardation* (e.g. SKB 2011, TR-11-01, Section 2.2.2, page 61).

- It is not clear why isolation (which might be defined as the removal of the waste from the accessible human environment) is not emphasised as an important safety function. Considering isolation as a safety function is a fairly standard approach that is adopted internationally.
- SKB’s approach of not regarding dilution as a safety function (SKB 2011, TR-11-01, Section 8.1.2) seems appropriate.

In more detail, SKB has defined a range of safety functions for different components of the proposed repository system (SKB 2011, TR-11-01, Section 8, e.g. Figures 8-2 and 8-3).

For some of the safety functions, SKB has identified safety function indicators (specific parameters) and quantitative criteria against which the fulfilment of the safety function may be assessed. It has not been possible to trace the derivation of all of the safety functions during this initial review task, but the following observations may be made:

- In cases where numerical safety function indicator criteria have not been specified, SKB sometimes suggests that the value of a particular safety function indicator parameter should be ‘*high*’ or ‘*low*’. Although the intention of giving such indications is sensible and understood, the absolute meaning of such qualitative terms is unclear and this may limit the utility of the safety functions (e.g. for compliance determination).

- SKB defines safety functions for the spent fuel - see Figure 8-3 on page 267 of SKB 2011, TR-11-01. On the basis of arguments made by SKB regarding the slow rate of spent fuel dissolution (e.g. SKB 2011, TR-11-01, page 44) and the results of the safety assessment calculations (e.g. SKB 2011, TR-11-01, page 693) more emphasis might have been placed on the chemical stability of the wastefrom and the fuel dissolution rate as an important safety function.
- SR-Site provides a significant amount of material that discusses the possible state of the various safety functions at different stages of repository evolution (e.g., SKB 2011, TR-11-01, Sections 8.5, 10.3.16, 10.4.11, 10.5.1, 10.6.4) and uses the safety functions to assist in the identification of scenarios for assessment (SKB 2011, TR-11-01, Section 11). In progressing to the assessments themselves, however, the possible loss of certain safety functions (e.g. 'Buff2. Reduce microbial activity') are subsumed within analyses of the loss of other safety functions (e.g. 'Buff1. Limit advective transport'). This process of subsuming safety function losses is done even though it is conceivable that, for example, the Buff2 safety function might be lost before the Buff1 safety function.
- The amounts of backfill and particularly of buffer mass loss due to physical and chemical erosion that might acceptable without affecting relevant safety functions (e.g. Buff1) are important considerations in the scenarios involving advective conditions in the deposition holes where there is the possibility of canister failure by corrosion. It is suggested that SSM considers a more detailed review of the acceptable backfill and buffer mass losses derived by SKB.

2.4. Adequacy of data and models

This section addresses the adequacy of the data and models used in the safety assessment and considers the following review questions:

- *Is the source information of key datasets related to the assignment sufficiently described and referenced? Is any data treatment explained and justified (e.g. derivation of effective parameters)?*
- *Are mathematical models including utilised assumptions related to the assignment sound and sufficiently explained and justified?*

SKB's models relating to aspects of disposal system evolution are discussed in Section 10 of SKB 2011, TR-10-11. SKB's models of radionuclide transport are described mainly in Sections 12 and 13.

Rather than detailing the data and models used, SKB 2011, TR-10-11 provides summary descriptions of the data and models, as well as selected modelling results and conclusions. For example, SKB 2011, TR-11-01 does not present detailed information on the radionuclide inventory. In most instances, therefore, it has not been possible to fully assess the adequacy of SKB's data in this initial review task; further review of the underlying reports would be necessary.

However, it is possible on the basis of the information reviewed, to make some observations and, based on the understanding of SR-Site gained, to make some

suggestions regarding the relative priorities for more detailed review of key areas of SKB's data and modelling (see Table 2.1).

General observations are that on the basis of the SR-Site main report (SKB 2011, TR-11-01) alone, it is not possible to understand in detail or trace how SKB has arrived at its statistical estimates of the number of deposition holes in which advection, buffer erosion and canister failure might occur. This relates to the clarity of the descriptions of SKB's groundwater flow modelling work and of how the groundwater flow models relate to the conceptual representation / hypothetical locations of the waste deposition holes in the groundwater flow field.

It is also noted that SKB's modelling, possibly necessarily, becomes rather speculative for future climate states (e.g. SKB 2011, TR-11-01, page 676) and it is suggested that results for these long timescales can only at best be regarded as illustrative.

It is further noted that SKB has in several instances (e.g., for bentonite piping and physical and chemical erosion – see TR-11-01 pages 306 and 399) presented empirical models in SR-Site, rather than using models with a mechanistic or phenomenological basis that might allow better understanding and more confident extrapolation to conditions outside those covered by the available experimental data sets.

Table 2.1: Key modelling areas, review observations and suggested review priorities

Modelling Area (Relevant Sections of SKB 2011, TR-11-01)	Review Observations	Relative Priority for More Detailed Review
Thermal modelling (Section 10.2.1)	The thermal modelling is fairly standard and appears well-done. Although it is important to repository layout and dimensioning, it is not highly significant to radiological safety.	Low
Hydrological modelling: partially-saturated phase (Sections 10.1.3, 10.2.3, 10.3.6, 10.3.8)	Hydrological modelling is central to SR-Site, but is poorly described in TR-11-01. Limited information is available on effects under partially-saturated conditions and it is not clear that the analyses are bounding. It seems important to understand in more detail SKB's work on buffer and backfill saturation (e.g. Åkesson <i>et al.</i> 2010a, b).	Medium
Hydrological modelling: saturated phase (Sections 10.1.3, 10.3.6, 10.4.6, 12.6.2)	Hydrological modelling is central to SR-Site, but is poorly described in TR-11-01. The description is not traceable and, on the basis of the information in TR-11-01, it is unclear exactly how SKB has estimated the numbers of deposition holes that might experience high groundwater flows.	High

Modelling Area (Relevant Sections of SKB 2011, TR-11-01)	Review Observations	Relative Priority for More Detailed Review
Mechanical modelling: host rock and EDZ (Sections 10.2.2, 10.3.5)	It seems important to understand in more detail SKBs work on thermal spalling and the basis for the proposed deposition hole rejection criteria.	Medium
Mechanical modelling: canister shear (Sections 10.4.5)	It seems important to understand in more detail SKB's work on the potential for earthquakes to cause shearing of the canister and the basis for the proposed respect distances and related criteria (e.g. Fåltth <i>et al.</i> 2010; Munier 2010 and subsequent work by SKB – see SKB 2011, TR-11-01, page 477).	Medium
Mechanical modelling: buffer and backfill swelling and homogenisation (Sections 10.2.4, 10.3.9)	SKB's modelling of bentonite swelling is based on a good experimental data base and level of understanding, but few experimental data are available on buffer and backfill homogenisation. As an assumption of successful buffer homogenisation underlies all of SKB's modelled scenarios, it seems important to assess in more detail SKB's work on homogenisation (e.g. by review of relevant experiments and of modelling by Åkesson <i>et al.</i> 2010a, b).	High
Chemical modelling of groundwaters and conditions in the repository (Sections 10.2.5, 10.3.7)	The chemical modelling is fairly standard and appears well-done. Although there are some detailed aspects of the work that could be questioned (e.g., regarding dolomite precipitation – see page 393 of TR11-01), the analyses seem to provide a generally good basis for the safety assessment.	Low
Modelling of buffer and backfill piping and physical erosion (Section 10.2.4)	SKB's understanding and modelling of piping and physical erosion of bentonite is based on a relatively small experimental dataset, which is still being compiled and developed. SKB's model of bentonite piping and mass loss is empirical, and is not underpinned by a mature understanding of the controlling phenomena. It seems important to understand in more detail the basis for the amounts (masses) of the buffer and backfill that SKB claim can be lost without jeopardising the relevant safety functions.	High

Modelling Area (Relevant Sections of SKB 2011, TR-11-01)	Review Observations	Relative Priority for More Detailed Review
Modelling of buffer and backfill chemical erosion (Section 10.3.11)	SKB's understanding and modelling of chemical erosion of bentonite is based on a relatively small experimental dataset. SKB's model of bentonite chemical erosion and mass loss is empirical, and is not underpinned by a mature understanding of the controlling phenomena. The modelling described in SKB 2011, TR-11-01 appears to be very much focussed on sodium-bentonite, and the applicability of the model to more complex chemical systems is uncertain. It seems important to understand in more detail the basis for the amounts (masses) of the buffer that SKB claim can be lost before advection can occur.	High
Chemical modelling: canister corrosion (Section 10.2.5, 10.3.11, 10.4.9, 12.6.2, TR-10-66)	SKB's models of canister corrosion comprise a suite of mass balance and related scoping calculations that consider the potential availability and rates of supply to the canister of various corrosive species under different conditions. Individually the calculations appear straightforward and generally reasonable. SKB 2010, TR-10-66 presents an assessment of canister corrosion integrated with an evaluation of the geochemical and hydrogeological evolution of the repository using the equivalent flowrate and transport resistance concept. These calculations suggest that the average number of failed canisters may take a non-integer value in range from zero to less than two, depending on uncertainties in buffer erosion, in the hydrogeological models, in assumed sulphide concentrations and associated with the assumed conceptual model of corrosion geometry. As the safety of the KBS-3 concept relies primarily on the resistance of the copper canister to corrosion (e.g., SKB 2011, TR-11-01, page 574), it is suggested that SSM considers more detailed review of SKB's treatment of corrosion. In particular, it is suggested that SSM considers making an independent verification of the buffer erosion-canister corrosion cases in SKB 2010, TR-10-66 using a suitable numerical model to solve standard advection dispersion equations.	High

Modelling Area (Relevant Sections of SKB 2011, TR-11-01)	Review Observations	Relative Priority for More Detailed Review
Radionuclide release and transport (Section 13.4)	<p>TR-11-01 contains only summary information on the data and models used by SKB to model radionuclide release and transport and it will be important, therefore, to review the Radionuclide transport report (SKB 2010, TR-10-50) and the Data report (SKB 2010, TR-10-52) to assess the inventory, the assumed release rates and the transport calculations. It also seems necessary to check the quality assurance and verification status of the models used, particularly of those that have been developed or modified specifically for use in SR-Site (e.g., MARFA, the COMP23 Matlab/Simulink solver, the analytical models embedded within COMP23, and FARF31 and the modifications made to it for SR-Site).</p> <p>Section 13.4.4 of TR-11-01 discusses the benchmarking and use of certain analytical models in SR-Site, but it is not clear where this work is documented.</p> <p>It appears that none of the models described in TR-11-01 has the capability to model the transport of radionuclides sorbed to mobile colloids in cases where desorption is kinetically-controlled or irreversible. As a consequence, the results and conclusions drawn in Section 13.5.6 may not be bounding as claimed.</p>	High
Biosphere (Section 13.2.3)	It is important to review and assess in detail the derivation, values and uncertainties of the Landscape Dose Conversion Factors (LDF's) as these parameters have a direct effect on calculated potential dose.	High

2.5. Handling of uncertainties

This section addresses the handling of uncertainties in the safety assessment and considers the following review question:

- *Are all known and relevant uncertainties related to the scientific area of a specific review assignment identified, analysed and discussed in sufficient detail?*

This review question is really applicable to initial review projects examining specific parts of the safety assessment or considering specific issues, rather than to a broad review of the SR-Site main report as a whole. Nevertheless some observations can be made on the handling of uncertainties.

SR-Site handles uncertainties in a range of ways, for example:

- Scenarios are used to represent alternative evolutions of the system.
- Various assumptions are made, and parameter values chosen, that are intended to err on the side of conservatism.
- Both deterministic and probabilistic safety assessment calculations have been conducted with the aim of evaluating the effect of parameter uncertainty on potential dose and risk.
- Sensitivity analyses have been performed on the safety assessment results to identify which parameters are most significant to calculated impacts.
- The results from the safety assessment have been considered as feedback to repository design.

This approach represents general good practice. It is noted, however, that SKB 2011, TR-11-01 does not provide all of the information that might be desired. For example, although it presents and discusses results from sensitivity analyses, it does not set out the *strategy* that underlies the range of sensitivity analyses conducted.

SKB has undertaken a probabilistic assessment of potential dose, and assessed potential doses have been multiplied by the dose to risk conversion factor (SKB 2011, TR-11-01, Section 13, page 724). It is suggested that this approach yields a risk value that is *conditional* on the occurrence of the scenario (although it is acknowledged that because of the way in which the scenarios have been defined and assessed they may include some probabilistic aspects e.g. the number of failed canisters).

The '*risk summation*' presented in Section 13 of SKB 2011, TR-11-01 appears simply to add the conditional risks from the highest calculated results for the corrosion and shearing scenarios, rather than estimating and taking account of the probabilities of those scenarios. SKB 2011, TR-11-01, page 43 states that '*The combination of pessimistic handling of uncertainties for which probability distributions could not be determined with the probabilistic handling of quantified uncertainties means that the total risk as determined in the risk summation is claimed to represent an upper bound on risk.*' This approach is conservative in that it would provide risk estimates on the high-side of the expectation value, but the risks calculated in this way may not represent either a true upper bound or the mean risk.

In terms of reducing uncertainties, it is considered that SKB 2011, TR-11-01 makes several strong arguments to the effect that it would be necessary to begin underground investigations at the proposed repository site in order to make significant further progress (e.g., TR-11-01, page 771).

2.6. Safety significance

This section addresses safety significance and considers the following review question:

- *Is the overall safety relevance of the specific review assignment within its scientific area explained and justified?*

This review question is really applicable to initial review projects examining specific parts of the safety assessment or considering specific issues, rather than to a broad review of the SR-Site main report as a whole. Nevertheless some general observations can be made on safety significance.

SKB suggests that (i) buffer erosion, copper corrosion and canister failure, and (ii) canister failure due to shear movement on fractures intersecting deposition holes are the most important processes and scenarios affecting disposal system safety (e.g., SKB 2011, TR-11-01, page 622).

It is clear from the statements on pages 574 and 674 of SKB 2011, TR-11-01 that for the corrosion scenarios, the copper corrosion rate and the associated time taken for the canister to fail represent the most important contribution to safety. After canister failure, the most significant parameters are the fuel dissolution rate and the geosphere transport resistance (SKB 2011, TR-11-01, page 693). Key contributors to calculated potential dose are Ra-226, Ni-59, Se-79, Np-237 and I-129 (SKB 2011, TR-11-01, page 657).

For the canister shearing scenarios, releases could occur sooner and some shorter-lived radionuclides (e.g. C-14, Cs-137, Nb-94) might also make a significant contribution to calculated potential dose (SKB 2011, TR-11-01, page 696). In these calculations the most significant parameters include the time of canister failure, the fuel dissolution rate and the solubilities of radium and thorium (SKB 2011, TR-11-01, page 697).

The results of the sensitivity studies presented are helpful in highlighting where further more detailed review work might focus (i.e. buffer erosion, copper corrosion, the criteria proposed for managing the potential effects of canister shearing, the data used to characterise the source term for the key radionuclides, the co-precipitation of radium, and the relevant geosphere transport resistances for the key radionuclides).

2.7. Transparency and traceability of information

This section addresses the transparency and traceability of information in the safety assessment and considers the following review questions:

- *Is the safety assessment strategy for handling of issues related to a specific review assignment explained in a clear manner?*
- *Is information at different levels in the safety assessment consistent and logically subdivided (e.g. main SR-Site report, main supporting references and other references)?*

SKB 2011, TR-11-01 provides a lengthy narrative description of SKB's safety assessment work, including discussions of FEPs, the Forsmark site, system

evolution, scenarios and safety assessment results, as well as supporting arguments and conclusions.

A key finding from this initial review is that, despite being nearly 900 pages long, the SR-Site main report does not provide enough information for the reader to be able to follow the details of the analyses that SKB has performed. It may ultimately be possible to do this, but it would probably need extensive review of SKB's supporting reports. Important parts of SKB 2011, TR-11-01 are not clear or traceable enough; for example, see the descriptions of the hydrogeological modelling in Sections 10 and 12, including the text on '*F factors*' on pages 604 and 605. As a result, the analyses performed by SKB could not be independently reproduced or confirmed without using information from a range of supporting reports.

SKB 2011, TR-11-01 does provide many references to the reports that support it but, nonetheless, it still contains unsupported or speculative statements (e.g. the argument that silica sol will permanently seal fractures on page 367; the number and durations of glacial standstills assumed on page 602; the assumed 10,000-year timing of pinhole failure growth on page 705). In some cases references are made logically to the second tier of reports (e.g. the Process reports), but in other cases references are made directly to the third or lower report tiers, even though relevant information is contained in the relevant second tier report. Sometimes closely similar information occurs in more than one report.

One feature of the referencing within SR-Site is that there are a few cases of circular and upwards referencing between reports describing the safety assessment. For example, for details of corrosion modelling the SR-Site main report (SKB 2011, TR-11-01, page 607) refers the reader to the more detailed SKB 2010, TR-10-66 report, but on examination of SKB 2010, TR-10-66, the reader is referred back upwards to SKB 2011, TR-11-01.

In summary, the transparency and traceability of SR-Site might have been better, and may cause its review to be more difficult that would otherwise have been the case.

2.8. Feasibility of engineering and implementation

This section addresses the feasibility of manufacturing, construction, testing, implementation and operation of repository and engineered barrier components and considers the following review question:

- *Are there any particular aspect of manufacturing, construction, testing, implementation and operation of the repository facility or its engineered barriers that might challenge the long term safety as presented in the SR-Site?*

On the basis of this initial review project, the following observations can be made:

- A key issue will be the ability to construct waste deposition holes at suitable locations. SKB notes the need to '*avoid deposition positions with potential for high future groundwater flow*' (SKB 2011, TR-11-01,

page 22). It is not clear how the potential for **future** groundwater flows can be determined during repository construction. This example highlights a general need to specify criteria against which compliance can realistically be assessed (e.g. by measurement during construction). SKB suggests that the number of deposition holes that might suffer high flows such that advective conditions might occur is estimated to be *'typically less than ten'* (SKB 2011, TR-11-01, page 39). It should be remembered that this result comes from modelling studies that provide only possible realisations of the repository layout and rock volume. Such estimates are almost certain to change once information becomes available from underground.

- SKB 2011, TR-11-01, page 43 states that *'There possibly could be improvements in the backfill design from an installation point of view but there does not seem to be a need to change the design to further improve its safety functions.'* This statement seems to be too weak in suggesting that there *possibly could be* improvements in the backfill design from an installation point of view – review of other SKB reports and experiments on backfilling (e.g. SKB 2010, TR-10-16; SKB 2008, R-08-59) make it clear that further development in this area is needed and that the design may need to be improved. SKB's Backfill production report (SKB 2010, TR-10-16), in particular, suggests that more work would be needed to demonstrate that the backfill can be emplaced in the repository satisfactorily at the rates currently envisaged in order to accommodate disposal of one spent fuel canister per day (TerraSalus 2012).
- According to SSMFS 2008:21 the *'barrier system shall be designed and constructed taking into account the best available technique (BAT)'*. The General Recommendations related to SSMFS 2008:21 state that *'The use of the best available technique means that the technology, from a technical and economic standpoint, shall be industrially feasible for application within this area. This means that the technique must be available and not merely at the experimental stage.'* SKB discusses optimisation and BAT in Sections 2.7.3 and 14.3 of SKB 2011, TR-11-01, where it makes several arguments that the SR-Site safety assessment need only consider the proposed design with vertical canister emplacement (KBS-3V) and, within this design, potential optimisation of the choice of materials and engineered barrier dimensions. Within this narrow context, Section 14.3 of SKB 2011, TR-11-01 discusses results from a limited set of analyses designed to demonstrate optimisation and the use of BAT. The analyses discussed include:
 - Copper canisters with walls half or double the proposed canister thickness of 5 cm.
 - A thicker buffer and larger buffer mass.

SKB provides very little information on the potential practicality, feasibility or other (e.g. cost, environmental) implications of such design options.

Even if the narrow context for optimisation studies proposed by SKB were to be accepted (i.e. restricted only to consideration of possible refinements to the KBS-3V design), the demonstration of optimisation in SR-Site could

have considered further design options and information on the range of factors that would be affected by following such options.

SKB notes that there is at present *'an incomplete conceptual understanding of buffer erosion'* (e.g. SKB 2011, TR-11-01, page 31), that there may be a poorly-quantified loss of buffer materials after emplacement, and that buffer erosion could play a key part in scenarios leading to canister failure. The potential role of buffer erosion in causing advective conditions the deposition holes, leading to enhanced corrosion and possibly failure of the canister could be viewed as a type of *'common cause'* failure of the system. As noted above, SKB suggests that the number of canisters that may fail as a result of buffer erosion and copper corrosion is small and that the resulting radiological impacts would be low. Given SKB's emphasis on *containment* and the incomplete understanding of buffer erosion, however, the identification of the buffer erosion - copper corrosion scenario does question whether the design is as robust as it could be and whether it could include more *'defence in depth'*. Could the design of the system or its implementation be improved to eliminate all canister failures for example? It is suggested that consideration of further design alternatives would be of use in allowing comparisons to be made and in helping to demonstrate that BAT had been selected.

On a related theme it is noted that SKB states that *'There is potential to further reduce risk due to shearing by further reductions of the maximum allowed buffer density and adapting the production of the buffer and deposition holes to conform to this design'* (SKB 2011, TR-11-01, page 43). It would be helpful if SKB could explain and provide more information on the envisaged adaptations to the production of the buffer and deposition holes.

It is recommended, therefore, that SSM should consider (i) whether it agrees that it is possible to identify BAT in this context with an analysis of KBS-3V only, and (ii) whether it wishes to request further complementary information from SKB on BAT and design optimisation.

3. Recommendations to SSM

This section compiles the various recommendation identified during the review.

- It is suggested that SSM should consider asking SKB to identify clearly the reports and information that comprise the SR-Site safety assessment and which are part of the Licence Application, as opposed to other information that may be cited by SR-Site as providing background information or additional support.
- It is suggested that SSM considers more detailed review of SKB's treatment of:
 - Partially-saturated and saturated groundwater flow.
 - Thermal spalling and deposition hole rejection criteria.
 - Earthquakes, canister shear and respect distances.
 - Buffer and backfill homogenisation.
 - Tunnel plug performance.
 - Physical and chemical erosion of the backfill and buffer, and acceptable backfill and buffer mass losses.
 - Copper corrosion and canister failure.
 - The data used to characterise the source term, the relevant geosphere transport resistances and Landscape Dose Factors for the key radionuclides.
 - Radium co-precipitation.
 - The release and transport of key radionuclides (e.g. uranium and thorium) that may be irreversibly sorbed on, or only slowly de-sorbed from, colloids.
 - The mechanical effects of corrosion products formed during corrosion of the cast iron insert following the entry of water to the canister.
 - The potential inventory and release of radionuclides from future spent fuels with higher burn-up.
 - Risk calculation and compliance determination.
- It is suggested that SSM should consider making an independent verification of the buffer erosion-canister corrosion cases in SKB 2010, TR-10-66 using a suitable numerical model to solve standard advection-dispersion equations.
- It is suggested that SSM should consider making an independent check of the quality assurance and verification status of the models used in SR-Site, particularly those which have been developed or modified specifically for use in SR-Site (e.g., MARFA, the COMP23 Matlab/Simulink solver, the analytical models embedded within COMP23, and FARF31 and the modifications made to it for SR-Site).
- It is suggested that SSM should consider asking SKB for additional analyses of the sensitivity of the safety assessment to FEPs that could cause deviations from the assumed initial state of the disposal system, generally, and of the buffer and tunnel plug in particular.
- It is suggested that SSM considers whether it is appropriate for SKB not to evaluate the effects of reasonable non-intrusive human actions (e.g., drawdown associated with waster abstraction).

- It is suggested that SSM should consider (i) whether it agrees that it is possible to identify Best Available Technology from an analysis of KBS-3V only, and (ii) whether it wishes to request further complementary information from SKB on BAT and design optimisation.

4. References

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Munier, R. (2010) Full perimeter intersection criteria. Definitions and implementations in SR-Site. SKB Report TR-10-21, Svensk Kärnbränslehantering AB.

NEA (2012) Cementitious Materials in Safety Cases for Geological Repositories for Radioactive Waste: Role, Evolution and Interactions, NEA Report RWM/R(2012)3. OECD Nuclear Energy Agency, Paris.

Neretnieks, I. (1986) Stationary transport of dissolved species in the backfill surrounding a waste canister in fissured rock: some simple analytical solutions. Nuclear Technology, 72, pp 194–200.

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SKB (2008) Backfilling of KBS-3V deposition tunnels - possibilities and limitations, Hans Wimelius and Roland Pusch, SKB Report R-08-59, Svensk Kärnbränslehantering AB.

SKB (2010) Backfill production report. Design, production and initial state of the backfill and plug in deposition tunnels. SKB Report TR-10-16, Svensk Kärnbränslehantering AB.

SKB (2010) Biosphere synthesis report. Biosphere analyses for the safety assessment SR-Site – synthesis and summary of results. SKB Report TR-10-09, Svensk Kärnbränslehantering AB.

SKB (2010) Buffer, backfill and closure process report. Buffer, backfill and closure process report for the safety assessment SR-Site. SKB Report TR-10-47, Svensk Kärnbränslehantering AB.

SKB (2010) Buffer production report. Design, production and initial state of the buffer. SKB Report TR-10-15, Svensk Kärnbränslehantering AB.

SKB (2010) Canister production report. Design, production and initial state of the canister. SKB Report TR-10-14, Svensk Kärnbränslehantering AB.

SKB (2010) Climate report. Climate and climate-related issues for the safety assessment SR-Site. SKB Report TR-10-49, Svensk Kärnbränslehantering AB.

SKB (2010) Closure production report. Design, production and initial state of the closure. SKB Report TR-10-17, Svensk Kärnbränslehantering AB.

SKB (2010) Data report. Data report for the safety assessment SR-Site. SKB Report TR-10-52, Svensk Kärnbränslehantering AB.

SKB (2010) FEP report. FEP report for the safety assessment SR-Site. SKB Report TR-10-45, Svensk Kärnbränslehantering AB.

SKB (2010) FHA report. Handling of future human actions in the safety assessment SR-Site. SKB Report TR-10-53, Svensk Kärnbränslehantering AB.

SKB (2010) Fuel and canister process report. Fuel and canister process report for the safety assessment SR-Site. SKB Report TR-10-46, Svensk Kärnbränslehantering AB.

SKB (2010) Geosphere process report. Geosphere process report for the safety assessment SR-Site. SKB Report TR-10-48, Svensk Kärnbränslehantering AB.

SKB (2010) Model summary report, 2010. Model summary report for the safety assessment SR-Site. SKB Report TR-10-51, Svensk Kärnbränslehantering AB.

SKB (2010) Radionuclide transport report. Radionuclide transport report for the safety assessment SR-Site. SKB Report TR-10-50, Svensk Kärnbränslehantering AB.

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SKB (2010) Spent fuel report. Spent nuclear fuel for disposal in the KBS-3 repository. SKB Report TR-10-13, Svensk Kärnbränslehantering AB.

SKB (2010) Underground openings construction report, 2010. Design, construction and initial state of the underground openings. SKB Report TR-10-18, Svensk Kärnbränslehantering AB.

TerraSalus (2012) Physical Properties and Processes of the Buffer and Backfill, Installation and Initial State, D.G. Bennett, TerraSalus Ltd., UK., 25 May 2012.

Åkesson, M., Kristensson, O., Börgesson, L., Dueck, A. and Hernelind, J. (2010a) THM modelling of buffer, backfill and other system components. Critical processes and scenarios. SKB Report TR-10-11, Svensk Kärnbränslehantering AB.

Åkesson, M., Börgesson, L. and Kristensson, O. (2010b) SR-Site Data report. THM modelling of buffer, backfill and other system components. SKB Report TR-10-44, Svensk Kärnbränslehantering AB.

Coverage of SKB reports

Table 3:

Reviewed report	Reviewed sections	Comments
SKB TR-11-01, SR-Site Main Report	All Sections	-
SKB TR-10-66, Corrosion calculations report for the safety assessment SR-Site.	All sections	-

APPENDIX 2

Suggested needs for complementary information from SKB

The following is a list of suggested questions to SKB requiring clarifications, complementary information, complementary data, etc.

1. Can SKB identify clearly the reports and information that comprise the SR-Site safety assessment (and which by implication are part of the Licence Application), as opposed to other information that may be cited by SR-Site as providing background information or additional support.

APPENDIX 3

Suggested review topics for SSM

The following is a list of suggested topics requiring substantial additional work on the part of SSM and SSM's external experts during the main review phase.

Topic	Relative Priority for More Detailed Review
1. Partially-saturated and saturated groundwater flow	High
2. Thermal spalling and deposition hole rejection criteria	Medium
3. Earthquakes, canister shear and respect distances	Medium
4. Buffer and backfill homogenisation	High
5. Tunnel plug installation and performance.	Medium
6. Physical and chemical erosion of the backfill and buffer, and acceptable backfill and buffer mass losses	High
7. Copper corrosion and canister failure	High
8. The data used to characterise the source term, the relevant geosphere transport resistances and Landscape Dose Factors for the key radionuclides	High
9. Radium co-precipitation	Medium
10. The release and transport of key radionuclides (e.g. uranium and thorium) that may be irreversibly sorbed on, or only slowly desorbed from, colloids	Medium
11. The mechanical effects of corrosion products formed during corrosion of the cast iron insert following the entry of water to the canister	Low
12. The potential inventory and release of radionuclides from future spent fuels with higher burn-up	Low
13. Verification of the buffer erosion-canister corrosion cases in SKB 2010, TR-10-66 using a suitable numerical model to solve standard advection-dispersion equations	High
14. Independent assessment of the quality assurance and verification status of the models used in SR-Site, particularly those which have been developed or modified specifically for use in SR-Site (e.g., MARFA, the COMP23 Matlab/Simulink solver, the analytical models embedded within COMP23, and FARF31 and the modifications made to it for SR-Site)	Medium
15. BAT and design optimisation	Medium
16. SKB's approach to risk calculation and compliance determination	Medium



2012:24

The Swedish Radiation Safety Authority has a comprehensive responsibility to ensure that society is safe from the effects of radiation. The Authority works to achieve radiation safety in a number of areas: nuclear power, medical care as well as commercial products and services. The Authority also works to achieve protection from natural radiation and to increase the level of radiation safety internationally.

The Swedish Radiation Safety Authority works proactively and preventively to protect people and the environment from the harmful effects of radiation, now and in the future. The Authority issues regulations and supervises compliance, while also supporting research, providing training and information, and issuing advice. Often, activities involving radiation require licences issued by the Authority. The Swedish Radiation Safety Authority maintains emergency preparedness around the clock with the aim of limiting the aftermath of radiation accidents and the unintentional spreading of radioactive substances. The Authority participates in international co-operation in order to promote radiation safety and finances projects aiming to raise the level of radiation safety in certain Eastern European countries.

The Authority reports to the Ministry of the Environment and has around 270 employees with competencies in the fields of engineering, natural and behavioural sciences, law, economics and communications. We have received quality, environmental and working environment certification.

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