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Review Statement and Evaluation of the Swedish Nuclear Fuel and Waste Management Co's RD&D Programme 2004

Swedish Nuclear Power Inspectorate

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To the Government
Ministry of Sustainable Development
103 33 Stockholm

SKI's Review Statement on the Swedish Nuclear Fuel and Waste Management Co's RD&D Programme 2004

Programme for Research, Development and Demonstration of Methods for the Management and Disposal of Nuclear Waste, including Social Science Research

SKI's Review Statement

The Swedish Nuclear Fuel and Waste Management Co (SKB) has submitted RD&D Programme 2004 to SKI for review in accordance with 12 § of the Act (1984:3) on Nuclear Activities.

Based on SKI's review and the review statements received, SKI considers that:

- ***The Swedish Nuclear Fuel and Waste Management Co (SKB), and thereby the reactor owners, have fulfilled their obligations in accordance with 12 § of the Act (1984:3) on Nuclear Activities***

- ***Disposal in accordance with the KBS-3 concept seems to still be the most suitable way of disposing of spent nuclear fuel from the Swedish nuclear power programme.***

SKI would like to draw the Government's attention to the following evaluations and comments.

Responsibility for a Closed Repository

- The question of who is responsible after the closure of a repository for spent nuclear fuel needs to be clarified. The Government should make a decision on this issue.

SKB's Plan of Action

- SKB's plan of action is incomplete and its structure needs to be improved. The authorities should have access to an improved plan of action within a reasonable time before starting the review of licence applications for new facilities.

- The revised plan of action needs a more detailed account of the content of the basis for decision-making that SKB intends to present on different decision-making occasions. This particularly applies to results from technology development, long-term experiments and other research that SKB intends to conduct on different timescales.

Technology Development - Canister

- As soon as possible, SKB should develop design premises for the canister and verify these premises in the next safety assessment which is planned for 2006. A clear and logical link between the detailed design premises for the canister and the requirements on long-term safety of the repository is still lacking.

- SKB should specify the limits for different parameters that are of importance for the canister function. The account must be based on an identification of defects that can occur and their consequences for canister integrity and repository function.

Technology Development - Repository

- SKB should clarify how the work on KBS-3H (horizontal deposition of the canisters) is to be developed. An estimate of how much time and resources will be required is needed in order to prepare a body of material corresponding to that for KBS-3V (vertical deposition which is, so far, the most studied concept).

- SKB should continue to participate in and contribute to the development of methodology for safeguards in connection with the disposal process. The area is the subject of considerable international interest and international developments should be taken into account, especially the process in Finland.

Transportation

- SKB should, already at this stage, initiate an analysis to evaluate technical protection systems for the monitoring of spent fuel canisters in connection with transportation.

Safety Assessment

The safety assessment area is being well handled at present. The next safety assessment (SR-Can) will not directly be a supporting document for an application. However, the authorities will nevertheless provide comments on SR-Can. SKB should take the comments into account before the SR-Site safety assessment, which will be one of the supporting documents for a licence application for a repository, is completed.

Fuel

- The fuel area must also continue to be given a high priority in SKB's programme. The understanding of the fuel's reaction in contact with the groundwater has improved considerably in recent years. However, this understanding needs to be better demonstrated in the form of quantitative model studies of mechanisms and processes.

Buffer

- Prior to forthcoming licence applications, SKB needs to show, through practical experiments, that SKB's knowledge and modelling of the buffer function are adequate. SKB should evaluate whether supplementary long-term experiments may be needed.

- Prior to future licence applications, SKB needs to clarify and specify detailed requirements for the buffer and to ensure that there is material that can justify requirements and criteria for the buffer function.

Backfill

- Prior to forthcoming licence applications, SKB should present a concept for the backfill of tunnels that can be shown to have good prospects of meeting the requirements made on the repository function. Furthermore, SKB needs to prepare material that better justifies these requirements.

- SKB needs to show how results from the Prototype Repository in the Äspö Hard Rock Laboratory are to be used.

Geosphere

- RD&D Programme 2004 lacks a clear link to the ongoing site investigations and research on issues of particular importance for assessing the suitability of the sites on different time scales, such as the occurrence of high rock stresses and saline groundwater. SKB needs to describe the need for further research on these issues.

Biosphere

- The biosphere programme lacks clear links between site investigations and model development and a complete description of the models that are to be used in the safety assessment.

- The development of models in the biosphere area must be prioritized and site data integrated into this work to verify the models in time prior to a licence application. Furthermore, the authorities assume that more long-term biosphere issues are being taken into account in SKB's new plan of action.

- In its biosphere research, SKB should take into account the possibility of using radionuclide concentrations and flows as complementary safety indicators.

Climate

- SKB should more clearly explain how it will ensure that studied climate scenarios will shed light on the most important climate-related stresses on the barrier function.

Alternative Methods

- It is justifiable for the research conducted by SKB and Sweden in the area of P&T to maintain its current level so that international developments can be followed and to maintain and develop scientific and technical expertise in areas of importance for nuclear safety.

- A clarification of the account of deep boreholes prior to the ultimate choice of a method and prior to licensing under the Environmental Code is needed. A comparison should be made with the KBS-3 method which utilizes safety assessment methodology including simple calculations.

Decommissioning

- SKB and the individual nuclear power plant licensees should specify the allocation of responsibility among themselves with respect to the choice of methods for decommissioning, waste management and for cost estimates.

- SKB needs to intensify the work on decommissioning issues and in order to present detailed plans and considerations in RD&D Programme 2007.

- SKB should investigate the shortest time required for the start of a licensing process for the disposal of decommissioning waste.

Low and Intermediate-level Waste

- In the next RD&D programme, SKB should provide a more detailed description of the programme for long-lived low and intermediate-level waste.

- SKB should take into account the viewpoint that long-term interim storage of waste while waiting for the construction of a repository should, as far as possible, be avoided and take this into consideration in its planning.

Social Science Research

- It is positive that SKB has incorporated social science research into its programme, since the findings from the research should be useful for the stakeholders to apply the research findings in ongoing and future consultation processes for an encapsulation plant and repository.

- SKB should, however, more clearly describe how the findings of the programme for social science research will be applied in the EIA and how SKB's other programme areas will benefit from these findings.

Regulatory Action

On September 22, 2004, SKB submitted RD&D Programme 2004 to SKI for review.

SKI has conducted the review of SKB's RD&D Programme 2004 in the same way as SKI's previous reviews of RD&D programmes. The programme has been distributed to sixty reviewing bodies for comment (including authorities, universities and NGOs). Review statements have been received from thirty of these.

Main Points of SKI's Review and Conclusions

In SKI's opinion, SKB has presented a research and development programme that complies with the requirements of Section 12 of the Act on Nuclear Activities.

Overall Evaluation of SKB's Programme

In terms of content, the programme is suitable for the continued development of a method for the disposal of spent nuclear fuel and nuclear waste in Swedish crystalline bedrock. The research is considered to be of good quality.

In SKI's opinion, disposal in deep geological formations in accordance with the KBS-3 method is still the most suitable method for the disposal of the spent nuclear fuel from the Swedish nuclear power programme.

SKI considers that the allocation of responsibilities for a closed repository for spent nuclear fuel needs to be clarified. This viewpoint is also expressed by some of the reviewing bodies.

Plan of Action

Of the requirements made by the authorities, in their review of RD&D Programme 2001, regarding SKB's plan of action, only the reporting of timetables for different activities in relation to the decision-making process has been conducted in a consistent and adequate manner.

SKI would still like to see an improved and more detailed account of the content of the basis for decision-making which is to be provided at different times. This applies with respect to the research findings, technology development, long-term experiments and acceptance criteria for the barrier system, as well as with respect to the research that SKB intends to conduct after applications are submitted, on different timescales up to the time of repository closure.

Based on the criticism directed to SKB's plan of action, SKI would like SKB to immediately prepare a new plan. The authorities should have access to an improved plan of action before starting to review licence applications for new facilities in the system for spent nuclear fuel.

Technology Development – Canister

SKI underlines the importance of formulating design premises for the canister and verifying them in the assessment of the long-term safety of the repository. In SKI's opinion, RD&D Programme 2004 is still lacking a clear and logical link between the detailed design premises for the canister and the requirements on long-term safety of the repository.

SKB needs to specify the limits for different parameters that are of importance for the canister function. The account must be based on an identification of defects that can occur and their consequences for canister integrity and repository function. In SKI's opinion, the preliminary limit for the minimum permissible copper cover is not clearly formulated, which is also a viewpoint expressed by several reviewing bodies.

SKI is positive to the work that has been conducted and that is planned for the development of testing methods for the weld, but would like to emphasize the necessity of SKB summarizing technical implementation and of documenting the methods.

SKI considers that SKB's work on the qualification of fabrication and sealing methods as well as on NDT methods is now being conducted in systematic manner.

SKI considers that an account of which stage in the process the verification of decay heat will be conducted is lacking and whether and how this will be combined with control measurements.

Technology Development - Repository

SKB should clarify how the work on KBS-3H (horizontal deposition of the canisters) is to be developed. An estimate of how much time and resources will be required is needed in order to prepare a body of material corresponding to that for KBS-3V (vertical deposition).

SKB should recognize that the Finnish Posiva's planned safety assessment cannot be expected to provide all of the answers to what KBS-3H concept entails for Swedish conditions. A relevant issue for Forsmark is, for example, how implementation can be made difficult by unfavourably high rock stresses.

SKB should continue to participate in and contribute to the development of methodology for safeguards in connection with the disposal process. The area is the subject of considerable international interest and international developments should be taken into account, especially the process in Finland.

Transportation

The need for a well-thought out system for the physical protection of nuclear material has, as is known, been highlighted in recent years. SKI considers that SKB should raise its ambitions in this area.

The analysis of possible threats and scenarios is primarily a task for regulatory authorities. However, equipment, technology and tactics for the surveillance of the fuel in connection with transportation are areas that SKB should investigate to a greater extent.

Safety Assessment

In SKI's opinion, the safety assessment area is being well handled at present. The reviews that were recently conducted have highlighted the most important weaknesses for SKB to rectify, such as quality assurance and methods for scenario selection. With the modified plan of action, SKB can further develop and test its method before it is used in connection with licensing.

The next safety assessment, SR-Can, will not directly be a supporting document for an application. However, the authorities will nevertheless provide comments on SR-Can. SKB should take the comments into account before the SR-Site safety assessment, which will be one of the supporting documents for a licence application for a repository, is completed. Certain remaining questions surrounding SKB's safety assessment method and the interpretation of regulations and general recommendations should be dealt with in SKB's consultation process with SKI and SSI on the system analysis and safety assessment. SKI would like to remind SKB of the importance of preparing easily accessible and high quality versions of SR-Can and SR-Site.

Fuel

In SKI's opinion, the fuel area must continue to be given a high priority in SKB's programme. A high confidence in the fuel's own barrier function will entail significant advantages for the safety assessment.

In SKI's opinion, the understanding of the fuel's reaction with the groundwater has improved considerably in recent years, with the reservation that the demonstration of this understanding in the form of quantitative model studies of mechanisms and processes needs to be better reported. There is also a certain lack of data for justifying the choice of several of the most important parameters for dose and risk calculations.

Buffer

SKB needs to evaluate the need for supplementary long-term experiments, especially taking into account technical problems with the measurement equipment of one of the canister positions in the Prototype Repository at the Äspö Hard Rock Laboratory. Prior to submitting future applications, there is a clear need to demonstrate, through comparisons with practical experiments, that SKB's knowledge and modelling tools for the buffer are adequate.

In the short term, SKI would like to see clearer priorities set regarding the buffer concept upon which future applications are to be based

SKB needs to continue its work on the clarification and determination of detailed requirements for the buffer specification and on ensuring that there is a basis that can justify requirements and criteria.

If the horizontal deposition programme is to be pursued, SKB must decide which long-term experiments may be needed for this purpose.

SKI supports SKB's plans for knowledge transfer from other nuclear waste programmes and considers that they are examples of efficient resource utilization. However, questions remain regarding whether this work can be transferred to Swedish conditions and utilized in SKB's safety assessment.

Backfill

SKI supports SKB's ambitions to evaluate alternative backfill designs over the next few years. The most important factor prior to future applications is that SKB should be able to present a concept for the backfilling of tunnels that can be shown to have good prospects of meeting the criteria.

In SKI's view, SKB needs to prepare material that better justifies the backfill criteria. In SKI's opinion, in the description of the initial state of the backfill, SKB should take into account the possibility that the quality of material, handling, application etc. can vary during the long period of time that the repository is in operation.

SKI considers that, just as for the buffer, SKB needs to systematically analyze features, events and processes (FEPs) that can cause a deterioration in long-term function.

SKI considers that SKB needs to show how results from the Backfill and Plug Test and the Prototype Repository at the Äspö Hard Rock Laboratory will be used prior to the submission of an application in 2008 for permission to construct the repository.

Geosphere

The section that describes the initial state of the geosphere completely focuses on describing the disturbances in the geohydrological and geochemical situation at the site of a future repository. In SKI's opinion, it is at least as important to take into account the disturbances to the geosphere that occur through the blasting of the repository, which affect the thermal and rock mechanical properties.

SKI considers that a clear link is lacking to the ongoing site investigations specific issues that are of particular importance for the evaluation of the different sites, such as the occurrence of high rock stresses and saline groundwater. In SKI's view, in the RD&D programme, SKB should discuss in greater detail how it intends to meet and handle problems that are now known.

Biosphere

The authorities are positive to the fact that SKB, in recent years, has increased its

level of ambition in the biosphere area. However, RD&D Programme 2004 does not provide an adequate description of the research that is being conducted. Clear links between site investigations and model development and a complete description of the models that are to be used in the safety assessment are lacking.

The authorities consider that the development of models in the biosphere area must be prioritized and site data integrated into this work to verify the models in time prior to a licence application. Furthermore, SKI and SSI assume that more long-term biosphere issues are being taken into account in SKB's new plan of action. In its biosphere research, SKB should also take into account the possibility of using radionuclide concentrations and flows as complementary safety indicators.

Climate

SKI considers that SKB should clarify how it will ensure that the selected climate evolutions will actually shed light on the most important climate-related stresses on the barrier function.

SKI finds that, in the chapter in RD&D Programme 2004 on climate, feedback to the chapters on the biosphere, geosphere and to the safety assessment is lacking. Future changes in the biosphere and geosphere are not adequately taken into account in the modelling of future climate evolution.

Alternative Methods

The research conducted by SKB and Sweden in the area of P&T should be maintained at the current level so that international developments can be followed and to maintain and develop scientific and technical expertise in areas of importance for nuclear safety.

In SKI's view, a clarification of the account of deep boreholes prior to the ultimate choice of a method and prior to licensing under the Environmental Code is warranted. SKI shares SSI's view that a more thorough comparison should be made with the KBS-3 method. In SKI's opinion, such a comparison should be made in a systematic manner which is based on the same principles that SKB has developed for the safety assessment of other repositories. SKI also agrees with SSI that the comparison can be illustrated with simplified calculations.

Decommissioning

SKI's overall evaluation of the account presented in RD&D Programme 2004 is that if SKB is to be able to deliver satisfactory cost estimates, the desired direction of work presented in RD&D Programme 2004 for the next six years must be realized. In SKI's view, it is particularly important for the following work to be conducted:

- SKB and the individual nuclear power plant licensees should specify how responsibilities will be allocated with respect to the choice of methods for decommissioning, waste management and for cost estimates.

- SKB needs to intensify the work on decommissioning issues and to present the results in RD&D Programme 2007. This work should be conducted taking into account the decommissioning plans that the reactor owners are obliged to prepare, for example, with respect to the analysis of competence in decommissioning issues, facility status and radioactive inventory.

- SKB and the reactor owners should also start work on investigating whether certain parts of the decommissioning work can be scheduled for an earlier date.

- SKB should investigate how soon a licensing process for the disposal of decommissioning waste can start.

In SKI's opinion, the construction of an interim storage facility for decommissioning waste should be avoided, since it will result in the need for additional handling of nuclear waste and could lead to the entire nuclear waste project becoming more expensive than planned. The construction of an interim storage facility would therefore probably mean that additional funds would have to be accumulated in the Nuclear Waste Fund since such a measure is not included in the RD&D programme nor in the cost estimate in the PLAN report.

Low and Intermediate-Level Waste

SKI shares SSI's view that the layout of a repository for long-lived low and intermediate-level waste should be clarified in the research programme and that such a description should be presented in RD&D Programme 2007.

SKI also shares SSI's view that the interim storage of waste while waiting for the construction of a repository should, as far as possible, be avoided. SKB should therefore reconsider the reasons for delaying a repository for long-lived waste until most of the nuclear power plants have been decommissioned.

Social Science Research

SKI notes that SKB in RD&D Programme 2004 has incorporated social science research as a new discipline in the research programme. SKI sees advantages in doing so since it should be possible for the stakeholders to apply the research findings in ongoing and future consultation processes. However, SKI, like several reviewing bodies, would like SKB to describe how the findings of the programme will be applied in the EIA and how SKB's other programme areas will benefit from these findings.

SKI finds that limited resources will be invested in the area of global changes in the social science research programme. This area should have deserved somewhat greater attention and a greater scope especially in view of the discussion currently in progress in international fora concerning the establishment of international repositories.

Conduct of this Regulatory Action

A decision on this matter was made by SKI's Board. Apart from the undersigned chairperson, the following board members participated in the decision: Andersson Öhrn, Axelsson, Dahllöf, Hagberg, Holm, Karlsson and Veiderpass as well as SKI employees Westerlind and Toverud, the latter in the capacity of rapporteur.

SWEDISH NUCLEAR POWER INSPECTORATE

Judith Melin

Öivind Toverud

Appendices

Swedish Nuclear Fuel and Waste Management Co (SKB):

RD&D Programme 2004. Programme for Research, Development and Demonstration of Methods for the Management and Disposal of Nuclear Waste, including Social Science Research, September 2004.

Swedish Nuclear Power Inspectorate (SKI):

SKI's Review Statement on SKB's RD&D Programme 2004. SKI Rapport 05:31. June 2005.

Reviewing Bodies' Statements on SKB's RD&D Programme 2004. SKI PM 05:10. June 2005.

Reviewing Bodies:

Original statements from 30 reviewing bodies.

Distribution List for Copies of the Review Statement

Reviewing Bodies

Swedish Work Environment Authority
Waste Network and Opinion Group for Safe Disposal (Oss)
Waste Network Association
National Board of Housing, Building and Planning
Swedish Energy Agency
Swedish Anti-Nuclear Movement
Gothenburg University
National Chemicals Inspectorate[1]
KSO (Network for co-operation among nuclear municipalities)
Linköping Institute of Technology[1]
Local Safety Committee for the Nuclear Facilities at Forsmark
Local Safety Committee at Ringhals Nuclear Power Plant
Luleå University of Technology
County Administration Board, Uppsala
Swedish NGO Office for Nuclear Waste Review (MKG)
Nuclear Waste Secretariat of the Environmental NGOs (MILKAS)
Swedish Environmental Protection Agency
Oskarshamn Municipality
National Heritage Board[1]
National Rescue Services[1]
Swedish Geotechnical Institute
Swedish Radiation Protection Authority
Stockholm University (Pereira – Mörner)
Geological Survey of Sweden

Swedish Defense Research Agency (FOI)
Umeå University
Uppsala University
Westinghouse Electric Sweden AB[1]
Swedish Research Council
Östhammar Municipality

[1]Refrained from submitting a review statement

For Information

AB SVAFO
Barsebäck Kraft AB
Danish Emergency Management Agency
Forsmarks Kraftgrupp AB
Swedish National Council for Nuclear Waste (KASAM)
OKG AB
Swedish Parliament
Ringhals AB
Norwegian Radiation Protection Authority
Prime Minister's Office
Studsvik Nuclear AB
STUK, Finland
Swedish Nuclear Fuel and Waste Management Co. (SKB)
Swedish IAEA Delegation
Swedish OECD Delegation
Sydkraft AB
Sydkraft Kärnkraft AB
Vattenfall AB

SKI's Evaluation of the Swedish Nuclear Fuel and Waste Management Co's RD&D Programme 2004

Review Report

Contents

Summary

The review of the RD&D programmes (Research, Development, Demonstration) prepared by the Swedish Nuclear Fuel and Waste Management Co (SKB) is a recurrent task that the Swedish Nuclear Power Inspectorate (SKI) must carry out as a regulatory authority with the support of reviewing bodies of whom the most important is the Swedish Radiation Protection Authority (SSI).

The review statement for the latest programme, RD&D Programme 2001, was submitted to the Government in March 2002.

In each new review, an evaluation is made of the progress of the Swedish nuclear waste programme which is SKB's responsibility. The company is the most important driving force in all waste management activities in different forms and, in this context, the important issue is how the spent nuclear fuel will be handled and disposed of in the long term.

The nuclear waste issue contains technical, scientific, social science and democratic challenges which are to be handled by SKB. All of these aspects are dealt with in SKI's statement to the Government even if, for natural reasons, the technical and scientific problems are the focus for a regulatory authority that works with safety issues and the supervision and regulation of nuclear facilities.

SKI's review is structured in accordance with the programme submitted by SKB and covers the company's plan of action, canister technology, the repository, transportation, safety assessment, fuel properties, disposal methodology and the buffer around the canisters, backfill, the geological conditions at the repository site (the geosphere), the land and environmental impact (the biosphere) and the impact of climate changes. Furthermore, SKB reports the knowledge and research on alternatives to a geological repository.

In addition to focusing on the management of spent nuclear fuel, SKB also describes how the decommissioning of nuclear power plants can be financed and carried out as well as the handling of long-lived low and intermediate-level waste which is generated as a result of the decommissioning of nuclear power plants etc.

A new feature of RD&D Programme 2004 is that SKB has also incorporated social science research into its research proposal. The basic problem of how high-level waste should be disposed of concerns issues relating to decision-making processes, infrastructure, economy and political decision-making.

This summary of SKI's Review Statement and Evaluation follows the structure of the main text which, in turn, follows the structure of SKB's RD&D Programme 2004.

Responsibility for Closed Repository

A basic requirement on the future repository for spent nuclear fuel is that it should be possible to leave the repository closed and without monitoring by future generations. At

the same time, this does not mean that the possibility of monitoring or institutional control by the state, for example, is excluded. It is also necessary to clarify who is responsible for the repository after closure.

SKI shares SKB's view that it can be assumed that some form of institutional control may be required, even after the closure of the repository for spent nuclear fuel if for no other reason but for safeguards and physical protection.

SKI understands the view of the reviewing bodies who would like to see a clear allocation of responsibilities after the spent nuclear fuel repository is closed and supports the reviewing bodies that would like an answer to the question of responsibility.

SKB's Plan of Action

In SKI's view, the plan of action presented by SKB in RD&D Programme 2004 provides a good and systematic description of SKB's timetables and for how different parts of SKB's programme are dependent on each other. Therefore, it is important for SKB to maintain and develop its plan of action as a living document so that it can be an effective instrument for further consultation prior to future decision-making processes.

The most severe criticism by the authorities of the plan of action in its original form concerned the link between the applications for the encapsulation plant and the repository.

During spring 2005, this issue has been dealt with through SKB submitting a proposal for a modified plan of action within the framework of the consultation between SKI, SSI and SKB on safety assessment and safety analysis.

SKB's proposal means that an application for the encapsulation plant under the Act on Nuclear Activities will be submitted separately in 2006, but with a joint licensing under the Act on Nuclear Activities and the Environmental Code, of the encapsulation plant and the repository in connection with an application for repository siting in 2008.

In SKI's view, the main problem of the original proposal involving two separate applications and licensing times can be resolved. Certain details must be worked out by SKB concerning the content and scope of the reporting that is to be conducted at different times.

Of the requirements made by the authorities, in their review of RD&D Programme 2001, regarding SKB's plan of action, only the reporting of timetables for different activities in relation to the decision-making process has been conducted in a consistent and adequate manner.

SKI would still like to see an improved and more detailed account of the content of the material for decision-making which is to be provided at different times. This applies with respect to the research findings, technology development, long-term experiments and acceptance criteria for the barrier system as well as with respect to the research that

SKB intends to conduct after applications are submitted on different timescales up to the time of repository closure.

SKI would like to particularly mention the following as some of the issues that SKB needs to work with further in its plan of action:

- SKB should make additional modifications to the constrained timetables.
- SKB should develop the system analysis, its role and content on different decision-making occasions.
- SKB should ensure that it has adequate flexibility and breadth of variation in its applications for facilities.
- SKB should further develop the basis for the preliminary safety assessment for the encapsulation plant and any link to the existing facilities.

Based on the criticism directed to SKB's plan of action, SKI would like SKB to immediately prepare a new plan. The authorities should have access to an improved plan of action before starting to review licence applications for new facilities in the system for spent nuclear fuel. This request is justified by the fact that planning and implementation of licensing in a stepwise process lasting many years requires both general and detailed knowledge of the content of the applications and supporting documents.

Canister

In SKI's opinion, SKB's work on the development of the canister and encapsulation is making satisfactory progress. After publishing RD&D Programme 2004, SKB has also continued its development work. In particular, the work on the programme for qualification and the choice of welding method can be mentioned.

SKI has nevertheless identified a number of areas where the report presented by SKB so far indicates deficiencies in the material.

SKI underlines the importance of formulating design premises. Furthermore, SKB should specify the limits for different parameters that are of importance for the repository function. In SKI's opinion, RD&D Programme 2004 is still lacking a clear and logical link between the detailed design premises for the canister and the requirements on the long-term safety of the repository.

SKB needs to specify the limits for different parameters that are of importance for the canister function. The account must be based on an identification of defects that can occur and their consequences for canister integrity and repository function. In SKI's opinion, the preliminary limit for the minimum permissible copper cover is not clearly formulated, which is also a viewpoint expressed by several reviewing bodies.

Since RD&D Programme 2001, SKB has made considerable progress in the development of Friction Stir Welding (FSW) as a method of canister sealing and in May 2005, this method was selected as a reference method for the weld. However, SKI still considers that a more detailed background material is lacking with results from the

development work but assumes that such material will be presented no later than in connection with the application for the encapsulation plant. In particular, SKB must still demonstrate if, and how, the properties of the weld material are different from the parent metal, as well as the impact of any impurities in the weld.

SKI is positive to the work that has been conducted and that is planned for the development of testing methods for the weld, but would like to emphasize the necessity of SKB adopting a co-ordinated strategy, technically and with respect to the documentation. With SKB's choice of Friction Stir Welding (FSW) as a reference welding method, SKI considers that it is important for the development of testing methods to focus on welds made using this method.

SKI considers that SKB's work on the qualification of fabrication and sealing methods as well as on NDT methods is now being conducted in systematic manner. SKI is positive to the fact that SKB has established contact with the qualification body, SQC, to adapt existing qualification procedures to a qualification programme for NDT.

SKI wishes to also emphasize the importance of SKB formulating a strategy for how the composition of fuel elements for the canisters will be achieved. The strategy must take into account temperature and criticality and should be long term so that all relevant types of fuel are covered, both the fuel that exists and forthcoming changes in fuel geometry and composition.

Safeguards

In its report, SKB has described the national and international safeguards system in a correct manner. However, it should be emphasized that the final disposal system entails a completely new type of facility for which previous experience of safeguards is lacking. SKI considers that an account of which stage in the process the verification of decay heat will be conducted is lacking and whether and how this will be combined with control measurements of nuclear substances.

Repository

SKI expects, with reference to the applicable legislation, that SKB will use the term "repository" in the future when referring to the repository for spent nuclear fuel.

SKI considers that if SKB is taking the requirements on limited impact on the rock in the repository seriously, SKB should decide already at this stage that mechanical excavation (full-face boring) of deposition tunnels and deposition holes will be conducted.

With respect to horizontal deposition (KBS-3H), there is concern for practical implementation as well as long-term safety. The possibility of avoiding (water-bearing) fractures of varying size and falling blocks in the tunnel is decreasing. The deposition method also has consequences for the sealing properties of the bentonite. Unfavourably high rock stresses can also lead to problems during the construction and deposition

phases which can result in requirements for compensatory measures (reinforcement and grouting).

Other questions that SKB needs to answer include: What is the maximum borehole deviation that can be accepted for the introduction of the deposition container in the tunnel? Additional questions that need to be answered are: The function of the distance block in the event of uneven wetting, the thermomechanical evolution of the deposition container, the buildup of swelling pressure and the function of the bentonite in the interface between the deposition hole and the tunnel periphery.

SKB should continue to participate in and contribute to the development of methodology for safeguards in connection with the disposal process. The area is the subject of considerable international interest and international developments should be taken into account, especially the process in Finland.

Transportation

SKB's account of existing regulations in the transportation area is unclear and partly incorrect. For example, SKB refers to already defunct regulations. It is unclear what the regulations for the transportation of hazardous goods will require and what the Act on Nuclear Activities and the Radiation Protection Act will require.

Furthermore, the account is based on the assumption that SKI will make the same stipulations for transportation as it does today, which is not self evident. In addition, when existing licence stipulations are mentioned, the issue of physical protection is completely neglected.

The need for a well-thought out system for the physical protection of nuclear material has, as is known, been highlighted in recent years. Therefore, SKI shares the view presented by FOI that SKB should raise its ambitions in this area.

The analysis of possible threats and scenarios is primarily a task for regulatory authorities. However, equipment, technology and tactics for the surveillance of the fuel in connection with transportation is an area that SKB should investigate more deeply.

Safety Assessment

In SKI's opinion, the safety assessment area is being well handled at present. The reviews that were recently conducted have highlighted the most important weaknesses for SKB to rectify, such as quality assurance and methods for scenario selection. With the modified plan of action, SKB can further develop and test its method before it is used in connection with licensing.

The next safety assessment, SR-Can, will not directly be a supporting document for an application. However, the authorities will nevertheless provide comments on SR-Can. SKB should take the comments into account before the SR-Site safety assessment,

which will be one of the supporting documents for a licence application for a repository, is completed.

Certain remaining questions surrounding SKB's safety assessment method and the application of regulations and general recommendations should be dealt with in the consultation process for system analysis and safety assessment. SKI would like to remind SKB of the importance of preparing easily accessible and high quality versions of SR-Can and SR-Site.

Fuel

In SKI's opinion, the fuel area must continue to be given a high priority in SKB's programme. A high confidence in the fuel's own barrier function will entail significant advantages for safety assessment. In SKI's opinion, the understanding of the fuel's reaction with the groundwater has improved considerably in recent years, with the reservation that the demonstration of this understanding in the form of quantitative model studies of mechanisms and processes needs to be better reported. There is also a certain lack of data for justifying the choice of several of the most important parameters for dose and risk calculations.

Canister as Barrier

In SKI's view, SKB's programme for obtaining knowledge about the canister as a barrier is well adapted to the needs that exist. However, SKI would like to point out that SKB needs to clarify the work and projects that must be carried out in order to be used in the basis for the application for the encapsulation plant.

SKI considers that it is necessary for SKB to present an updated and overall description of temperature evolution in the canister, including the impact of uncertainties. This must be connected to clarifying plans concerning the maximum permissible canister temperature. Correspondingly, an overall account of experiments and modelling of creep (a form of plastic deformation) in the canister must be prepared.

In several areas, SKB still has to show how the results from experiments and calculations are to be used in the safety assessment and whether the existing knowledge is adequate. This does not only apply to temperature evolution and creep in copper but also to the corrosion of cast iron and copper.

In the case of copper corrosion, SKI still sees deficiencies in the material for evaluating stress corrosion, the importance of the oxide layer for different types of corrosion, especially in chloride and sulphide-rich water and the capability of the microbes to survive in the bentonite buffer.

Buffer

In SKI's opinion, SKB has a good programme for buffer issues and a commendably clear account of these issues is provided in RD&D Programme 2004. Significant progress has been achieved in recent years in terms of model studies and code development and experiments.

However, in SKI's opinion, SKB should evaluate the need for supplementary long-term experiments, especially taking into account the recent malfunction of measurement equipment for one of the canister positions in the Prototype Repository. Prior to submitting future applications, there is a clear need to demonstrate, through comparisons with practical experiments, that SKB's knowledge and modelling tools for the buffer are adequate.

If the horizontal deposition programme is to be pursued, SKB must decide whether long-term experiments may be needed for this purpose. In the long term, SKB must also decide whether long-term experiments for the evaluation of the importance of conditions at the final repository site are needed.

SKI observes that SKB, compared with the work on the copper canister, has not made as much progress in the development of fabrication technology and procedures for practical handling. For example, SKB has not yet been able to test its reference method for full-scale bentonite block compaction (isostatic pressing).

SKI is not aware of any major practical difficulties that have to be solved in connection with the buffer, but it is nevertheless important that future safety assessments should be based on information that is as well-founded and realistic as possible. For example, during future routine operating conditions, poor quality bentonite blocks or an unsuitable block emplacement may occur. It is not clear to SKI whether SKB intends to take into account such practical problems explicitly in connection with the description of the initial state of the repository or whether they will be completely excluded and, if so, on what grounds.

In recent years, SKB has made progress in broadening its concept to include more buffer materials and a different buffer design for KBS-3H. In SKI's view, this work is well justified in the long term since it will result in greater freedom of action and possibly conditions for improved cost-efficiency. However, SKI would like to see clearer priorities set regarding the concept upon which future applications are to be based (2006 and 2008, according to the current timetable). Without clear priorities, there is a risk that the limited competence and resources available in Sweden will become too fragmented.

SKI observes that the specification for the buffer is multifacetted and partially difficult to interpret. SKB needs to continue its work on the clarification and determination of detailed requirements in the specification and on ensuring that there is a basis that can justify requirements and criteria.

In SKI's opinion, SKB needs to start planning the basis that will be needed for submitting an application for permission to start operation in around 2020. This planning needs to cover the handling of practical issues related to the fabrication, handling procedures, testing, documentation and quality programmes as well as long-term experiments.

Unlike a copper canister, a bentonite buffer is a component that is included in the nuclear waste programmes of most other countries. SKB has previously stated that the need for research and long-term demonstration can partially be satisfied through knowledge transfer from other programmes and RD&D Programme 2004 contains several examples of this. SKI supports these plans and considers that they are examples of efficient resource utilization. However, in order for SKI to judge the value of an exchange of information from international long-term experiments, SKB must specify the relevance of the information to a KBS-3 repository and describe any critical differences that must be taken into account in the interpretation of data.

Backfill

SKI supports SKB's ambitions to evaluate alternative backfill designs over the next few years. The most important factor prior to future applications is that SKB should be able to present an alternative to the backfilling of tunnels that can be shown to have good prospects of meeting the criteria.

In SKI's view, SKB needs to prepare material that better justifies the backfill criteria. To more easily put the backfill into a safety context, more detailed analyses are required of how different possible properties in the backfill can have an impact on the safety goals. In SKI's opinion, in the description of the initial state of the backfill, SKB should take into account the possibility that the quality of material, handling, application etc. can vary during the long period of time that the repository is in operation.

SKI considers that, just as for the buffer, SKB needs to systematically analyze features, events and processes (FEPs) that can cause a deterioration in function.

SKI considers that SKB needs to show how results from the Backfill and Plug Test and the Prototype Repository at the Äspö Hard Rock Laboratory will be used prior to the submission of an application in 2008 for permission to construct the repository.

Geosphere

The section that describes the initial state of the geosphere completely focuses on describing the disturbances in the geohydrological and geochemical situation at the site of a future repository. In SKI's opinion, it is at least as important to take into account the disturbances that occur through the blasting of the repository, which affect the rock mechanical and thermal initial states.

Furthermore, in SKI's opinion, a clear link is lacking to the ongoing site investigations and the problems at each of the sites can have (such as high rock stresses, saline groundwater etc.).

In SKI's view, in the RD&D programme, SKB should discuss in greater detail how it intends to meet and handle problems that are now known. SKB should also have been clearer in describing which resources and preparedness exist to handle these site-specific issues which require some type of research work.

SKI wonders whether the RD&D Programme is sufficiently flexible to handle, at short notice, any new issues that arise in connection with the site investigations and if there is preparedness for dealing with such questions. The lack of or deficiency in preparedness concerning the acquisition of knowledge can impact on future applications since the timetables for the application do not allow greater delays in knowledge acquisition.

In SKI's view, the link between ongoing site investigations and research work must be clarified.

Biosphere

In recent years, SKB's research in the biosphere area has been conducted more methodically and with a higher level of ambition than has previously been the case. The Swedish Radiation Protection Authority (SSI) considers this to be positive.

Unfortunately, RD&D Programme 2004 does not provide an adequate description of the research that is being conducted on the biosphere. The connection between data from the site investigations and the requirements made by the site-specific systems ecology models must be clear. For example, it is not clear when critical R&D results and models must be developed with respect to the needs of the site investigations.

A comprehensive documentation must exist of the processes involved in the biosphere models that are used as is the case for other repository parts. Furthermore, a comprehensive description of all models to be used in the safety assessment and accounts of how well they represent the identified processes in relevant ecosystems are necessary.

SKB should clarify how environmental protection will be taken into account in model development and in the site investigations. SKB's claim that data already collected from the site investigations far exceeds the needs specified in the EU Fasset project must be justified.

In addition, SKI would like to particularly emphasize that SKB's account does not clearly specify how the different parts of the programme are to be co-ordinated with each other on the basis of the needs of the safety assessment. This may be due to an unsuitable structuring of material in RD&D Programme 2004. It may also be a reflection of the need for better internal co-ordination of SKB's biosphere programme.

SKB needs to clarify its programme in these respects so that the authorities can decide whether the programme can, within a reasonable time in relation to SKB's overall plan of action, meet the goals that have been set. SKI assumes that these viewpoints are being taken into account in the improved plan of action that SKB is to present before it submits an application for the encapsulation plant.

SKI would also like to remind SKB that biosphere modelling should include elements that can be used in connection with complementary safety indicators for disposal such as radionuclide concentrations and flows.

Climate

SKI observes that SKB, as a first step in its plans, is focusing its modelling work on simulating the first deglaciation period. However, it is important to point out that this is only one example of many possible climate evolution alternatives. Even if SKB bases its assumptions on and uses knowledge of the paleoclimate, little is known about what can happen in the future, for example, since the impact of the greenhouse effect on the climate is difficult to assess.

SKI also considers that SKB should clarify how it will ensure that the selected climate evolutions will shed light on the most important climate-related stresses on the barrier function.

The authorities previously observed that, in coastal areas, the future position of the shoreline and its importance for groundwater conditions and the biosphere is an important issue. Therefore, it is satisfactory that SKB has initiated several projects to understand the causes of climate variations and shoreline position within different time periods. SKB can thereby postulate the development of a future shoreline in the areas where site investigations are currently being conducted.

SKI finds that, in the chapter on climate, feedback to the chapters on the biosphere, geosphere and to the safety assessment is lacking. Future changes in the biosphere and geosphere are not adequately taken into account in calculations of how groundwater flow, water chemistry, rock stresses etc. around a future repository can change.

Alternative Methods

In SKI's view, it is justifiable for the research conducted by SKB and Sweden in the area of P&T to maintain its current level so that international developments can be followed and to maintain and develop scientific and technical expertise in areas of importance for nuclear safety.

In SKI's view, a clarification of the account of deep boreholes prior to the ultimate choice of a method and prior to licensing under the Environmental Code is warranted. SKI and SSI both consider that a more thorough comparison should be made with the KBS-3 method. Such a comparison should be made in a systematic manner which is based on the same principles that SKB has developed for the safety assessment of other

repositories. SKI also agrees with SSI that the comparison can be illustrated with simplified calculations.

Decommissioning

SKI's overall evaluation is that if SKB is to be able to deliver a good result with its cost estimates, the desired direction of work presented in RD&D Programme 2004 for the next six years must be realized. In SKI's view, it is particularly important for the following work to be conducted:

- SKB and the individual nuclear power plant licensees should specify the allocation of responsibilities among themselves with respect to the choice of methods for decommissioning, waste management and for cost estimates.

- SKB needs to intensify the work on decommissioning issues and to present the results in RD&D Programme 2007. This work should be conducted taking into account the decommissioning plans that the reactor owners are obliged to prepare, for example, with respect to the analysis of competence in decommissioning issues, facility status and radioactive inventory.

- SKB and the reactor owners should also start work on investigating whether certain parts of the decommissioning work can be scheduled for an earlier date.

- SKB should investigate how soon a licensing process for the disposal of decommissioning waste can start.

In SKI's opinion, a review of decommissioning logistics based on an assumption that the operation of nuclear power plants will be extended from 40 years to 60 years cannot be prioritized.

The premises for such a plan are not included in RD&D Programme 2004 or in PLAN 2004. In fact, such a measure could actually prove to be counterproductive since it could lead to the delay of scheduled work in practice which, in turn, could lead to a delay in the startup of the repository for decommissioning waste by an additional couple of decades.

By investigating a changeover from 40 to 60 years of reactor operation, a situation can be created where the mental preparations required for the successful planning of decommissioning are neglected for such a long time that existing knowledge is lost. It is difficult to see how decommissioning can be delayed for 20 years without having to construct a new interim storage facility for decommissioning waste. In SKI's opinion, the construction of an interim storage facility for decommissioning waste should be avoided, since it will result in the need for additional handling of nuclear waste and could lead to the entire nuclear waste project becoming more expensive than planned.

The construction of an interim storage facility would probably mean that additional funds would have to be accumulated in the Nuclear Waste Fund since such a measure is not included in the RD&D programme or in the cost estimate in the PLAN report.

Low and Intermediate-Level Waste

SKI finds that a clear research plan for low and intermediate-level waste is lacking and assumes that SKB will present such a plan in the next RD&D programme.

SKI agrees with SSI that the layout of a repository for long-lived low and intermediate-level waste should be prioritized in the research programme and that such a prioritization should be presented in RD&D Programme 2007.

SKI considers that SKB should describe how long-lived low and intermediate-level decommissioning waste is to be managed in the event that the waste is generated at an earlier stage than planned.

The authorities, SKI and SSI, share the view that long-term interim storage of waste while waiting for the construction of a repository should, as far as possible, be avoided and that SKB should consider whether there is actually any reason to delay a repository for long-lived waste until most of the nuclear power plants have been decommissioned.

Social Science Research

SKI notes that SKB in RD&D Programme 2004 has incorporated social science research as a new discipline in the research programme. SKI sees advantages in doing so since it should be possible for the stakeholders to apply the research findings in ongoing and future consultation processes. However, SKI, like several reviewing bodies, would like SKB to describe how the findings of the programme will be applied in the EIA and how SKB's other programme areas will benefit from these findings.

SKI notes that limited resources are being invested in the area of global changes (a project) in the social science research programme. This area should have deserved somewhat greater attention and a greater scope especially in view of the discussion currently in progress in international fora concerning the establishment of international repositories.

1 Introduction

1.1 Background to the Programme

According to the Act on Nuclear Activities, the holder of a licence to operate a nuclear reactor must adopt all necessary measures to manage and dispose of spent nuclear fuel and nuclear waste. The Act stipulates requirements on a research programme which is to be submitted to the competent regulatory authority once every three years. The Swedish Nuclear Power Inspectorate (SKI) is the competent authority that reviews and evaluates the programme. SKI distributes the programme to a wide range of reviewing bodies for comment, including authorities, municipalities, universities and environmental NGOs.

The Swedish programme for final disposal of spent nuclear fuel started about 30 years ago and, according to Swedish Nuclear Fuel and Waste Management Co. (SKB), the planned repository will not be closed until sometime in the 2050's. A series of decisions must be made before this goal is attained. The decision-making process can therefore be described as a multi-stage process. During these stages, safety will be evaluated and there will be the opportunity for conducting further development work or for selecting improved solutions. SKI's task is to ensure safety compliance throughout all of the stages.

In its decision in January 2002, the Government found that the Programme for Research, Development and Demonstration of Methods for the Management and Disposal of Nuclear Waste (RD&D Programme 2001) complied with the requirements of § 12 of the Act (1984:3) on Nuclear Activities. In its decision, the Government took into account what SKI, the Swedish Radiation Protection Authority (SSI) and the Swedish National Council for Nuclear Waste (KASAM) stated with respect to SKB's timetable and the relationship between different parts of the development work for an encapsulation plant and a repository for spent nuclear fuel.

SKB's current programme, which was submitted to SKI on September 22, 2004, is the seventh regular programme in the series which started with RD&D Programme 1986. The previous RD&D Programme 2001 focused on research and technology development. RD&D Programme 2004 mainly focuses on shedding light on the development of the fabrication and sealing of canisters for the disposal of spent nuclear fuel. On the basis of the opinion of the regulatory authorities and the Government regarding the previous RD&D Programme, SKB also presents the plan of action that was requested at that time.

1.2 Conduct of this Regulatory Review

SKI has conducted the review of SKB's RD&D Programme 2004 in the same way as SKI's previous reviews of RD& D programmes. SKI has distributed the programme to sixty reviewing bodies for comment (authorities, municipalities, universities, environmental NGOs etc.). Review statements were received from 30 of these, of which five refrained from stating their opinion on the programme. About one-third of the review statements focus on issues relating to alternative methods, social science research, decommissioning and low and intermediate-level waste. A corresponding number of review statements comment on the structure of the report, the readability and

the comprehensibility of the description of the programme. The decision-making process, including the plan of action and repository monitoring have also been frequently commented upon. A smaller number of reviewing bodies have commented upon the account given of the technical areas of backfill and safety assessment. Five reviewing bodies discuss canister issues while a small number of reviewing bodies have commented upon geosphere and biosphere issues. Comments on resources for authorities, the Government Offices and the Environmental Court were put forward by Oskarshamn and Östhammar municipalities.

In addition to the review of the RD&D programme, the regulatory authorities, SKI and SSI, have had two meetings (in February and March 2005) with SKB regarding the plan of action that was attached to the RD&D Programme and the revised plan of action that SKB reported after the programme was submitted to SKI. These meetings took place within the framework of the consultation on the system and safety analysis that the Government decided on in 1996 and 2001.

In February, SKI's Board was informed of important issues that SKI had chosen to focus on in its review. In April, the Board was informed of the content of the review comments received and some of SKI's preliminary viewpoints on SKB's programme. SKI's review statement to the Government and the accompanying review report were submitted to and evaluated by SKI's Board in June.

At the beginning of each chapter in the review report, SKI specifies the parts of SKB's programme that are being commented upon. Several chapters contain the following headings "SKB's Report", "Comments by the Reviewing Bodies" and "SKI's Evaluation". In addition, a few chapters contain the following headings: "SSI's Comments" and "SKI's Overall Evaluation".

This volume (SKI Report 2005:31) comprises SKI's review statement to the Government with the accompanying review report:

- SKI's review statement on SKB's report on RD&D Programme 2004 – Programme for Research, Development and Demonstration of Methods for the Management and Disposal of Nuclear Waste, including Social Science Research
- SKI's review report on SKB's RD&D Programme 2004

In addition, the comments by reviewing bodies are submitted in full to the Government as well as a compilation of the review comments referred to in the review report (SKI-PM 2005:10).

2 Overall Opinion of SKB's Programme

In this chapter, SKI presents the findings from its inspection of SKB's process for the preparation of RD&D Programme 2004. SKI also presents its comments on the structure and content of this programme. Furthermore, SKI provides views on certain issues that SKI previously highlighted and which SKB has chosen not to include in this programme, for example, issues relating to the decision-making process and the process for the preparation of Environmental Impact Statements, namely Environmental Impact Assessment (EIA).

2.1 Introduction

In RD&D Programme 2004, SKB has primarily focused on issues relating to technology development relating to the encapsulation plant and the repository. The reason for this is the application for permission to construct an encapsulation plant that SKB intends to submit during the forthcoming programme period (in mid-2006). The programme for safety assessment and research on the long-term processes that occur in the repository are then linked together with the technology development programmes. One new feature of this RD&D Programme is an account of a programme for social science research that several reviewing bodies requested in connection with the review of RD&D Programme 2001. SKB's account is presented in a single volume where the complete plan of action requested is presented in an appendix. Each chapter has an extensive reference list.

RD&D Programme 2004 has been structured in a different manner than RD&D Programme 2001. In RD&D Programme 2004, SKB has divided the report into four different parts which describe SKB's programme and plan of action (Part I and appendix), technology development (Part II), safety assessment and research (Part III) and low and intermediate-level waste (Part IV).

To make it easier for the readers and reviewers, SKB starts off each chapter with a background to the area of research in question. Each section then presents an account of the viewpoints put forward by the regulatory authorities in connection with RD&D Programme 2001. Finally, knowledge gained since the last RD&D programme and the programme for planned research are presented.

2.2 Inspection of the Preparation of RD&D Programme 2004

In autumn 2004, SKI carried out an inspection at SKB with the aim of evaluating SKB's compliance with the Act (1984:3) on Nuclear Activities and the requirements of the Ordinance to the Act in connection with the process for planning and preparation of the RD&D Programme 2004 report. The starting point for SKI's evaluation of how SKB planned, prioritized and carried out the preparation of the report and of how SKB implemented SKI's recommendations and the Government's requirements from previous reviews was an inspection plan.

Seventeen different documents were reviewed comprising relevant parts of SKB's quality and management system, project plan and other documents for the preparation of the RD&D report. The documentation provided by SKB was the starting point for a list of questions which were used in connection with interviews with four individuals involved in the project at SKB.

The inspection showed that established procedures existed for steering, management and implementation in connection with the preparation of an RD&D report based on the requirements of SKB's formal system for project implementation. In SKI's view, SKB's RD&D activity is steered and managed with the support of a quality system and responsibility and authority are defined and documented.

The inspection also revealed that certain procedures existed for evaluating expertise, particularly of hired consultants, and for evaluating work conducted in the project.

However, SKI observed that the necessary conditions existed to improve the procedures for the preparation of project decisions and project plans, primarily with respect to how the content and organization are specified as well as to how and which external expertise is used. SKI also observed that the existing procedures for maintaining the relevance of project plans through revisions should be used to a greater extent.

2.3 Structure and Content of the Report

Comments by the Reviewing Bodies

The Waste Network and the Opinion Group for Safe Disposal consider that the RD&D programmes should be redesigned to make them easier to read and less technical, thereby making them more accessible to those lacking technical specialist expertise. The programmes should also contain an account of selection criteria, focus and objective that are in agreement with the relevant legislation and environmental targets.

The Swedish Anti-Nuclear Movement considers that the report is characterized by a wealth of details over which it is difficult to obtain an overview and which is unorganized. In the report, one piece information – be it large or small – is stacked upon the other and the necessary framework for the reader to be able judge how and to what extent the individual details contribute to the goal fulfilment of the project is lacking. The Swedish Anti-Nuclear Movement thereby considers that an overall structured strategy is lacking.

The Local Safety Committee for the Nuclear Facilities at Forsmark consider that the report sheds light on what lies within the Committee's area of expertise in a well-thought out, clear and, with a few exceptions, comprehensible manner. However, the Committee would like to see a more comprehensible presentation of the safety assessment.

The National Environmental Protection Agency finds SKB's account of newfound knowledge in the different sub-areas to be presented in a very pedagogical manner and considers that it provides a good overview of the state-of-the-art. On the other hand, the Agency considers that the issue of liability in connection with decisions, in the event of accidents in connection with decommissioning, transportation and industrial establishment as well as operation should be reviewed in order to legally ensure that there is no third-party liability for damages. The Agency finds that liability issues are missing from SKB's plan and proposes that SKB should supplement the RD&D

programme with research into liability and insurance in the event of releases from a repository, all handling of radioactive waste, effects on the ecosystem and property as well as effects with respect to the health of people living in the vicinity of and far away from the waste facilities.

The Misterhult Group and the Society Group at Oskarshamn Municipality consider that the report is structured in a clear manner and that large parts of it are accessible and interesting, even for "non" experts. They also consider that the programme report is well-written and easy to read and that the technical issues are in focus.

Oskarshamn Municipality emphasizes the difficulty of obtaining an overall view of SKB's programme since it is presented in separate contexts, of which the RD&D process is one. Other contexts are the EIA – the consultation process for the Environmental Impact Statement (EIS) – and the site investigation programme. The municipality observes that the problem is partly resolved by the plan of action that SKB reports in the appendix to RD&D Programme 2004. What is still missing, above all, is the link between the different parts.

The Swedish Radiation Protection Authority (SSI) states that, in order to comply with the requirements of the Act on Nuclear Activities, future RD&D reports should contain at least a general description of all of the parts of the nuclear waste programme, and this is missing from this programme.

SSI considers that the account of SKB's site investigation programme is brief and general, in accordance with what SKB stated in RD&D Programme 2001. However, in SSI's opinion, an account of the research and technology development issues that SKB needs to solve and the link between these and the continued site investigation programme is missing.

SSI also emphasizes that issues of importance to site selection which concern radiation protection-related (scientific and research-oriented) considerations should also be presented in the RD&D programme in the future.

The Swedish Defence Research Agency considers that the report is well structured and well written on the whole. The areas of work that have been and are in focus are clearly justified and, in many cases, SKB manages to nevertheless keep alternative routes open if future research findings should warrant this.

In the opinion of Östhammar Municipality, the summary and the plan of action in the report are written in a manner that is accessible even for a layman. Furthermore, the Municipality considers that it would be desirable, in addition to this, for the context of the other chapters to be comprehensible to the politicians and civil servants who are specifically working with this issue on behalf of the Municipality. In the Municipality's view, Chapter 14 on safety assessment is difficult to read and does not give the Municipality an overview of the methods and purpose of the safety assessment. The municipality also notes that the Swedish summary of SKB's SR-Can interim report provides a more comprehensible overview of SKB's methodology for the safety assessment.

SKI's Evaluation

In SKI's opinion, an introduction is missing which contains a summary presenting an overall description of the programme and focusing on important issues for the progress of the programme. The report could also have provided a short retrospective on the content and important advancements made in previous RD&D programmes. This would mean that new readers would not have to question material already presented in previous RD&D programmes, for example, how SKB selected the sites in the municipalities where site investigations are currently in progress.

Furthermore, in SKI's view, SKB could more clearly have presented a more overall strategy for the goals to be met by each chapter. It is also difficult for the uninitiated reader to judge the importance of individual items of information so as to be able to assess how and to what degree these items contribute to the fulfilment of the project's goals. The Swedish Anti-Nuclear Movement has also noted these deficiencies.

SKI shares the view of SSI and Oskarshamn Municipality that SKB, initially in the report, should have more clearly presented the fact that, in addition to the RD&D process, there are three important activities in progress to achieve the goal of a safe disposal of nuclear waste: PLAN, the EIA and site investigations. With respect to PLAN, the planning process (SKB's annual estimate of the cost of the radioactive waste from nuclear power), SKB cannot assume that all readers of the RD&D programme know that this process is underway. The first time it is mentioned is in Chapter 24, which is about decommissioning. As far as the EIA is concerned, for example, the outcome of consultations so far conducted as well as in-depth planned investigations could have been briefly reported as well as whether the findings have so far affected any of the processes in the RD&D programme to any extent. With respect to the site investigations, results so far achieved could have also been briefly summarized at the beginning of the report and in greater detail in the plan of action in the appendix. Furthermore, relevant reports could have been referred to, for example, the annual reports for each site. This would have made it easier for anyone wishing to learn about the area in depth.

2.4 Resources for Authorities

Comments by the Reviewing Bodies

Oskarshamn Municipality wishes to emphasize the importance of the Government, the Environmental Court and authorities ensuring the timely buildup of expertise and resources that will be required for the handling of this, perhaps the most comprehensive and complex environmental issue that Sweden has had to handle. The authorities must have resources for conducting an independent review and, with their own capacity, must be able to, themselves, carry out critical parts of the safety assessment. The Government Offices must have resources to be able to co-ordinate the two licensing actions. The Environmental Court needs to learn about the licensing action and to acquire the necessary expertise. "As Oskarshamn Municipality has expressed on several occasions, we are concerned about the fact that society is not allocating sufficient resources to develop the expertise as well as the capacity that is needed. This particularly applies to the competent authorities, SSI and SKI. It also applies to the licensing by the

Environmental Court and the Government's preparedness for co-ordinating licensing under the Act on Nuclear Activities and the Environmental Court." The Swedish Environmental Protection Agency is an important actor for handling the matter in accordance with the Environmental Code and, also in this case, the Municipality is concerned since the Environmental Protection Agency is an invisible actor in the nuclear waste process.

SSI states that it is still uncertain whether SSI will have sufficient resources to conduct future reviews in accordance with SKB's timetable.

Östhammar Municipality notes that the role of the reviewing authorities, SKI and SSI, in the nuclear waste programme is of decisive importance for the Municipality's trust in the process. Both authorities have shown great interest in communicating important issues in the municipality.

Issues that the inhabitants of the municipality, to the greatest extent and to an increasing degree, are interested in concern the biosphere and how humans can be affected by a repository. In the Municipality's view, the extent of the need to discuss and have these issues elucidated will increase until the time that an application for permission to construct a repository has been dealt with. Therefore, the Municipality identifies an increasing need to communicate with SSI's experts within the area.

The Municipality has repeatedly reacted over the fact that SSI did not have resources to, on an equivalent basis with others (SKI, the municipalities, SKB), participate in different projects. Therefore, the Municipality considers that it is necessary for sufficient resources to be made available for the authority so that the programme can be scrutinized in the manner required by the Municipality.

The Environmental Court and the Government are the bodies that will ultimately make a decision on the application for permission to construct the encapsulation plant and the repository. In connection with this review statement, the Municipality would like to express its concern over the fact that these bodies will not be adequately prepared for the scope and complexity of the material upon which the application will be based. It takes time to learn about the different parts of the disposal project and the Government Offices should, as soon as possible, build up its expertise so that it can meet the need that will exist in 2006 and onwards.

SKI's Evaluation

In different contexts, SKI has previously reported that it has, for a long time (10 to 15 years), in different ways, with the help of supporting research invested resources into preparing itself for future reviews of the industry's planned applications for permission to construct new nuclear facilities.

SKI is currently investigating the possibility of obtaining financial reinforcement, in addition to the normal research budget, in connection with the review of planned applications from SKB. SKI is also conducting a dialogue with the Ministry for Sustainable Development on the need for reinforcement of its human resources.

SKI considers that it is important for all actors participating in the disposal process to be given the necessary resources to build up their expertise so as to be able to participate and contribute to the implementation of the process in an effective manner.

2.5 Decision-Making Process

Comments by the Reviewing Bodies

The National Board of Housing, Building and Planning has observed that SKB, in its timetable, states that the application for permission to construct an encapsulation plant will precede an application for permission to construct a repository for spent nuclear fuel. If permission is granted for the construction of an encapsulation plant before a decision is made regarding permission to construct a repository, an irreversible choice will be made regarding the method for management and disposal of the spent nuclear fuel.

The Swedish Anti-Nuclear Movement states that, during the almost 30-year-old process (disposal in accordance with the KBS-3 concept) politicians and authorities have successively abdicated their freedom of action in the nuclear waste question. The Swedish Anti-Nuclear Movement considers that they have thereby put themselves in a situation which requires, not only clearsightedness, but also the necessary courage to get out of the whole thing with their honour somewhat intact.

Oskarshamn Municipality states that the encapsulation plant and the repository must be licensed in accordance with both the Environmental Code and the Act on Nuclear Activities which is an untried process. The decision-making process that is just ahead is complex and it is a question of making it as transparent as possible in advance so that the main stakeholders share a common perception of the process. One reason for the complexity is that the environmental issue that is handled by the Environmental Court also includes nuclear safety and radiation protection, where SKI and SSI have the main responsibility. In accordance with previous practice, SKI, in its review statement to the Government under the Act on Nuclear Activities, proposed stipulations for a licence to construct a nuclear facility. The fact that the Environmental Court, under the Environmental Code, can on its own, make stipulations raises the issue of how both of the licensing processes are to be co-ordinated. The Municipality would like the main parties, including the Government, to clarify these issues in good time before the start of the decision-making process, namely as soon as possible.

Oskarshamn Municipality considers that when an application for permission to construct an encapsulation plant is formally submitted, there should be a need for SKB, the authorities, the municipalities, the Environmental Court and the Government, in the formal process, to consult on the subject of how the licensing and the environmental process, as a whole, can be designed. Therefore, in the Municipality's view, consultations need to continue and to be expanded even after the formal consultation process, in accordance with the Environmental Code, is concluded.

On the topic of site selection, Oskarshamn Municipality states that it is decisive for the decision-making process that SKB's site evaluation should be carried out in a

transparent manner so that the method and criteria for evaluation are evident before the actual site is selected.

Oskarshamn Municipality also considers that the decision-making process prior to future licensing for active operation, full operation, control programmes and closure also need to be clarified. The clarification of the decision-making process is an important prerequisite for the Municipality's preparations to participate in the process and to formulate its terms prior to a decision.

SKI's Evaluation

SKI finds that, on the basis of SKB's modified plan of action (see Chapter 3), the consultations on system and safety assessment need to continue until SKB has submitted an application for permission to construct a repository and until this has been evaluated under both the Act on Nuclear Activities and the Environmental Code. The need to continue the consultations should therefore be discussed by the authorities concerned and SKB.

According to the Government's decision, consultations concerning site investigations should continue until SKB has submitted an application for the construction of a repository at a site. Any subsequent consultation will be a question between the authorities concerned, SKB and the municipality where the repository is to be located. SKI thereby supports Oskarshamn Municipality which considers that the decision-making process needs to be clarified also in preparation for the future licensing for active operation, full operation, control programmes and closure.

2.6 Environmental Impact Assessment (EIA)

Comments by the Reviewing Bodies

The Swedish Anti-Nuclear Movement and the Opinion Group for Safe Disposal state that the environmental licensing, which is regulated by the Environmental Code, EC directives and the Espoo Convention, will be decisive in the licensing process. The project will, hopefully, also be considered in relation to environmental targets and agreements that Sweden has entered into in different environmental conventions.

In the opinion of the Nuclear Waste Secretariat of the Environmental NGOs (MILKAS), the Environmental Impact Assessment (EIA) should not be managed by SKB but by an independent body. This opinion has previously been expressed to both SKB and to the competent authorities.

MILKAS also emphasizes the need for the ongoing disposal/deep repository process to be halted and revised, for the disparities taken up here to be examined and rectified and for the competent authorities to utilize their mandate and not simply follow SKB.

MILKAS also considers that the nuclear waste issue and the related EIA is a matter of such power that it must be raised to a higher level than the municipal plane and be made into a national issue to a much higher degree. MILKAS also considers that the dividing up of the consultations into separate consultations for different groups creates additional

confusion and renders any essentially serious consideration concerning alternative sites, methods and strategies difficult.

The Swedish NGO Office for Nuclear Waste Review (MKG) considers that, for the relevance of the RD&D programme to be evaluated, it is necessary to specify the disposal project's environmental task and objective. Furthermore, in the view of MKG, such a specification is an indispensable step in the process of carrying out an EIA which complies with the requirements of the Environmental Code.

SKI's Evaluation

In its review of RD&D Programme 2001 (SKI, 2002), SKI stated that SKB intends to deal with all issues linked to the siting process during the EIA and will not give an account of these issues in future RD&D programmes. At that time, SKI assumed that SKB would clarify what it meant by *all issues linked to the siting process* in the EIA plan that SKB intended to present in 2002. SKI still considers that SKB should shed light on the role of the RD&D programme versus the EIA in order to achieve a consistent and structured decision-making process.

2.7 Responsibility for a Closed Repository

Comments by the Reviewing Bodies

Oskarshamn Municipality states that, in the continued dialogue with municipal inhabitants, in the event of a possible siting of a repository in the municipality, it is important to have a decision on the responsibility issue in the long term, before an application is submitted. This issue must be settled before the Municipality can submit its response to "the veto question" concerning the construction of a repository, and requests a statement from the Government regarding how it intends to deal with this issue. The Municipality notes that the approach that is for example expressed in the recent final report from the Committee of Inquiry on Financing (SOU 2004:125, p. 48), is not an approach that the general public and the Municipality can accept. The Municipality considers that it must be given answers to concrete questions such as: "Who is responsible for what and for how long?"

Östhammar Municipality considers that the issue of who is responsible for the repository after closure must be clarified before the Government makes a decision regarding the licence to construct the repository.

SKI's Evaluation

SKI can well understand the reviewing bodies requesting a clear division of responsibilities after a repository for high-level spent nuclear fuel has been closed and supports the reviewing bodies that request a decision on the issue of responsibility.

3 Comments on SKB's Plan of Action

3.1 Introduction

3.1.1 Background

In its review of RD&D Programme 2001, SKI requested a better and more detailed documentation of SKB's plan prior to future applications. SKI stated that, "the need for a planning instrument in the form of a strategy document, which describes how SKB will attain the goal of a safe disposal of spent nuclear fuel, has become increasingly urgent now that SKB's programme has entered a more intensive phase". Furthermore, SKI stated that, "already within a year or two, the competent authorities will need to know which regulatory reviews are anticipated over the next ten years and the extent to which these reviews depend on each other".

The idea behind the strategy document or rather, the term "strategy document" was originally launched by the international peer review group for SKB's safety assessment, SR-97 (OECD/NEA, 2000). The original idea was that SKB, in a systematic manner, would describe its strategy for achieving a safe disposal and that this would focus on the design and assessment of the repository itself, not on the development programme or decision-making process. However, the description of this type of strategy is normally presented in the safety report for the repository. Instead, SKI and SSI developed their view of what SKB's strategy document should contain. On the whole, both of the authorities shared similar views with the difference that SKI focused more on the content of different applications and on the timetable for these applications, while SSI focused more on reporting when different research and development goals should be reached.

The most important requirements on SKB's strategy document, presented by the authorities in their review of RD&D Programme 2001, included the following:

- a timetable, both an overall, realistic timetable and a timetable for future safety assessments and system analyses
- an objective for ongoing and planned long-term experiments
- a report of when critical research findings and models must be ready
- the content of future reports
- requirements on the different barriers in the system and a timetable for when it should be demonstrated that the requirements are met
- the timetable for ("the final") choice of engineered barrier design.

Based on the authorities' review, in its decision of December 2002, the Government stated that it "assumes that SKB is conducting a dialogue with the authorities and municipalities concerned and that a description of SKB's timetable and accompanying plan of action concerning a safe disposal of nuclear waste would be included in RD&D Programme 2004".

3.1.2 The Development of SKB's Plan of Action

SKB took into account the comments in the authorities' review and the Government's decision concerning the need for a more detailed plan of action. SKB therefore commissioned a revision and clarification of its own internal plan and the preparation of a version of the plan that could comply with the authorities' request for a strategy document or plan of action. Furthermore, in 2003, SKB's Board made a decision concerning the revision of the timetable for the disposal of spent nuclear fuel.

On a number of occasions, SKB's work on the plan of action was also reported within the framework of the consultation on safety assessment and system analysis with authorities and municipalities. On these occasions, the authorities also had the opportunity to submit their viewpoints on SKB's work on the plan of action. However, afterwards, SKI can note that even if the overviews presented by SKB on these occasions seemed to be promising, the outcome would have probably benefited from SKB presenting a more detailed account at an earlier stage than is now the case.

3.1.3 SKI's Evaluation

SKI's evaluation largely follows the structure of SKB's plan of action as presented in Appendix A of RD&D Programme 2004. This structure has been chosen to make it easier for the reader to follow since it allows for detailed comments to be made on different sections in a traceable sequence.

However, this structure entails a difficulty with respect to the reporting of the comments by the reviewing bodies. Only in exceptional cases do the comments by reviewing bodies contain detailed comments on this particular section and the most important comments are of a general nature, focusing on the programme for spent nuclear fuel. Therefore, SKI has chosen to present all of the comments by the reviewing bodies in the next section, 3.2, apart from one or two exceptions.

In the main body of RD&D Programme 2004, there is a chapter (Chapter 2, "Plan of Action") which summarizes SKB's plan of action. However, SKI's comments below are based on the detailed plan in Appendix A. SKI has no particular comments to make on Chapter 2, apart from to state that it provides an adequately comprehensive description of the plan of action, in general, as it is now presented in the appendix.

SKB's points of departure for the plan of action are presented in Section A1.2 of the appendix to RD&D Programme 2004. For editorial purposes, comments on this section are presented under the following heading.

3.2 Programme for Spent Nuclear Fuel

SKB's Report

In its points of departure for the plan of action (A1.2), SKB states that the current nuclear waste programme is the result of almost 30 years of work. SKB briefly

describes the progress made during this time, for example, with respect to the realization of parts of a system for nuclear waste disposal, the handling of the financing issue, the development of a body of regulations and the political support for the activity. SKB considers that these advances that have been made should be further driven forward in a programme with an adequate level of intensity to prevent them from being annhilated through a break in the continuity of the process and a squandering of knowledge capital. Furthermore, SKB states that the stepwise process with insight and participation from concerned municipalities has been proven to lead forward, even if progress is at a slower pace than originally anticipated. In summary, SKB considers that a guiding principle for the remainder of the work must be based on a balance between, on the one hand, legitimate requirements on sufficient time for decision-making processes and, on the other hand, requirements on the continuity and intensity in the programme that must exist in order for the programme to be implemented with a satisfactory outcome within a reasonable period of time. SKB also considers that this requires a similar approach on the part of the other actors involved.

SKB starts off by presenting a brief description of its programme in two time horizons: the period up to 2017 and the period up to 2008. The main points are the licence applications for the siting of the encapsulation plant and the repository, which are each reported with its timetable. According to SKB, the preparation of supporting documents for licence applications for these facilities is an extensive and prioritized activity. SKB emphasizes the importance of quality of the material, the authorities' resources and the political will to make a decision as the factors governing the time that the licensing processes will take. Schematic diagrams of SKB's overall long-term plan with decision-making processes and EIAs, taken from Appendix A of RD&D Programme 2004, are reproduced in Figures 1 and 2. Figure 2 also shows a very brief summary of the material required for the different applications. Of particular interest is the fact that, according to the plan of action in RD&D Programme 2004, the decision deadline for the encapsulation plant is expected to occur before that for the repository but only after the application for the repository is submitted. SKB also states that its view is that the authorities and the Government can make a decision on SKB's choice of method in connection with the licensing of the encapsulation plant, namely, during 2009, according to SKB's plan. (However, these assumptions have changed since RD&D Programme was submitted, see Section 3.5).

SKB also briefly describes the decision-making process with respect to consultations and the EIS in Section A.2.2. (in this case, the assumptions also changed in spring 2005).

The next section of SKB's plan of action (A.2.3 System Design) mainly deals with system analysis, the principles for long-term safety and the programme for the alternative involving horizontal deposition (KBS-3H). SKB describes the system analysis as a way of systematically developing and evaluating different alternatives for the design of the repository, for example, with respect to safety, environment and feasibility. According to this account, the focus of SKB's interest is on the choice of optimum alternatives for repository siting, the encapsulation plant, the total quantity of fuel, deposition method, retrieval and time for closure. SKB also states that revised system analyses will be reported, namely "Sysinka", prior to the application for the encapsulation plant, and "Sysdjup", prior to the application for the repository. The

supporting documents for the system analyses will comprise system descriptions, facility descriptions, the preliminary safety reports (PSRs) for each facility, alternative studies and safety assessments. In a separate section (A.2.3.3), SKB provides a short description of the basic safety principles (its safety philosophy) for long-term repository safety. The section on system design concludes with a relatively detailed description of the horizontal deposition alternative (A2.3.4).

SSI's Comments

According to SSI, SKB's plan of action provides a good overview of SKB's timetables for the different parts of the nuclear waste programme and gives the impression of a systematic approach. This overview should be updated and reported as a natural part of future RD&D programmes.

However, SSI finds that a description of critical development issues that need to be resolved prior to the successive stages of SKB's programme is lacking. Furthermore, according to SSI, the main report does not supplement the plan of action in this respect. In SSI's view, SKB should therefore, in a clearer way, be able to justify its R&D work on the basis of an analysis of the material that is needed for evaluating safety in connection with future decision-making. The objectives of the development work on safety assessment methods, model development and the work on alternative designs also need to be clarified in this way. In SSI's view, a clarification of SKB's plan of action in these respects would give the authorities a better possibility to provide timely comments on SKB's work and, thereby, reduce the risk of issues that are difficult to judge causing problems in connection with future licensing.

SSI maintains that it is necessary to carry out an analysis of the need for different types of long-term experiments on the basis of a significantly longer time horizon. This applies to the large-scale experiment, Prototype Repository, as well as the Backfill and Plug Test. SKB does not specify which criteria must be fulfilled for SKB to consider that the programme can continue. Of the large-scale experiments, for example, only one section of the Prototype Repository will continue to be operated after 2008 and SSI raises the question of whether it would not be more optimum to allow the experiments to continue until applications to start operation of the repository are submitted. SSI also finds that an account is missing of the demonstration work on deposition and backfilling that SKB is planning before initial operation is started in 2017 with canisters containing spent nuclear fuel.

In addition to the possibility of conducting further long-term experiments at Äspö, SSI considers that SKB should investigate how the operating time (up to closure) could be utilized to reinforce knowledge of barrier performance. In SSI's opinion, SKB should show in its plan of action that it has considered the advantages and disadvantages of different forms of measurements or experiments during the operation period. SSI also considers that SKB should clarify the objectives of the evaluation that is expected to occur after the initial operation before full-scale (regular) operation is started in 2023.

SSI comments on SKB's system analysis in a separate section in its review statement. SSI points out that SKB, in RD&D Programme 2004, only provides a very general description of future reporting of the safety analysis. As a background to its opinion, SSI refers to its regulations (SSI FS 1998:1) which contain requirements that an

optimization of radiation protection should occur in connection with the final management of nuclear waste and spent nuclear fuel. This means that SKB needs to describe how different alternatives have been taken into account for siting, design and operation with respect to the protective capability of the repository.

In SSI's view, the account of the system analysis provided in RD&D Programme 2004 is far too brief for it to be possible to distinguish, in detail, SKB's aims with respect to the future system analyses. SSI particularly points out the importance of the links between different system parts and how the operation of the different facilities is to be designed in order to ensure that the initial state of the repository will be as desired.

In summary, SSI considers that SKB should develop its plan of action, and its description, in future RD&D programmes, with a better justification of planned RD&D work on the basis of an analysis of critical remaining research and development issues. Examples of issues that, in SSI's view, should be highlighted in this way include, acceptance criteria for the canister, long-term experiments on buffer and backfill performance, demonstration of deposition methods, evaluation of the initial operating phase (also with respect to the test of barrier performance) and the need for models for the biosphere, climate and rock mechanics.

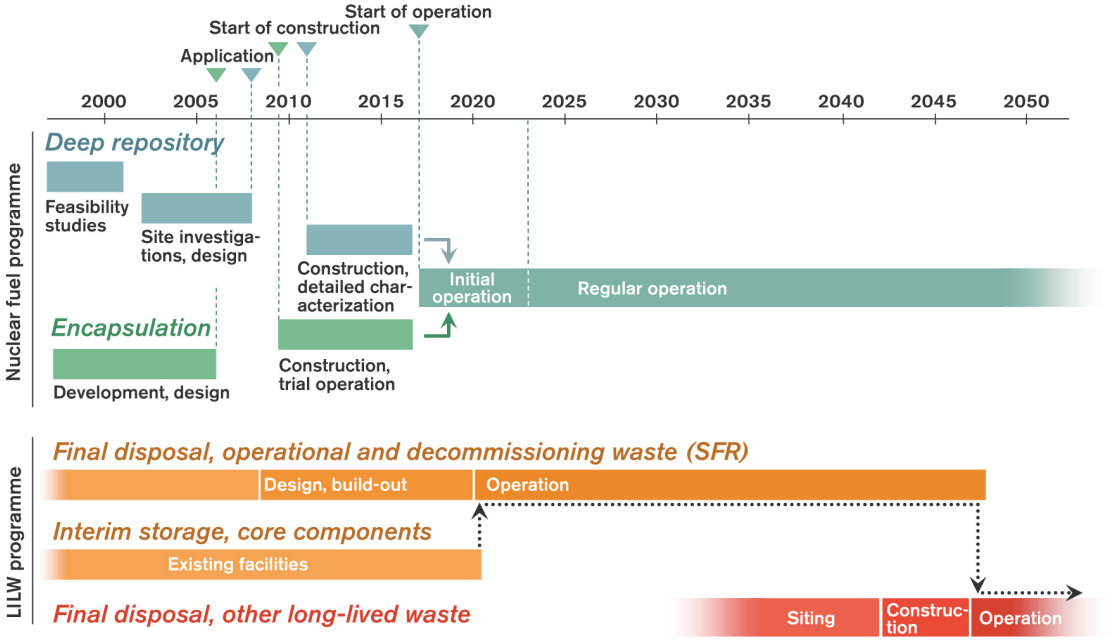

Figure 1. Main features of SKB's long-term plan (from SKB's TR-04-21, p. 362).

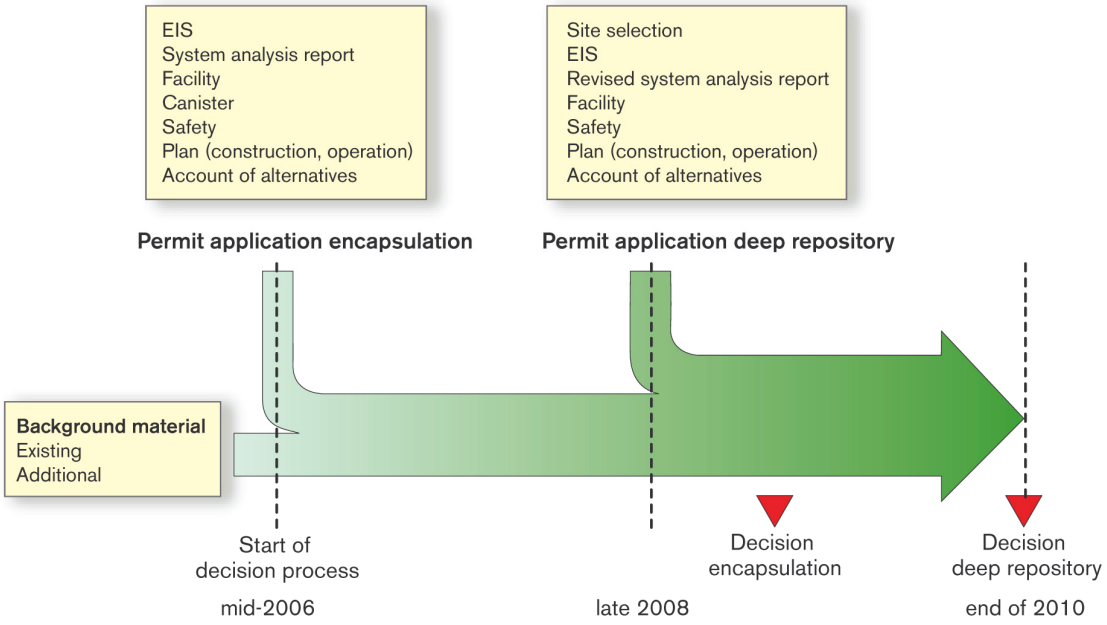

Figure 2. Licence applications and decision-making process for the repository system (from SKB's TR-04-21, p. 366).

Comments by Other Reviewing Bodies

The National Board of Housing, Building and Planning notes that SKB's plan of action does not state why SKB finds it necessary for the licence for an encapsulation plant (INKA) to precede the licence for a repository. According to verbal information provided by SKB to the Board, construction-related reasons (early construction start), mean that the licensing of INKA first is important since both of the facilities must be ready at the same time. The Board considers that it should be clarified when the decision should be made concerning the choice of method. In the Board's view, if a licensing decision on INKA needs to be made before the decision on the repository, the issue of choice of method should also be decided at the same time as the decision on INKA in order to economize resources and time.

The Swedish Anti-Nuclear Movement notes that SKB continues to assume in its planning that the licensing of INKA and the repository will occur at different points in time. The Movement would like to emphasize the importance of both facilities being considered as an integrated system and being treated in a single context in terms of safety assessment and environmental impact, as well as, naturally, the licensing action as a whole. The Movement also notes that SKB has not been able to present any justification that is well-support by fact for the licensing of the two facilities at different times.

The Local Safety Committee at the Nuclear Facilities at Forsmark considers that SKB's plan of action shows, in a pedagogical manner, that SKB intends to carry through the project.

The County Administration of Uppsala emphasizes the regulations of Chapter 16 § 7 of the Environmental Code which state that "in connection with the consideration of cases and matters pursuant to this Code, attention shall be paid to other activities or special structures that are likely to be necessary for efficient operations." According to the Administration, it is therefore suitable with respect to these regulations that permissibility/licensing under the Environmental Code for an encapsulation plant and for a geological repository for spent nuclear fuel should be conducted in a single context.

The Nuclear Waste Secretariat of the Environmental NGOs (MILKAS) considers that the application process for INKA and for the repository must be co-ordinated. Furthermore, in MILKAS's opinion, there is no logic in separating the two since an encapsulation plant is meaningless unless the KBS-3 method is approved and vice versa. MILKAS also considers that the application for the handling of low and intermediate-level waste should also be incorporated into the same process for the EIS since, otherwise, this process will be postponed unreasonably far into the future. The dividing up of the consultations into separate consultations for different groups creates additional confusion and renders any essentially serious consideration concerning alternative sites, methods and strategies difficult.

The Swedish NGO Office for Nuclear Waste Review (MKG) notes that SKB intends to handle the repository for nuclear waste and INKA as separate licensing actions under the law. This will lead to unreasonable consequences in terms of the timetable, co-ordination and inherent impacts, for example, by leading to irreversible decisions being made regarding disposal methods that have not yet been approved. In MKG's opinion, the licence to construct an encapsulation plant cannot be granted until the choice of method has been evaluated in a decision to construct a repository for nuclear waste.

Stockholm University (Pereira) considers that the deadlines of 2006 and 2008 for the application for the encapsulation plant and for siting and permission to construct a repository, respectively, are too close in time to be realistic.

Oskarshamn Municipality considers that separating the applications for the encapsulation plant and the repository and that the licensing of these facilities on two separate occasions with an interval of two years between them has certain advantages since it allows all stakeholders to conduct evaluations and make the necessary decisions over a longer period of time than if both facilities had to be evaluated and licensed at the same time. In the case of co-ordinated licensing, the Municipality sees a risk that the encapsulation plant could be given a lower priority, less resources and end up overshadowed by the repository.

However, the Municipality considers that it is important to discuss how the links between the two facilities should be handled and how the different alternatives should be reported and evaluated, in accordance with both the Act on Nuclear Activities and the Environmental Code. When the application has formally been submitted, there is reason for SKB, the authorities, the municipalities, the Environmental Court and the Government, within the formal process, to consult on how the licensing and decision-making process, as a whole, can be designed. Thus, it is the Municipality's opinion that

the consultations need to continue and be extended even after the formal consultation process under the Environmental Act is completed.

In summary, Oskarshamn Municipality sees advantages in separating the applications so that the licensing process can start with a part of the system that is manageable.

Östhammar Municipality considers that, from a municipal time perspective, the time frames of RD&D Programme 2004 are very tight. SKB should anticipate that the planned programme could be delayed for many different reasons, some of which are described in the reviewing body's comments to SKI.

Östhammar Municipality notes that problems could arise if SKB first applies for a licence for the encapsulation plant and, in connection with this application, describes its choice of disposal method. The KBS-3 method will thus be used as a basis for the application, whereas SKB's intention is to raise that issue in future RD&D programmes, prior to an application for permission to construct the repository. The intention of giving the authorities a longer time to evaluate material upon which an application for a licence to construct the repository will be based is good. However, it can be expected that the supporting material will be changed and improved up to the time that an application is submitted in 2008. The question is whether the authorities can allocate resources to start reviewing parts of the application that may contain improvements when an application is submitted in 2008.

SKI's Evaluation

To begin with, SKI would like to make a few general comments on SKB's design of its plan of action. Like SSI and the Local Safety Committees at the Nuclear Facilities as Forsmark, SKI considers that the plan of action is a good attempt at a systematic description of SKB's timetables and how different parts of SKB's programme interact with and are dependent on each other. In SKI's view, it is therefore important that SKB should maintain the plan of action as a living document that is continuously updated.

On the other hand, it is difficult to see how the current detailed structure of the plan of action will be able to fulfil in an effective manner the purposes described in the authorities' review statement on RD&D Programme 2001. Furthermore, SKB does not seem to have clearly defined these purposes other than with respect to timetables and temporal links to different activities. In SKI's view, one possible explanation of this is that it has been difficult for SKB to separate the role of the plan of action in relation to the RD&D programme. This view is also supported by SSI's review of the deficient links between R&D and the plan of action and by the comments concerning the design of different parts of the plan presented below. Furthermore, SKI has found that the different parts of the plan do not have a uniform structure, which would have facilitated traceability and comprehensibility. Clearly stated purposes and instructions for readers or a description of the structure of the introduction would have been beneficial in this respect.

In its introduction, SKB states the need for continuity in the development work and in the licensing processes and it would seem that, with this statement, SKB wishes to justify the constrained timetable. SKI acknowledges that this attitude is legitimate from an industrial perspective and also with respect to the continuity of the regulatory work.

However, SKB also states that it is important to achieve balance between continuity and the time allocated to achieve a good decision-making process and to prepare adequate background material. SKI agrees with this view and would like to emphasize that this balance must not be tipped in favour of the purely industrial perspective. A constrained timetable, especially for licensing, will lead to a decrease in trust in the decision-making process in society. This is the case even if the timetable is subsequently delayed so that a reasonable amount of time is created to conduct additional work and other activities. Furthermore, such a procedure would not make the most efficient use of the authorities' limited resources.

In SKI's opinion, SKB has presented a summary of its programme for spent nuclear fuel that is on a suitable level (compared with Chapter 2). However, SKI considers that this section of the plan should preferably have been structured as an introduction to sections A3-A4.

In SKI's view, the description of the supporting documents for the applications (provided in connection with Figure 3 in the appendix) should have focused more on documents that are included in the basis for decision-making and their content.

SKI shares the view of a large number of reviewing bodies that SKB's timetable seems to be unrealistic with respect to the short period of time between the submission of the applications for an encapsulation plant and for a repository. Furthermore, in SKI's opinion, separate decisions for the two facilities are not reasonable bearing in mind the need for a simultaneous licensing of both the choice of method and the entire disposal system in a single context. Moreover, in SKI's and SSI's view, it is not possible to make a final decision on the choice of method separately from the siting of the repository. This has also been pointed out by the authorities in connection with previous RD&D programme reviews and SKI is supported in this view by many of the reviewing bodies. At the same time, SKI agrees with Oskarshamn Municipality that, there may be advantages of a separate licensing of the encapsulation plant, for example, that the plant is given adequate priority in relation to the repository. However, the premises for the review of this issue changed in spring 2005 when SKB proposed changes in its plan of action with respect to the link between the applications for the encapsulation plant and the repository. For a further discussion, see Section 3.6.

In SKI's opinion, in its plan of action, SKB should have reported issues relating to consultations and EIS in greater detail than it has in Section A2.2. Above all, this applies to the content of background reports and the actual content of an EIS. Furthermore, SKB should plan in good time for the structure and content of a final EIS for the encapsulation plant and Clab, see also Sections 3.3 and 3.5. (See Chapter 2 of this review report for additional information).

In SKI's view, the account of the system analysis etc. provided in Section A2.3 is inadequate and the structure is confusing. The design premises, system analysis, principles for disposal and a disproportionately long description of the KBS-3H alternative have been assembled under a single heading without any explicitly visible context. The justification for the system design hardly belongs to a plan of action of this kind. Instead it would be more suitable for it to be included in a basic document for an application or as an introduction to an RD&D programme or a safety assessment. In

support of the system design, an account of the method choice and a system analysis supporting the choices made must be provided separately at a later stage. SKI agrees with SSI that this is inadequately reported, but at the same time, SKI would like to express a reminder about the consultation which is currently in progress between SKB and the authorities on this issue.

The section on system design includes a description of the development plan for the alternative with horizontal deposition, KBS-3H. In SKI's view, such an account is, in itself valuable. However, it would appear to be more suitable for inclusion in the RD&D programme itself than in the plan of action. In any case, the issue of the breadth of variation in an application for a repository is being addressed here. SKB should thoroughly consider the content of an application from this perspective and, in time, gain acceptance for its plans in these respects from the authorities and other actors in the decision-making process. SKB should therefore, in good time before an application is submitted, consult on the scope, delimitations and suitable decision procedures in the event of requests for future changes in the system design.

3.3 Encapsulation

SKB's Report

In this part of its plan of action, SKB presents both a general overview and a detailed description of its programme for canister development. SKB states that canister sealing and quality control of the finished canisters by non-destructive testing is important. This also includes quantifying the risk, through testing, that canisters that do not comply with the acceptance criteria might pass the inspection system. The two time horizons of 2017 and 2008 are also used here to describe the sub-goals in technology development that are to be attained at different times in a decision-making process.

The design and planning of the encapsulation plant is described very briefly in Section A3.2.

A more detailed description of method development for encapsulation and canister fabrication is provided in Section A3.3. In Section A3.4, on safety assessment, the links are described between canister development and the assessment of long-term repository safety (SR-Can), which is to be submitted as a basis for an application for the encapsulation plant. The qualification of fabrication and inspection methods is described very briefly in a special section, A3.5. (However, the links to the goals within this programme and different application times are presented more clearly in the overview in A3.1).

SKI's Evaluation

In SKI's view, the section, "Encapsulation" (A3), of SKB's plan of action, in itself provides a good view of timetables for the encapsulation plant and canister development. However, SKI considers that far too little information is provided about the content of the documentation that must be prepared at different times. SKI's opinion thereby agrees with SSI's. Furthermore, in SKI's opinion, SKB has not divided up, in a manner that is sufficiently clear, the accounts of the plans for the encapsulation process,

the accounts of canister development and of preparations for an application for permission to construct the encapsulation plant. These issues must naturally be seen in a single context. However, as a result of SKB's manner of dividing them up, individual issues are difficult to trace at different levels.

In SKI's view, the section, "Facility Design" (A3.2), of SKB's plan of action is a typical example of the difficulties that SKB has had in logically structuring its plan. The section contains very little information and does not appear to belong to this context. Comments are provided on canister fabrication both in this section and in section A3.3.

In SKI's opinion, the section on canister development seems to be a superfluous repetition of the information already provided in the RD&D Programme. A closer link to the timetable presented in Figure 8 of SKB's plan and comments on the timetable would have been warranted.

Furthermore, the sections, "Safety Assessment" (A3.4) and "Qualification" (A3.4) do not fit into a logical structure. Instead, they should have been subordinated to the section on canister development in connection to a timetable. SKI would also like to remind SKB of the need for a report where design premises/performance requirements for the canister are derived and where it is shown how the canister is fabricated to comply with the performance requirements (canister report). However, since the publication of RD&D programme 2004, SKB has announced that such a report is being prepared and it is mentioned in SKB's revised plan of action (see 3.5).

As far as SKI can see, SKB has not discussed the Preliminary Safety Report for the encapsulation plant in the text. This issue only exists as an item in the timetable presented in Figure 7 and it is completely missing from the plan in Figure 8. This is very surprising since the Preliminary Safety Report (PSR) is one of the most important documents in an application for the encapsulation plant. SKI would also like to remind SKB that nowadays a PSR also needs to be subjected to independent safety review and linked to supporting documents that describe how a licensee has complied with the requirements in accordance with SKI's regulations from the time that the licence was obtained. The construction of a nuclear facility is now considered to be a nuclear activity according to SKI's regulations (SKI FS 2004:1). In addition, SKI considers that SKB should bear in mind that, if the encapsulation plant is sited next to Clab, both of the facilities can and should be considered to be a single facility. Such an integration of the two activities should take into consideration, in a suitable manner, the experience gained from the operation of Clab and from the construction of Clab stage 2.

3.4 Disposal

SKB's Report

Chapter A4, "Deep Disposal", starts off with a number of brief reviews of what is to be achieved in terms of technology development and the preparation of a basis for decision making in different time horizons. The plan is illustrated by detailed timetables for different activities to be carried out during the periods of 2003-2023 and 2003-2008.

In Section A4.2, SKB presents an account of the status and remaining work to be conducted for the site investigations in Forsmark and Oskarshamn. SKB also presents, in tabular form, a number of remaining key issues for each site investigation.

The planning and design of the repository is described in relative detail in a special section (A4.3) with tables of the sub-goals and decisions that should be made at different times. A very compact summary of the programme for technology development (cf Chapter 10 of RD&D Programme 2004) is presented in the following section (A4.4), including a timetable and a detailed table (Table 5) which shows the link between different objectives and the applications that are to be submitted. The remaining section of this chapter provides a brief description of the status and plans for "Safety Assessment" (A4.5) and site selection (A4.6). SKB states that the purpose of the safety assessment (long-term safety) in connection with an application for the repository (SR-Site) is to show that disposal at the selected site complies with regulatory requirements. SKB also states that its intention is to perform safety assessments for two sites. A more unambiguous view is presented in the site selection section which, according to SKB, will be based on an EIS for a single site where the selection of the site will also be justified from other perspectives besides long-term safety.

SKI's Evaluation

In SKI's opinion, it is particularly difficult to provide fair comments on SKB's account of the plan for the repository (A.4 "Deep Repository") in a fair manner. On one hand, this section gives a good overview of the plan, from different time perspectives, with a moderate amount of detail and with illustrative timetables for different activities to be conducted until the time that applications are submitted and for the time following this. On the other hand, a section is provided which is of more interest for SKB's internal planning ("Facility Design") as well as descriptions of safety assessment and site investigations which do not easily belong to an actual plan of action. It would have been better if SKB had focused more on the content of different accounts and key reports in connection with the decision-making process. Furthermore, the plan does not give adequate information on the content of the safety assessments to be conducted for both sites, for example, regarding whether any distinction will be made between the selected site and the alternative site.

On the other hand, SKI considers that the section on technology development contains valuable information which is presented in a practical format, both in the form of a timetable and a comprehensive table (Table 5). This can provide a good basis for further consultation between SKB and the authorities. However, SKI agrees with SSI that, in terms of the results from the technology development and large-scale experiments that are to be obtained at different times, the information is inadequate.

3.5 Programme for Low and Intermediate-Level Waste (LILW)

SKB's Report

The main items in SKB's plan for LILW are the future extension of SFR to receive decommissioning waste from the nuclear power plants (to be ready by 2020) as well as

the siting and construction of a special deep repository for other long-lived waste (to be ready by 2045; formerly known as SFL3-5). The plan is based on a reference scenario where the plants are operated for 40 years before decommissioning. In addition to this assumption, the space in the existing SFR will be sufficient for operational waste until 2025.

SKB presents an account of its plans for the interim storage of other long-lived waste in an extended SFR after 2020, pending the completion of the special repository. SKB does not intend to start the siting of this repository until some time in 2025-2030. However, a preliminary safety evaluation is planned for 2011.

(For more details on this programme, see Chapter 11 of this report).

Comments by the Reviewing Bodies

SSI considers that the design of a repository for long-lived low and intermediate level waste should be prioritized in the research programme. SKB should also review the reasons to wait before constructing a repository for long-lived waste until most of the nuclear power plants have been dismantled.

SKI's Evaluation

In SKI's view, the section on low and intermediate-level waste in the plan of action is adequately detailed, bearing in mind the timetables that SKB has now established. However, in SKI's opinion, in the case of the repository for decommissioning waste, it may be justified to review these timetables, especially taking into account the closure of Barsebäck 2. At the same time, SKI recognizes the difficulty, in terms of resources, of being able to handle the application, design and planning and the construction of more than one repository. If the repository for decommissioning waste is scheduled for an earlier date, in relation to SKB's current plan of action, this will mean that the plan will fairly soon have to be improved in order to bring it to the same level as the plan for the programme for spent nuclear fuel.

SKI would also like to remind SKB that both SKI and SSI now require that licensees of nuclear facilities should prepare decommissioning plans. This work may place greater demands on a more detailed plan of action on the part of SKB with respect to the storage and disposal of different types of decommissioning waste.

SKI shares SSI's opinion that the timetable for the repository for long-lived waste needs to be reviewed. For example, if possible, the siting and planning of this repository should, in a better way, take advantage of the resources developed in connection with the repository for spent nuclear fuel.

3.6 SKB's Modified Plan of Action

Background

In SKB's plan of action for RD&D Programme 2004, separate licensing actions under the Act on Nuclear Activities and the Environmental Code were envisaged for the

encapsulation plant and the repository. SKB intended to submit applications for permission in 2006 and in 2008, respectively. According to the plan, the Government's decision on the encapsulation plant would be made in 2009 and, in the case of the repository, at the end of 2010.

In a memorandum from SKB, dated March 18, 2005 (attached to the minutes from the consultation meeting on system analysis and safety assessment in March 2004), SKB proposed changes to the plan, as described above. SKB justified its proposal on the basis of a number of questions and views presented by SKB's consultation partners in different contexts. Issues mentioned by SKB included the following:

- the construction of facilities is assumed in the KBS-3 method. This means that the Government cannot be expected to make separate decisions
- there is a lack of clarity regarding how an ongoing licensing of the encapsulation plant will affect the licensing process for the repository
- there is a lack of clarity regarding whether the authorities' resources will be adequate for review work in accordance with the desired timetable.

SKB's Proposal

In the memorandum, SKB states that it has carried out a new analysis of the structure of the plan of action and has arrived at a new and more developed proposal for the structure of, as follows (directly quoted from the memorandum):

2006 SKB will apply for permission, under the Act on Nuclear Activities, for the encapsulation plant. At the same time, SKB will submit the following documents to SKI. The documents purpose is to show the role of the encapsulation plant in the KBS-3 system: a safety assessment focusing on canister function in the repository (SR-Can), a system analysis focusing on the encapsulation plant's role in the KBS-3 system and a description of the planned canister transportation process.

2008 SKB will apply for permission under the Act on Nuclear Activities for the repository. At the same time, SKB will supplement the above-mentioned application for the encapsulation plant on the basis of the review and consultation statements that are received during the period of 2006-2008 (SKB does not expect any final decision on the encapsulation matter until this supplement is completed). SKB will apply for permission under the Environmental Code for the encapsulation plant and the repository.

2010 The Government will have a chance, on one and the same occasion, to make a decision regarding permission in accordance with the Act on Nuclear Activities and permissibility under the Environmental Code for all parts of the KBS-3 system, namely, for both the encapsulation plant and the repository. Decision-making on a single occasion will also allow for a review of both of SKB's applications to be conducted at the same time.

SSI's Comments

SSI is positive to the new proposal which means that simultaneous decisions can be made for both facilities on the basis of a co-ordinated body of material. However, in SSI's view, there is still uncertainty regarding whether SSI's will have adequate resources to carry out future reviews in accordance with SKB's timetable.

SKI's Evaluation

SKI is also positive to SKB's proposal and, for the same reasons as those presented in SSI's statement. However, SKI would like to remind SKB that there are several additional questions concerning the licensing process for the encapsulation plant which must be clarified before SKB can submit an application under the Act on Nuclear Activities. Examples of such issues include:

- the scope/delimitation of the Preliminary Safety Report (PSR) and the EIS in relation to Clab, in the case where SKB applies for siting permission near to Clab
- the scope and content of the complete EIS for an encapsulation plant, together with Clab as one facility
- the account of the choice of method and alternatives provided on each licensing occasion
- the description of the canister as a common component in both facilities. (The separate canister report mentioned in SKB's memorandum).

3.7 SKI's Overall Evaluation of the Plan of Action

In SKI's view, the plan of action presented by SKB in RD&D Programme 2004 provides a good starting point for a systematic description of SKB's timetables and for how different parts of SKB's programme interact with and are dependent on each other. Therefore, it is important for SKB to maintain and develop its plan of action as a living document. It is important for SKB to define the target groups for the plan of action so that it can be a practical and effective instrument for further consultation between SKB, the authorities and other actors in the future decision-making processes. In SKI's view, SKB should recognize that, in the future, the plan of action, in any case, in the eyes of society and others, will be the document that steers all activities relating to the licensing process for future facilities. The part of SKB's organization that is responsible for the plan of action and for its design should therefore be centrally located in the organization and should be responsible for the co-ordination of all of SKB's activities relating to the construction and operation of the new facilities.

In SKI's opinion, SKB seems to have had some difficulty in clearly defining the purpose of the plan of action, especially in relation to the RD&D programme. SKI also considers that the structure of the plan of action needs to be improved. SKB needs to, in a logical and consistent manner, distinguish between the content of and background material for the plan and to distinguish between the RD&D Programme and the plan of action. The plan should be given a more logical and uniform hierarchical structure which is consistent for different levels of the different sub-programmes.

The most severe criticism of the plan of action in its original form, which both SKI and SSI recognized at an early stage, concerned the link between the applications for the encapsulation plant and the repository. During spring 2005, this issue has been dealt with through SKB submitting a proposal for a modified plan of action within the framework of the safety assessment and system analysis. SKB's proposal means that an application for the encapsulation plant will be submitted separately in 2006, but with a joint licensing together with the licensing of the siting of the repository in 2008. In SKI's view, the main problem is resolved with simultaneous licensing although certain details remain to be worked out concerning the content of the reporting that is to be conducted at different times.

Of the requirements made by the authorities, in their review of RD&D Programme 2001, regarding SKB's plan of action, only the reporting of timetables for different activities in relation to the decision-making process has been conducted in a consistent and adequate manner. In particular, SKI still would like to see an improved and more detailed account of the content of the basis for decision-making which is to be provided at different times. This applies with respect to the research findings, technology development, long-term experiments and acceptance criteria for the barrier system, as well as particularly with respect to the experiments and research that SKB intends to conduct after applications are submitted, on different timescales up to the time of repository closure. SKI considers that these factors should be clearly described, if not quantitatively then qualitatively. The authorities consider that this is necessary to avoid unnecessary requirements regarding supplementary information and ensuing delays in the decision-making process. In SKI's view, analyses of the results that are needed and, thereby, also of the need for research, should be carried out and provide a separate and joint basis for the plan of action as well as the RD&D programme.

SKI would like to particularly mention the following as issues that SKB needs to work with further prior to future versions of the plan of action:

- necessary modifications, taking into account the constrained timetable and links between the applications and reviews that can be expected to lead to delays and other difficulties in the decision-making process. (This issue has now been partly resolved according to Section 3.5)
- the system analysis, its role and content on different decision-making occasions
- an adequate breadth of variation in the application
- a preliminary safety assessment for the encapsulation plant and its link to the existing facilities.

The above criticism of SKB's plan of action is so severe that SKB should, as soon as possible, prepare a new plan. SKI can hardly start to review licence applications for new facilities in the spent nuclear fuel system until a plan of an acceptable standard has been submitted to SKI. This stance is especially justified by the fact that planning and implementation of licensing in a stepwise process lasting many years requires both general and detailed knowledge of the content of the applications and supporting documents.

4 Technology Development

In Sections 4.1-4.4, SKI comments on SKB's work on canister and encapsulation development which is described in Chapters 5-8 of RD&D Programme 2004. Since the RD&D Programme was written, SKB's work has continued and, in certain cases, made considerable progress. This is particularly the case for the work on the qualification programmes and the choice of welding method. SKI has taken these achievements into account to a certain extent in its evaluation. Where material provided after the publication of RD&D Programme 2004 has been taken into account, this is specified for the topic in question.

4.1 Canister Design and Fabrication

4.1.1 Design Premises and Acceptance Criteria

SKB's Report

SKB states that the design premises for the canister are based on the report on the overall design premises (SKB, 2002) and on Werme (1998). Since RD&D Programme 2001, the overall design premises for the deep repository in the KBS-3 system have been compiled. The work on transferring the design premises to database form has also started.

The design premises for the canister will be updated before an application for permission to construct the encapsulation plant is submitted. Since 2002, research has been underway to carry out a probabilistic analysis of canister strength. The final determination of the canister insert dimensions will be based on the findings of this project.

When SKB specifies acceptance criteria for allowable defects, SKB will take, as its starting point, a survey of discontinuities that can occur in the different process stages during canister fabrication (defect descriptions) as well as an account of how these affect the canister's ability to meet the design premises (damage tolerance analysis). The main purpose of the acceptance criteria is to guarantee the functional safety of the canister. At the same time, they must correspond to the fabrication quality and be commensurate with detection and resolution capabilities of the inspection methods.

Furthermore, SKB states that acceptance criteria for an electron beam-welded canister sealed through electron beam welding will be prepared, on the basis of the lifetime estimate of the necessary canister thickness (Ahonen et al., 2001), of studies that show that surface defects do not increase copper sensitivity to local corrosion and of fracture toughness measurements that show that there is no risk for fracture propagation. Otherwise, SKB has set a radial extension of 3.5 cm as a preliminary criterion for the highest permissible discontinuity, in both the sealing welds and the copper shell.

Comments by the Reviewing Bodies

The Waste Network Association notes that SKB, as a preliminary criterion, states that the minimum permissible copper cover is 1.5 cm for a copper thickness of five centimeters. The Waste Network Association criticizes SKB's account of the thickness of the copper shell as diffuse and imprecise. In the view of the Association, a layman would take the account to mean that the thickness of the shell can vary between 1.5 cm and 5 cm. Furthermore, the Association doubts that 1.5 cm will provide adequate resistance against corrosion and the bulging of the material that can be caused by gas pressure.

The Safety Group in Oskarshamn Municipality considers that the account of acceptance criteria for the copper canister is difficult to grasp. Moreover, the Safety Group states that the Municipality has long requested an explanation of the assumption that 0.1 % of the canisters in the safety assessment are postulated to have early defects in a repository and expresses its satisfaction that SKB now seems to have started a programme to provide answers to this question.

SSI states that, in the supporting documentation for future licence applications, SKB needs to report established acceptance criteria and to explain how these link to the methods for non-destructive testing so as to be integrated into the safety assessment. The documentation should be prepared on the basis of an identification of the different types of defects that can occur.

Stockholm University (Pereira) notes that acceptance criteria for a canister sealed with electron beam welding are to be prepared, but that it is unclear what is the case for Friction Stir Welding and whether this may be due to the fact that fracture toughness data in a weld made by Friction Stir Welding are still lacking. In the opinion of the University, it must be possible to replace the welding method if a refined non-destructive testing method shows that one of the welding methods is significantly superior to another.

SKI's Evaluation

SKI has previously (in its review of RD&D Programme 2001 etc.) emphasized the importance of design premises and acceptance criteria being prepared and verified in the safety assessment (with consequence analyses). The design premises should also steer many other activities. In SKI's opinion, RD&D Programme 2004 is still lacking a clear and logical link between the detailed design requirements for the canister and the requirements for the repository. Compiling design premises into a database is naturally a step in this direction. After writing RD&D Programme 2004, SKB initiated Dokap, a project aiming at compiling documentation on the canister. SKI considers this to be a commendable step in compiling the overall account that is needed for the application.

In SKI's view, the results from the probabilistic analysis of canister strength are valuable for determining and justifying the dimensions of the insert which have to be shown to be adequate to withstand the loads arising in the repository. When calculating the canister strength, the design basis loads must be clearly specified. The design basis should also take into account the temperature increase during the initial period and,

therefore, any temperature dependency of the properties of the materials should be included.

Like SSI, SKI would like to stress that acceptance criteria must be based on and originate from the consequences that a certain defect can have for canister integrity and repository performance. Limitations in the detection capabilities of inspection methods or fabrication quality must not be allowed to determine the acceptance criteria.

In SKI's opinion, the acceptance criteria for the sealing weld must be reported for the sealing weld reference method that is selected (now being determined as Friction Stir Welding, FSW). Stockholm University (Pereira) has noted that RD&D Programme 2004 states that acceptance criteria are to be prepared for electron beam welds but that it is unclear what will be done in the case of Friction Stir Welding.

SKI considers that, in order to show that acceptance criteria for the largest allowable defects in the canister material (in fabricated parts as well as in welds) are adequate, it is not sufficient to show the consequences of large defects. Instead, the sensitivity must also be demonstrated through the analysis of the impact of small (even several small) defects.

In SKI's opinion, the preliminary acceptance criterion that the smallest permissible copper cover is 1.5 cm (with a copper thickness of 5 cm) was formulated in an unclear manner as several reviewing bodies have also pointed out. A clearer definition is needed, for example, other dimensions (length andwidth) of the defects must be included.

All aspects of the question of remaining ligaments must be examined. Requirements on what the exterior of the canister should look like in connection with deposition may be determined by other processes besides corrosion. When determining the largest permissible defect (or, expressed in another manner, for example, as the smallest permissible copper cover), the possibility must be taken into account of tensile stresses occurring from loading or subsequent load redistributions, which could cause a defect to open up.

In connection with SKI and SSI's review of SKB's interim report for SR-Can (SKI, 2005), the authorities stated that SKB should justify its assumption (that only 1 canister in 1,000 has a copper thickness of less than 15 mm) on the basis of an unbiased discussion of possible defects. Furthermore, in the view of the authorities, the justification of SKB's account of the thickness of the remaining ligament as having a triangular distribution is inadequate.

4.1.2 Canister Material

SKB's Report

The canister insert is the pressure-bearing component and it must meet the strength requirements that this entails. The insert is made of cast iron. Comprehensive materials testing has been conducted on a number of cast iron inserts, both with cast-on test bars

and test bars made from the inserts themselves. SKB has observed a relatively large variation in materials properties in several individual inserts.

It will not be possible to completely avoid some presence of non-nodular graphite and casting flaws such as minor porosities, slag particles and individual large casting flaws in such a large cast piece as a canister insert. In individual tensile test bars taken from different locations in inserts, microscopic defects will also result in relatively low values of ductility in particular. This will result in some variation in the data obtained. However, results from the probabilistic materials strength calculations and compression tests in an isostatic press indicate that the inserts, in spite of this, have a strength that meets the design requirements with a good margin. Further work will focus on establishing the necessary materials requirements to ensure the strength of the inserts.

SKB has compiled a specification for the copper material whereby the material must meet the requirements in accordance with the EN 1976:1988 standard for Cu-OF1, although with several additional requirements that the grain size in forged lids and bottoms and in tubes must be less than 360 µm. In the justification for these additional requirements, SKB states that a large or uneven grain size is unfavourable for the properties of the material and also entails difficulties in connection with ultrasound testing. The permissible grain size of the copper shell has therefore been set at a maximum of 360 µm (average grain size according to EN ISO 2624:1995).

In its account of the selection of corrosion protecting material, SKB states that a pure oxygen-free copper is to be used. SKB states that the additional requirement of a maximum oxygen concentration compared with the standard derives from the requirement that it must be possible to conduct Electron Beam Welding on the material.

Comments by the Reviewing Bodies

In SSI's opinion, the materials composition of the canister is of importance for both the canister's corrosion properties as well as its mechanical properties. Bearing in mind the possibility that the area around the weld of the canister can have a different structure and composition than the original, SSI considers that it may be necessary to conduct additional investigations.

SKI's Evaluation

SKI agrees with SKB that a homogeneous microstructure and uniform graphite throughout cannot be achieved with such a large cast piece as the insert. With the expected variations in microstructure and defects, the objective must be to obtain the required properties, in this case, mechanical properties. Therefore, SKI considers SKB's focus and programme to be suitable.

SKI agrees that a large and uneven copper grain size will lead to poor materials properties. Requirements on grain size are thus completely natural and in line with SKI's opinion. On the other hand, SKI considers that a comprehensive account is lacking which justifies why an average grain size of 360 µ is what is necessary in order to ensure that the material has properties that are completely satisfactory. Furthermore, SKI considers that an account is lacking of the requirements that Friction Stir Welding makes with respect to oxygen concentrations in copper.

4.1.3 Fabrication and Fabrication Inspection

SKB's Report

SKB has continued its work on developing the methods for the fabrication of the different canister components. The results have been compiled in a special report (Andersson et al., 2004). Among the work conducted on canister insert development, computer simulation of the casting processes and probabilistic analysis of canister strength can be specifically mentioned. Important stages in work on copper tubes, lids and bottoms include the optimization of tools, process parameters, inspection methods and technical specifications.

Methodology and equipment for non-destructive testing with ultrasound as an inspection method is being developed. In addition to the detection of discontinuities in the cast material, the possibility of investigating the nodularity of the cast iron and the grain size of the copper will be studied.

Development of laser technology for dimension measurement of copper tubes will continue.

SKB has surveyed methods used by manufacturers to test the canister components and new knowledge has been compiled on transmission testing of the nodular iron inserts.

Preliminary testing procedures will be determined in 2005. As a part of this work, suitable reference bodies will be developed.

Comments by the Reviewing Bodies

The Safety Group at Oskarshamn Municipality points out that SKB's timetable for testing methods for fabrication and quality control was previously questioned by both the authorities and by the Municipality. In the view of the Safety Group, RD&D Programme 2004 gives the impression that much work remains to be done by SKB before canister development is completed.

In SSI's opinion, SKB has not devoted sufficient attention to how the bottom weld will be inspected.

SKI's Evaluation

In its evaluation of RD&D Programme 2001, SKI stated that SKB should, to a greater extent, verify the mechanical properties of the inserts by investigating fabricated inserts in greater detail and by using simulation codes in its development work. SKI is satisfied to see that SKB has implemented this approach in its development programme.

In SKI's opinion, the focus of the account of SKB's work on fabrication and the development of inspection methods is good. However, SKI considers that a comprehensive programme for all canister parts is lacking. The programme needs to include fabrication of a sufficiently large number of parts and investigations using both destructive and non-destructive testing methods. SKI's opinion, and the opinion of

Oskarshamn Municipality, is that there is a danger that there will not be enough time for SKB to accomplish this work.

4.1.4 Canister Factory

SKB's Report

SKB is planning to construct a canister factory, where canister components from different sub-contractors will be finished-machined, inspected and assembled into finished empty canisters which will be transported to the encapsulation plant.

In RD&D Programme 2004, SKB states that the following aspects, among others, will be taken into account in the design of the canister factory:

- the experience from trial fabrication
- the choice of welding method
- the establishment of acceptance criteria and their impact on the requirements on testing methods.

A technical description of the canister factor will be attached to the application for an encapsulation plant. However, the siting work for the canister factory is not expected to be completed when an application is submitted for the deep repository.

Comments by the Reviewing Bodies

In the view of Oskarshamn Municipality, the fabrication of copper canisters, inserts, lids etc. is part of the system and a siting of these activities should be included in the planning and consultation for the Environmental Impact Statement.

SKI's Evaluation

In SKI's opinion, SKB's focus in its work on the canister factory is completely reasonable. However, SKI would like to reiterate the comments made in its review of RD&D Programme 2001, with reference to the review conducted by SKI on SKB's planned canister fabrication (Lundin et al., 2001). One of the comments presented was that SKB should review the allocation of tasks to be conducted by sub-contractors and tasks to be conducted at the canister factory, with the aim of ensuring canister quality.

SKI considers that an account is lacking of how the empty canisters will be transported from the canister factory to the encapsulation plant and the possible need for special transportation devices, vehicles etc.

SKI would also like to point out that there is a possibility that the canister factory can be subjected to IAEA inspection since the product that will be fabricated, canisters/containers for the disposal of irradiated fuel, is covered by the "Additional Protocol". This means that the production capacity and actual production will be reported via SKI to the IAEA on an annual basis. The facility may also be inspected by the IAEA.

4.2 Canister Sealing

SKB's Description

In RD&D Programme 2004, SKB states that two different methods are being considered for canister sealing, Friction Stir Welding (FSW) and Electron Beam Welding (EBW). SKB is investigating these methods in parallel. Furthermore, SKB states that it intends to choose one welding method as a reference method in spring 2005. SKB has followed its plan and made its choice in May 2005, which means that FSW is the reference method for the sealing weld.

When SKB is ready to submit an application for permission to construct the encapsulation plant, SKB should have chosen methods for sealing and testing. The reason for this is that the methods affect the design of the encapsulation plant. At this time, a programme for the qualification of the methods should also exist. The overall milestones for the work on sealing technology and non-destructive testing are to:

- verify the welding process, namely, to identify the most important process parameters and within which limits they can be allowed to vary
- demonstrate the welding process
- determine the reliability of the non-destructive testing
- choose the reference method for canister welding
- obtain data for the safety assessment, SR-Can.

4.2.1 Electron Beam Welding (EBW)

SKB's Report

SKB is conducting parallel work on developing equipment (a new type of cathode, electron beam oscillation, improved vacuum level in the welding chamber) and the actual welding process itself (welding speeds, oscillation etc.). The work procedure has resulted in problems relating to availability when untested solutions have been implemented in the system.

The welding process has been developed through trial welding, where full-scale lids are joined to shortened cylinders. An important part of the development work is to determine how often discontinuities occur in the welds and under what conditions they are formed. The aim is to design the welding process so as to minimize the risk of defects occurring in the welds.

In RD&D Programme 2004, SKB states that it is now possible to obtain welds of very high quality with a homogeneous weld metal and a good weld surface. The occasional flaws that occur are mainly due to machine-related faults.

SKI's Evaluation

SKI notes that SKB has made considerable progress and improvement, but that SKB has still not demonstrated that the reliability for EBW as a possible welding method for the sealing weld is satisfactory.

In SKI's opinion, the programme for further development work is too briefly described in RD&D Programme 2004 to enable an evaluation to be made of whether the work is adequate to develop EBW into a usable method.

4.2.2 Friction Stir Welding (FSW)

SKB's Report

SKB has conducted an intensive programme to develop the welding tool, the material and the design of the probe as well as the material in the shoulder. Further work primarily concerns the material in the probe and its geometry. SKB has transferred the technology to the Canister Laboratory by purchasing and taking a new welding machine into operation.

Improvements in the monitoring and inspection of the welding process are continuing. SKB has also developed a solution for weld termination by "parking" the exit hole in the copper material above the joint line and then machining away this material.

An important milestone in encapsulation technology has been attained through the fabrication and closure of a full-scale canister using FSW in accordance with a quality plan. The components have complied with SKB's existing quality requirements. No significant discontinuities have been found in the lid and bottom welds.

SKB summarizes the experience by stating that the FSW process is robust and stable. However, it has not been completely developed with respect to fully automating the process and, thereby, eliminating the human factor. An important phase of the continued programme is to optimize the weld parameters and establish parameter tolerances.

Materials evaluation concerning both non-destructive and destructive testing will be carried out in order to evaluate the integrity of the lids welded using FSW. The results from metallurgical investigations are also to be compared with the results from the non-destructive technology development in order to obtain defect descriptions.

Comments by the Reviewing Bodies

In the opinion of Stockholm University (Pereira), SKB should carry out a mass-spectroscopy study in order to shed light on the quantity of impurities that will come from the weld crown and its possible impact on the quality of the copper.

SKI's Evaluation

Since RD&D Programme 2001, SKB has made considerable progress in the development of FSW as a sealing method for the copper canister, especially with

respect to the installation and start of operation of the full-scale machine at the Canister Laboratory. In SKI's opinion, RD&D Programme 2004 is a reasonable account of SKB's development work. However, SKI considers that more detailed background material with results from the development work is lacking. SKI assumes that such background material will be presented no later than in connection with the application for the encapsulation plant.

As was stated by Stockholm University (Pereira) and, as was previously stated by SKI (in its review of RD&D Programme 2001), an important part of the analyses is to investigate possible impurities in the weld (from the FSW tool or through, for example, oxidation) and their impact on the material. Analyses of the properties of the welded material and possible other deviations from the properties of the parent metal must naturally also be reported.

4.2.3 Methods for Non-Destructive Testing (NDT)

SKB's Report

SKB's work on the development of testing methods for the weld has been conducted in parallel with the development of the welding methods. Since the welding methods are all different, different NDT methods or applications of the NDT methods are required.

One milestone which was attained is that testing procedures have been determined for X-ray and ultrasound testing of the sealing weld carried out with Electron Beam Welding. For welding using FSW technology, the evaluation up to 2004 mainly focused on investigated volumetric flaws with X-ray technology. In the development of ultrasound technology for FSW welds, new equipment has been acquired with better capabilities with respect to programming, frequency range and the focus of the sound beam for such testing.

In ultrasound testing, development work has been conducted to obtain methods for the investigation of welds made by FSW. In order to specify suitable test frequencies, sound attenuation and propagation properties have been studied. The ultrasound testing is based on "phased array" technology which, in different configurations, has been developed to detect discontinuities in possible directions and angles.

According to SKB's account in RD&D Programme 2004, SKB has worked on in-depth studies of X-ray technology, primarily with simulation, to investigate the reliability and any need to adapt the method for welding with FSW. Furthermore, inductive testing methods have been studied and results show that the testing technology is not dependent on the structure of the material, namely, the weld and parent metal give the same results.

Comments by the Reviewing Bodies

Stockholm University (Pereira) states that the NDT technology for both welding methods has not provided an answer to how small the defects and discontinuities are that can be detected with existing methods. The University notes that SKB has written that, prior to submitting an application to construct the encapsulation plant, the methods for sealing and non-destructive testing must be decided. The University wonders

whether the timetable for making this specific decision (2006) is realistic and, in the opinion of the University, research and development of methods for non-destructive testing can and must be continued since it can hardly affect the safety assessment itself.

SKI's Evaluation

SKI is positive to the work that has been conducted and that has been planned to develop testing methods for the weld, but considers that the account of the continuation of the programme is unclear. It is necessary for SKB to adopt a co-ordinated strategy for its technical development work and for documentation. A description of the testing methods to be used for the chosen welding method and of how testing will be conducted must be attached to the application for permission to construct the encapsulation plant. The goals to be achieved and the reliability of the welding and testing must be described on the basis of the design premises and acceptance criteria that are to be verified in the long-term safety assessment. The qualification programme describes how reliability will be demonstrated (see also Section 4.3.2).

In view of SKB's choice of FSW as the reference welding method, SKI considers that it is vital for the development of the testing methods to focus on welds made by FSW and for testing procedures to be developed as was previously done for EBW.

Furthermore, SKI considers that the continued role of inductive testing is unclear in RD&D Programme 2004.

4.3 Method Qualification

In RD&D Programme 2004, SKB generally states that methods for fabrication, welding and non-destructive testing will be qualified before the encapsulation plant and canister factory are taken into operation. The qualification comprises documented investigations that guarantee that the fabricated canisters meet the ultimate requirement that the canister should be a reliable barrier in the repository. Specified requirements are to be prepared for each sub-process and the qualification is to be carried out in relation to these requirements. A qualification programme is to be prepared and presented as a basis for the application for the encapsulation plant.

4.3.1 Qualification of Fabrication and Sealing Methods

SKB's Report

SKB states that the reference welding method is to be chosen before the application and that this can be seen as a first step in the qualification process. Among the criteria used in connection with the choice, SKB mentions reliability, robustness, repeatability and testability. After the publication of RD&D Programme 2004, SKB chose FSW as the reference welding method in May 2005.

SKB's programme in the next few years includes:

- developing a programme for the reliability of the fabrication methods
- better quantifying some of the important variables and establishing optimal settings for stable operation in the welding process
- demonstrating that welding can be conducted with an adequately high level of quality under conditions that are similar to the serial production sealing in the encapsulation plant.

SKI's Evaluation

In SKI's view, SKB's work on the qualification of fabrication and sealing methods is being conducted in a systematic manner.

The qualification programmes for fabrication and sealing that SKB intends to develop for the upcoming applications in 2006 and 2008 should particularly describe which processes and products are to be qualified, how and when data will be developed as well as the work that the regulatory authorities are expected to carry out. Furthermore, it will facilitate the process if the different qualification programmes and timetables are designed in a similar manner – depending on the requirements of each time of qualification.

SKI agrees with SKB that the link between qualification and safety assessment is important and, once again, SKI would like to remind SKB that the premises for canister fabrication must be derived taking a bottom-up approach. In SKI's view, this means investigating events and conditions, preparing design premises including material and environmental data, load data and strength analyses. The requirements on fabrication and inspection will be derived from these data.

4.3.2 Qualification of Non-Destructive Testing Methods

SKB's Report

The NDT methods have not been established but development work is underway, primarily within X-ray and ultrasound testing, and to a certain extent, for eddy-current testing. Qualification is the step that shows that the NDT methods meet the requirements for which they have been developed, so that the methods ultimately guarantee canister quality. SKB states that the NDT methods will be chosen by the time that an application for permission to construct the encapsulation plant is granted, since the choice affects the design of the plant.

SKB states that, in the discussions that are carried out with SKI (through technical meetings during the consultation for system analysis and safety assessment), the need to clarify the different stages in the qualification programme, the logic of the underlying documentation and links to the safety assessments, SR-Can and SR-Site, has arisen.

In SKI's opinion, when the welding method has been decided, models together with the preparation of test blocks with possible welding flaws will further clarify how the

testing methods are intended to be used individually and together. The work on technical justifications and procedures will thereby be clearer and this will shape the direction of the basis for the qualification of the copper canister and the other parts of the canister.

SKB has established contact with the qualification body, SQC (SQC Kvalificeringscentrum AB) and guidelines have been discussed for the qualification procedure which will be reported in connection with the licence application. SKB's main line is that a qualification body will carry out the qualification. This body is to be approved by SKI.

Method development is underway in parallel with the establishment of acceptance criteria and will be reported prior to the licence application for the encapsulation plant. The establishment of acceptance limits for the NDT systems is mentioned as an item that is being given priority and SKB states, in particular, that these systems need to have a high degree of reliability in order to identify and eliminate canisters that do not meet the acceptance criteria.

A programme for investigating the reliability of the testing methods is underway and covers the link between the NDT systems and mathematical models of these systems. Reconstructions of actual defects are used as input data to the models. SKB's work on the investigation of the reliability of the testing methods also includes development work in radiography and digital detector technology.

SKI's Evaluation

SKI agrees with SKB that it is important that the type of data that will be included at each milestone in the timetable for the development of NDT should be clarified. Nevertheless, SKI considers that SKB, in RD&D Programme 2004, is taking the qualification issues seriously and has described forthcoming work in a reasonable manner.

SKI is positive to the fact that SKB has established contact with the qualification body, SQC, to adapt existing qualification procedures to a qualification programme for NDT. SKI considers that it is valuable to have continuous information on the progress of this work (through, for example, technical meetings in the framework of the consultation for system analysis and safety assessment).

In SKI's opinion the use of mathematical models to determine the reliability of the NDT methods is necessary, especially for financial reasons. However, for the models to be useful, they must always be verified. In SKI's opinion, modeling will be an important issue even for the qualification body when the reliability studies that are a part of the qualification data are to be evaluated.

4.4 Encapsulation

4.4.1 Encapsulation Plant

SKB's Report

SKB's main alternative is to construct the encapsulation plant adjacent to Clab. Various siting alternatives have previously been compared and, in parallel, SKB is studying the alternative of siting the encapsulation plant at Forsmark, in the case where the repository is also located there. SKB specifies the advantages of siting the encapsulation plant adjacent to Clab, including the experience of fuel handling at Clab and the possibility of using several of the existing systems and the plant components at Clab.

During design and construction, the safety report will be handled independently of Clab. The safety report will then be integrated with the report for Clab.

The overall production requirements on the encapsulation plant include the possibility of handling and encapsulating all existing types of spent nuclear fuel stored at Clab. In the case of certain other fuel types, SKB intends to be able to use spacers to modify the space in the channels of the inserts. Any damaged fuel that may be stored in special boxes must be lifted out of theboxes.

A limiting factor for the fuel content of a canister is the canister shell's outer temperature in the deep repository. When designing the encapsulation plant, it is assumed that the maximum permissible heat output of each canister is 1.7 kW. SKB writes that the content of each canister must be thoroughly planned in order to permit maximum utilization of the canisters.

Since 2003, Clab has had equipment for the calometric measurement of the decay heat in fuel elements, combined with the measurement of gamma probes that measure heat losses caused by gamma radiation. The plan is to measure 15 to 20 fuel elements per year and to compare with gamma measurement. The aim is then to verify the calculated decay heat using only gamma measurement in connection with the transfer of fuel elements from storage canisters to transport canisters.

SKB states that an action plan will be prepared with the aim of describing what it would mean for the encapsulation activity if the verifying measurement of fuel that is conducted directly before encapsulation should indicate large discrepancies in relation to the information that the nuclear power plants provided in connection with the transfer of fuel to Clab. Furthermore, SKB has started an investigation to prepare a long-term strategy for how changes in fuel geometry and source terms can affect facilities and the transportation system (indications of such changes are included in the plans of the nuclear power plants).

In RD&D Programme 2004, SKB describes its plans for canister handling in the encapsulation plant. For the part of the handling that occurs after welding, SKB states that the canister will first be subjected to NDT and, if approved, it will be transported to the station for machining.

Comments by the Reviewing Bodies

In the opinion of the Swedish NGO Office for Nuclear Waste Review (MKG), the stipulated decision-making process for the choice of method and siting is rendered difficult by the lack of clarity in the RD&D programme concerning the quantity of waste, its origin and its content. SKB's owners have large quantities of different types of spent nuclear fuel that they must dispose of. It should be clarified which types are to be managed in the disposal system before the system is chosen. Factors such as the extent of future nuclear power plant operations in Sweden and the import of nuclear waste means that the discussion on nuclear waste management in Sweden must take greater quantities of waste into account than has so far been the case, longer operating periods as well as the issue of possible new repositories.

In the view of Oskarshamn Municipality, the possibility of an extended reactor operating time must affect SKB's forthcoming application so that the report must include the consequences of an extended operating time for the encapsulation plant and the repository. SKB needs to initiate the question of an expanded storage volume during the site investigation work. SKB should also clarify the consequences of planned power uprates for the quantity of spent nuclear fuel and the decay heat of the fuel as well as present its findings to the Municipality.

SSI would like to see an in-depth account of the methods and procedures that SKB plans to use to inspect the fuel and canisters during the operation of the canister factory and the encapsulation plant (including Clab). SSI would like to particularly emphasize the determination of the fuel's decay heat. The investigations that SSI has read indicate that, at least for certain types of fuel, it may be difficult to meet the criterion of 1,700 W per canister without having to extend the decay time in Clab or by adopting other measures (for example, canisters that are not completely filled, a greater distance between the deposition holes and the fuel element configuration).

Furthermore, SSI states that any need for burnup credit to show that criticality cannot arise in the canister requires that the burnup of each fuel element should be known when the canisters are being filled. In SSI's opinion, SKB needs to describe how the quality assurance of the proposed measurement of cesium-137 to determine burnup will be conducted as well as any other information that is necessary for an assessment to be made.

Moreover, in SSI's opinion, SKB does not give an unambiguous description of the work procedure for NDT of the sealing welds in the encapsulation plant. In SSI's view, a final inspection of the weld must be conducted after the final machining.

SSI notes that, in the report, SKB states that in order to protect personnel and people in the vicinity, high demands are placed on safety in connection with facility operation. However, SKB does not develop argument with a description of the requirements (external, internal etc.) and does not state how they are to be met. SSI also considers that a risk assessment from a radiation protection standpoint, namely an identification of risks that can arise during operation, is lacking.

To summarize, SSI considers that SKB should have put greater emphasis on presenting a more in-depth and unambiguous account of work in progress and of current plans for the encapsulation plant.

SKI's Evaluation

SKI considers that SKB's proposed approach with a separate preliminary safety report for the encapsulation plant during the design and construction stages, and a later integration with the safety report for Clab prior to an application for permission to take the plant into operation does not adequately take into account how integrated Clab and the encapsulation plant will be, even at an early stage. In other contexts (apart from RD&D Programme 2004), SKB states that changes in Clab's operations organization as well as changes and revisions of the safety report for Clab will be made. In May 2005, SKB decided to itself take charge of the operation of Clab. In connection with this decision, SKB has decided to establish a new department for nuclear safety which will be responsible for the independent review that is required according to SKIFS. Furthermore, SKB has announced that it intends to modernize the safety report for Clab (probably in 2006), and that the periodic safety review required by SKIFS 2004:1 will be submitted no later than by the end of 2009. SKI recommends that SKB should review its strategy for how the preliminary safety report for the encapsulation plant will be co-ordinated with other safety reports for Clab.

Like SSI, SKI wishes to emphasize the importance of SKB formulating a strategy for how the composition of fuel elements for the canisters will be achieved. The strategy must take into account temperature (heat decay) and criticality (burnup and possibly the necessary burnup credit), and should be long term so that all relevant types of fuel are covered, both existing fuel (including other fuel types and damaged fuel) and future changes in fuel geometry and composition. Some of this work has already started through the above-mentioned investigation into the impact of modifications in the fuel made by the nuclear power plants as well as through the presentation of such strategy work after RD&D Programme 2004 was written. The action plan that SKB is preparing in order to investigate how the encapsulation activity will be affected by major discrepancies between the decay heat measurements and the fuel data submitted by the nuclear power plants is completely necessary.

SKB states that is will be possible to encapsulate all types of fuel handled at Clab and that spacers can be used to modify the space in the inserts. However, in SKI's opinion, a description is lacking of whether and, in that case, which special measures must be adopted in connection with the encapsulation of other types of fuel and damaged fuel removed from the specialboxes.

Like SSI, SKI considers that SKB's description of the role of machining in relation to NDT of the sealing weld is unclear. This is the case with respect to the possible need for machining before NDT and final inspection after machining as well as with respect to how this will affect handling and logistics at the plant.

4.4.2 Safeguards

SKB's Report

In its report, SKB has described the national and international safeguards system as it is at present. However, the safeguards system does not yet specifically include facilities such as an encapsulation plant. Through its participation in international fora in the area, SKB has the opportunity to affect as well as acquire knowledge on the requirements that can be made on an encapsulation plant. SKB also states that the international safeguards system is currently being developed and modified and that this will affect the safeguards system of the encapsulation plant.

SKB intends to take into account the future requirements by allowing as great an opportunity and scope as can be anticipated at present to facilitate safeguards and limit transportation routes for the fuel in the plant. The plan is that only gamma measurements for the verification of fuel decay heat will be conducted at the facility. The description states that there will be a possibility for the supervisory body to "share" the signal from the measurement probes.

Furthermore, SKB states that all of the data for the fuel are now at Clab and that the documentation on the positioning of the fuel in the canister will be achieved through links to unique identities which will be checked visually. Furthermore, SKB assumes that, from the accounting perspective, the encapsulation plant will belong to Clab's MBA (Material Balance Area) if the facility is located there. Otherwise, a separate MBA will have to be set up.

Comments by the Reviewing Bodies

In the view of the Swedish Defence Research Agency (FOI), SKB should take responsibility for the development and demonstration of how safeguards can be applied to the handling of nuclear substances in connection with waste handling and not simply follow international developments.

In the opinion of the Swedish NGO Office for Nuclear Waste Review (MKG), future requirements on safeguards for disposal might affect the design of the facility and this should therefore be clarified.

In its review statement, Oskarshamn Municipality emphasized the importance of informing the local population about what safeguards are and how safeguards work.

SKI's Evaluation

In its report, SKB has described the national safeguards system in a correct manner. However, it should be emphasized that the final disposal system entails a completely new type of facility for which previous experience of safeguards is lacking. SKB's account of nuclear safeguards is complete with respect to the extent of the safeguards. However, on the other hand, it should be more detailed in certain respects.

An account of which stage in the process the verification of decay heat will be conducted is lacking. This is important from the perspective of nuclear safeguards since knowledge of the fuel must be retained if a measurement of nuclear materials is conducted at the same time. In that case, after inspection, the fuel must be stored under seal and/or camera surveillance until the fuel is encapsulated. SKB also needs to describe how this can be done. If the decay heat measurements are conducted at a late stage prior to encapsulation, SKB must, on the other hand, be aware that a certain minimum amount of time can be required for safeguards before the fuel is encapsulated, which could render the concept of combined measurement difficult.

Moreover, SKI considers that an account is lacking of how SKB will verify that the data for the fuel that are obtained from the nuclear power companies are correct. SKI wonders whether SKB intends to simply rely on the data from the power companies and whether these will be the data that will be retained for the future. SKB must also describe how it intends to handle the fuel in the case where there are discrepancies between the documentation and the measurement results. Furthermore, SKB has not described how it intends to conduct its nuclear materials accounting, how it intends to present data to inspectors and how these data will be retained for the future.

SKI also notes that SKB has not described how the visual surveillance of the fuel in the facility will be conducted. Furthermore, SKI would like to point out that a more accurate identity control of canisters and transport casks than visual identification may be necessary to ensure that whole units are not replaced.

4.4.3 Physical Protection

SKB's Report

In RD&D Programme 2004, SKB briefly states that physical protection covers the surveillance and other measures adopted to prevent unauthorized access to or sabotage of nuclear waste or nuclear material.

SKI's regulations for physical protection are part of the design premises for the encapsulation plant. Furthermore, SKB states that the encapsulation plant's buildings will be integrated with Clab's protected area and protection of buildings and that access, fencing-in, surveillance etc. will be regulated and designed in a corresponding manner as at the nuclear facilities that are being operated today.

SKI's Evaluation

SKI's requirements on physical protection are stipulated in the forthcoming regulations on the physical protection of nuclear facilities (SKIFS 2005:1). The regulations have been sent to SKB with a request for comments to be submitted by May 29, 2005.

SKI would like to emphasize that it is important for measures for physical protection to be planned at an early stage and included in the basic design of future nuclear facilities.

SKB's account states that canisters that are filled with fuel are to be put in transport casks. These casks are then to be placed in monitored storage pending transport to the

repository. However, SKB has not specified which measures for physical protection will be taken at the storage facility.

4.4.4 SKI's Overall Evaluation of the Canister and Encapsulation

In SKI's opinion, SKB's work on the development of the canister and encapsulation is making satisfactory progress. After publishing RD&D Programme 2004, SKB has also made considerable advances and, in particular, the work on the programme for qualification and the choice of welding method can be mentioned. SKI has, to a certain extent, taken this recent progress into account in its comments on RD&D Programme 2004. The challenge for SKB is now to compile the entire set of material that has been prepared and which will comprise the basis for the application for the encapsulation plant. In its review of RD&D Programme 2004, SKI has nevertheless identified a number of areas where the report presented by SKB so far indicates deficiencies in the material.

SKI underlines the importance of formulating design premises and acceptance criteria and of verifying them in the safety assessment (with consequence analyses). In SKI's opinion, RD&D Programme 2004 is still lacking a clear and logical link between the detailed design premises for the canister and the requirements on long-term safety of the repository.

Acceptance criteria are to be prepared for selected reference methods for fabrication and welding and are to be based on an identification of the defects that can arise and their consequences for canister integrity and repository performance. SKI considers that the preliminary acceptance criterion that the minimum permissible copper cover is 1.5 cm (with a copper thickness of 5 cm) is formulated in an unclear manner, which several reviewing bodies have also stated. All aspects of the issue of remaining ligaments must be investigated since other processes besides corrosion can also make demands on the exterior of the canister in connection with deposition.

Since RD&D Programme 2001, SKB has made considerable progress in the development of Friction Stir Welding (FSW) as a method of canister sealing and in May 2005, this method was selected as a reference method for the weld. However, SKI still considers that a more detailed background material is lacking with results from the development work but assumes that such material will be presented no later than in connection with the application for the encapsulation plant. In particular, SKB must still demonstrate if, and how, the properties of the weld material are different from the parent metal, as well as the impact of any impurities in the weld.

SKI is positive to the work that has been conducted and that is planned for the development of testing methods for the weld, but would like to emphasize the necessity of SKB adopting a co-ordinated strategy, technically and with respect to the documentation. With SKB's choice of Friction Stir Welding (FSW) as a reference welding method, SKI considers that it is important for the development of testing methods to focus on welds made using this method.

SKI considers that SKB's work on the qualification of fabrication and sealing methods as well as on NDT methods is now being conducted in systematic manner. SKI is

positive to the fact that SKB has established contact with the qualification body, SQC, to adapt existing qualification procedures to a qualification programme for NDT.

SKI wishes to also emphasize the importance of SKB formulating a strategy for how the composition of fuel elements for the canisters will be achieved. The strategy must take into account temperature (heat decay) and criticality (burnup and any necessary burnup credit), and should be long term so that all relevant types of fuel are covered, both the fuel that exists (including other fuel types and damaged fuel) as well as forthcoming changes in fuel geometry and composition.

In its report, SKB has described the national safeguards system in a correct manner. However, it should be emphasized that this concerns a completely new type of facility for which previous experience of safeguards is lacking. SKI lacks a description of which stage of the process the verification of decay heat will be carried out and if and how this is to be combined with the measurement of nuclear materials.

4.5 Repository

In this section, SKI comments on SKB's account of the repository which corresponds to Chapter 10 to 12 of RD&D Programme 2004.

In its review of RD&D Programme 1998, SKI stated, with reference to the legislation, that the facility for the disposal of spent nuclear fuel is to be called a "repository", which SKB has not yet heeded. To signal that it is not yet a question of a repository with irretrievable spent nuclear fuel, SKB still prefers to use the term "deep repository".

4.5.1 Technology

Prior to the submitting an application for permission to site the repository, SKB is continuing the technical work on selecting methods to construct and operate the repository as well as on designing different parts of the repository. The development work covers rock excavation and sealing technology for tunnels, the manufacturing and emplacement of the buffer, canister and buffer deposition technology as well as backfill and sealing of the deposition tunnels. SKB is investigating, in co-operation with SKB's sister organization in Finland, Posiva Oy, the possibility of modifying the KBS-3V reference method and depositing the canisters horizontally, KBS-3H.

SKB's Report

With respect to rock excavation technology, SKB states that construction and operation will have a limited impact on the safety functions of the rock and of the other barriers. SKB also reaches the conclusion that of two investigated methods for rock excavation, mechanical excavation resulted in a small damaged zone in comparison with conventional drill-and-blast (the ZEDEX experiment at the Äspö Hard Rock Laboratory).

SKB considers that freedom of action with respect to the choice of *methods for the excavation* of tunnels and deposition holes will remain even after deposition has begun. The investigation concerning methods/technology for rock excavation is being

conducted in two stages until 2007. With respect to conventional drill-and-blast, cautious blasting is proposed as a preliminary reference method for all tunnel types in the planned Layout D1.

With respect to *grouting*, SKB is focusing on the work of sealing small highly water-bearing fractures. Cement with a low pH for large fractures – or non-cementitious (silica sol) material for fractures smaller than 0.1 mm – is being investigated by SKB, Posiva and Numo (Japan). In connection with tests carried out at the Äspö Hard Rock Laboratory (Emmelin et al., 2004), SKB has also indicated a limited need for grout and good sealing.

With respect to the *technology for the fabrication* of bentonite blocks and rings, SKB has so far used uniaxial pressing in full-scale format. With isostatic pressing technology (SKB's reference alternative), SKB has had blocks fabricated at the ceramic company, Ifö Cheramics, on the scale of 1:4, which shows that the technology should also be suitable on a large scale. SKB now plans to investigate buffer fabrication through isostatic pressing with the aim of preparing process descriptions, materials handling, pressing and handling as well as storage of blocks and rings. According to SKB's plan of action, the design and fabrication of handling equipment for the buffer will be started in mid-2008.

SKB considers that the equipment for the handling and emplacement of the buffer units will not determine the layout while the opposite applies for the canister deposition machine. SKB is planning to conduct a conceptual study and a subsequent demonstration of a wheeled deposition machine instead of the rail-bound machine that is used in the Äspö Hard Rock Laboratory.

SKB is developing and testing compaction technology and backfilling material in the Backfill and Plug Test and the Prototype Repository at the Äspö Hard Rock Laboratory. SKB presents a new research programme (in co-operation with Posiva) with three backfill concepts in four stages where stage one has been conducted. Pilot tests are being planned for the period of 2005-2007 and large-scale experiments are being planned for the period of 2008-2011.

With respect to tunnel *plugging technology*, according to SKB, the choice of concept for plugs will depend on the method used for rock excavation and on the backfill concept used. In co-operation with Posiva, SKB has identified two concepts for the application of clay plugs in investigation boreholes; sealing with pre-compacted bocks or compacted pellets. Additional stages of the initiated research programme will be conducted during the forthcoming RD&D period.

With respect to the canister *retrieval,* increasingly greater efforts are required the further in the future that the need is discovered. SKB has studied four different methods for retrieval. The result of the tests conducted indicate that a hydrodynamic method (slurrying the material with a saline solution) should be developed and further tested. The authorities' regulations do not include any formal requirements on retrieval.

Together with Posiva, SKB is conducting a programme for the *horizontal deposition* of canisters comprising three areas: technical development, preparation for a

demonstration and initial studies of the long-term safety of the concept. An external expert group has judged the concept to be technically feasible and considers that the long-term safety requirements are fulfilled and can, thereby, comprise a reference alternative to KBS-3V. A safety assessment for KBS-3H based on site data from Olkiluoto in Finland is to be presented by Posiva in 2007. The assessment will be preceded by the identification of critical issues such as bentonite swelling through the perforated steel container, pressure buildup due to the corrosion of the container, piping and erosion of the bentonite.

Comments by the Reviewing Bodies

The Swedish Work Environment Authority notes with satisfaction that work environment requirements are given a central place when one of the main purposes of the plan is described: showing that a deep repository can be built and operated with known technology where high demands on personal safety, work environment, rationality and cost-efficiency are met.

The Waste Network and the Opinion Group for Safety Disposal (Oss) note that SKB is continuing to use the term "deep repository" instead of "repository" which is the object of their mandate. The Waste Network and Oss assume that this is a conscious decision on the part of SKB in order to obtain acceptance from the public and local politicians in the municipalities concerned and to confuse concepts in the discussions concerning deep boreholes and the reporting of alternatives.

The Waste Network and Oss also note that retrievability has become a key issue for SKB in the discussion on method selection in spite of the fact that the Act on Nuclear Activities stipulates disposal and safeguards and in spite of the fact that the environmental legislation stipulates that risks must be minimized. In view of the choice of methods, it is clear that retrievability is the only factor that speaks in favour of the KBS-3 method, at the same time that the possibility for retrievability may be the method's greatest environmental weakness since both intentional and unintentional intrusion may entail the dispersion of radioactive material on the ground surface in an undesirable manner.

The Swedish Anti-Nuclear Movement notes that a basis is lacking for SKB's claim that the KBS-3 system does not entail any long-term sealing measures. The Movement also notes that SKB seems to mean that, to the extent that it does not see any possibility of achieving controlled conditions, even in a hundred-year perspective, the issue is best resolved by leaving it unresolved.

The Swedish Anti-Nuclear Movement also notes that, in RD&D Programme 2004, interest in a possible retrieval of canisters seems to be limited to the time directly following deposition (a period of 5 years) and that it is highly likely that a backfilled tunnel will mean that canister damage that is detected at a late stage or other problems that should require a retrieval of the deposited canisters will not be rectified if SKB sees any possibility of avoiding doing so.

Luleå University states that knowledge of excavation methods and reinforcement methods, experience of construction at great depth in the rock as well as high safety demands can be obtained from the mining industry. The University also states that new

requirements on rock facilities as well as the increasing excavation depths may lead to the possibility that new knowledge that is useful for the repository, modified or unmodified, may be developed independently of the research programmes conducted within the framework of SKB's responsibility.

SSI supports the research programmes for horizontal deposition of canisters (KBS-3H) that SKB is conducting. In SSI's view, if KBS-3H is to be an acceptable alternative, SKB must demonstrate that it has found practical solutions to all of the specific problems arising during the deposition process and that the identified problems of erosion and piping can be resolved.

The Swedish Geotechnical Institute (SGI) considers that RD&D Programme 2004 lacks a description of the methods/concepts that will be applied to estimate the required types and quantities of rock reinforcement. SGI's recommendation is that traditional methods of estimating rock reinforcement should be supplemented by probabilistic tools for predicting block breakout due to unfavourable fracture geometry. Such tools enable comparable predictions to be made in order to find the most optimum orientations for the deposition tunnels and to estimate the necessary rock volume for the deep repository. The probability of unstable rock can also be quantified and later included in decision models which can be tested against failure criteria and tolerable risk levels.

Stockholm University (Mörner) notes that SKB has stopped using the term "repository" and is instead now using the term "deep repository". Furthermore, SKB states – after being asked to do so – that the waste is retrievable. In addition, the University notes that if it is a question of a retrievable deep repository, this is not a "repository" in the original sense of the word (and the law).

SKI's Evaluation

Excavation Methods

If SKB is taking the requirements on limited impact on the rock seriously, SKB should decide that mechanical excavation of deposition tunnels and deposition holes will be conducted. This method entails the smallest damage zone around the openings, the best possible wall stability, the minimum rock reinforcement and probably the smallest need for tunnel plugging. Thus, SKI does not agree with SKB that there is freedom of action with respect to the excavation method up to the time of the excavation of deposition tunnels and deposition holes and after deposition is initiated.

Furthermore, SKI considers that it is doubtful whether cautious blasting can be conducted with conventional production drilling. Blasting damage experiments previously conducted at the Äspö Hard Rock Laboratory (Olsson et al., 1996) demonstrated the difficulties of blasting effectively, particularly the bottom of the tunnel.

However, choosing drilling and blasting in the layout proposal in design Stage D1 may be rendered difficult in view of the fact that the method is the most frequently used in Swedish underground construction today. On the other hand, SKI considers that SKB should describe an alternative in its forthcoming layout proposal, D2, where rock excavation is conducted using mechanical methods alone.

In SKI's opinion, rock bolts, shotcrete reinforcement, metal netting with or without a combination involving shotcrete as well as conventional rock constructions will be required during the construction and operation phases. Therefore, SKI considers that SKB should increase its research work in rock reinforcement (and grouting) and submit to SKI a more detailed programme for rock reinforcement research and development.

Grouting
SKI is positive to SKB's support to grouting research in Sweden (which has resulted in Licentiate degree dissertations and PhD theses) since rock sealing with grout is one of the most uncertain stages in the planning and construction of the repository. Major leakage can lead to problems with blasting and deposition and, through groundwater leaching/groundwater lowering, will increase the risk of leaching of highly saline deep groundwater with subsequent risks for the repository function, especially with respect to tunnel backfilling.

SKI's notes that research that has been completed and that is in progress has focused on developing both cementitious grout and non-cementitious material with a good capability for penetrating into fine cracks. In the case of cementitious grout, ongoing research concerning the filtering stability of the grout is decisive for the possibility of using grout mixtures based on finely ground cement with the aim of achieving the best possible penetration into finefractures.

If the research on developing non-cementitious material with good penetration into fine fractures and on developing cementitious grout which results in a leachate with a pH that is lower than 11 is not achieved, it is vital that all of the repository sealing should be carried out through systematic pre-grouting. The purpose of pre-grouting is to, as far as possible, avoid leakage which results in an increased groundwater flow through the repository and, thereby, increased leaching.

SKI observes that the work on developing the technology for sealing large fractures and fracture zones, which will be required during the construction phase, has been - neglected. SKI therefore considers that the sealing of large fracture zones should not be neglected in SKB's programme for further research on grouting.

Furthermore, SKI questions whether SKB will have time to acquire the knowledge, materials, methods and equipment for grouting that will be required up to the start of construction which, according to SKB's plan, is expected to start in 2011. In the light of this, SKI would like to see a more detailed programme for the sealing of the rock using grouting already in RD&D Programme 2007.

Fabrication Technology
In spite of SKI's positive view of isostatic pressing of bentonite blocks in its review of RD&D Programme 2001, SKI notes that SKB is late with its work. There are now considerable time constraints to conducting the outlined programme since an isostatic press for full-scale blocks is still not available. Moreover, it is a reasonable requirement that field tests with isostatic blocks should be conducted, although not to the same extent as for uniaxial pressed blocks.

Deposition Technology
SKI can see certain advantages of using wheeled equipment for canister deposition since a concrete ground plate/sleepers in the deposition tunnel then do not seem to be needed. On the other hand, positioning problems can arise. SKI observes that the ultimate design of the canister deposition machine will determine the layout of tunnels, independently of the deposition method. SKI supports SKB's view that a demonstration to verify the chosen method and equipment for deposition will be needed.

Backfill Technology
SKI observes that no results from tests so far conducted in the Äspö Hard Rock Laboratory have been reported in RD&D Programme 2004. On the other hand, results from the Backfill and Plug Test involving bentonite and crushed rock in a 30/70 proportion (concept A) are presented in the report by Gunnarsson et al. (2004). The results from tests on compacted Friedland clay are reported by Pusch (2001) and Johannesson and Börgesson (2002).

Reported parameters for the bentonite/crushed rock mixture meets specified requirements with the exception of hydraulic conductivity which is somewhat too high ($4\ 10^{-10}$ m/s). It is probable that the backfill in the test might not correspond to the requirements for adequate density. Contributing factors are the potential for an uneven grain size distribution, piping and erosion as well as a groundwater salinity above 1.2 %. In tests conducted with Friedland clay, an adequate density was achieved, although an adequately low compressibility was not. In the field test, certain practical problems were encountered with compaction, especially close to the tunnel roof.

In SKI's opinion, SKB needs to present an alternative to tunnel backfilling which can be shown to have good capabilities for meeting the requirements. Bearing in mind the fact that results from new large-scale tests will not be conducted until 2008-2011 (Gunnarsson et al., 2004), SKB needs to specifically analyze the significance of uncertainties for the properties of the backfill and the repository function. Such analyses should be reported no later than in connection with the submission of an application in 2008.

Plugging Technology
In its review of RD&D Programme 2001, SKI stated that SKB should investigate why the concrete plug in the Backfill Test at the Äspö Hard Rock Laboratory does not meet the sealing requirement. SKI observes that SKB has not yet reported any results from operational plugging in the form of plugs in the full-scale Backfill and Plug Test and the Prototype Repository experiment carried out at the Äspö Hard Rock Laboratory.

It is hardly reasonable for SKB to present a final solution to technology for tunnel plugging and, in particular, borehole plugging, before the application for the repository is submitted to SKI. As far as the respect distance is concerned, SKB has written a memorandum (presented at the consultation meeting with SKI and SSI) stating that no respect distance from borehole to deposition hole is necessary. At the same time, SKB states in the RD&D Programme that the question of the distance between borehole and deposition hole is to be dealt with in the safety assessment and repository design. SKI repeats, as does SSI, its recommendation from the review of RD&D Programme 2001 that SKB should maintain some form of respect distance between the borehole and

deposition hole. Furthermore, SKI considers that the issues surrounding the plugging of boreholes at great depths, where coredisking and breakouts occur, should be more closely investigated in SKB's programme.

Retrieval
In SKI's regulations and general recommendations (SKI, 2002), § 8 states that "the impact on safety of such measures that are adopted to facilitate the monitoring or retrieval of deposited waste or material from the repository, or to make access to the repository difficult, shall be analyzed and reported to the Swedish Nuclear Power Inspectorate." The general recommendations to § 8 state that: "Measures can also be adopted during construction and operation with the primary aim of facilitating the retrieval of deposited nuclear materials and waste from the repository, during the operating period or after closure. For these measures, the safety report for the facility, in accordance with § 9, should show that these measures either have a minor or negligible impact on repository safety, or that the measures result in an improvement of safety, compared with the situation that would arise if the measures were not adopted."

Horizontal Canister Deposition
SKI is awaiting the planned safety assessment before making any evaluation/judgement of long-term safety and technical feasibility of KBS-3H. SKB mentions a number of critical questions that must be answered. In addition to these, certain concerns can already be raised, such as a limited flexibility to avoid (water-bearing) fractures of varying size and falling blocks in the tunnel and their consequences for the sealing properties of the bentonite. Unfavourably high rock stresses can also lead to problems during the construction and deposition phases which can result in the need for reinforcement and grouting. Other questions that need to be answered are: what is the maximum borehole deviation that can be accepted for the introduction of the deposition container in the tunnel. Additional questions that need to be answered are: the function of the distance block in the event of uneven wetting, the thermomechanical evolution of the deposition container, the buildup of swelling pressure and the function of the bentonite in the interface between the deposition hole and the tunnel periphery.

4.5.2 Design

Design is a collective term for the activities where technical data are gathered, processed and analyzed so that they can then be translated into facility descriptions. These descriptions are important supporting documents for the planning of the construction phase, safety assessment during operation, system analysis, long-term safety assessment and environmental impact assessment. The facility descriptions which are prepared after initial site investigations at Forsmark and Simpevarp/Laxemar will then provide the basis for SKB's application for permission to start construction of the repository in accordance with the Environmental Code and the Act on Nuclear Activities.

SKB's Report

In Chapter 11 of RD&D Programme 2004, SKB mentions that the preparation of main and design documents will be started during the application period and will then continue during the construction phase.

For the design of the rock caverns in the underground part of the repository, SKB has prepared a document (SKB, 2004) which describes the design methodology. The document also states which of the interim results of rock cavern design are to be checked and verified by SKB before work can continue.

In its design methodology for layout D1, SKB has structured the methodology around a number of critical issues that SKB subsequently deals with in a number of design stages from A to L (SKB, 2004). SKB then refers to the methodology section for rock mechanics and hydrogeology in order to resolve each of the design stages.

SKB considers that the task of the design work is to adapt the facility to the information that has been obtained about the site. At the same time, the design work must result in requirements with respect to how further site investigation work is to be conducted with respect to design needs.

The design premises are a necessary basis for design and construction. SKB divides the design premises into engineered (fuel) and natural conditions (site) and features that control the design of the facility and processes that affect the repository's safety functions and long-term development. The requirements can be broken down into stakeholder requirements, system requirements (subsystem requirements) and configuration requirements

In Section 11.2.1, SKB states how the overall design premises presented in 2002 will be evaluated, revised and integrated in the design work. A computer program has been acquired to handle the systematic handling of requirements.

SKB states that the design of the repository will be conducted in stages and, prior to each new design stage, methodology and premises will be updated as the results of the site investigations become available, as methods are developed and as safety assessment provides new information.

Comments by the Reviewing Bodies

The Swedish NGO Office for Nuclear Waste Review (MKG) considers that the special regulations that limit ownership and control of fissionable material might also be a limitation with respect to the design and function of the repository.

SKI's Evaluation

Documents and Design Methodology
SKI observes that it is not possible to see, from SKB's description, which main and design documents SKB intends to deliver before and after an application is submitted for permission to construct the repository. SKI considers that it is important for SKB to provide a more detailed plan for which main and design documents it intends to submit as a basis for the application.

With respect to SKB's design methodology, SKI considers that there is an alternative way of carrying out the design by dealing with each of the system parts individually – ramp, shaft, rock cavern, tunnels, deposition holes etc. – and by shedding light on the

critical issues as well as proposing design and location of the parts taking into account the geological conditions. Prior to the work on the design of layout D2, SKB should evaluate the experience of the design work for layout D1 and, at the same time, consider adopting a more systematic layout method.

In connection with the site investigations, SKB presents site-descriptive models within each of the following disciplines: geology, hydrogeology, rock-mechanics, thermal properties, transportation, hydrochemistry and ecosystems. SKI considers that, for the design of layout D1, the design of the facility, in terms of the thermal properties of the rock, has not been given adequate attention since the thermal properties of the rock and the heat content of the fuel canisters play a very important role in the layout work. SKI would like to thereby emphasize the importance of giving greater priority to the thermal issues in the repository design in the remainder of the design work.

As mentioned above, SKB considers that the task of the design work is to adapt the facility to the information obtained about the site at the same time that the design is to result in requirements on how further site investigation work should be conducted bearing in mind the design needs. In SKI's opinion, this is a delicate task/balancing act for SKB since the design needs that arise at an early stage in the site investigations must not dominate the direction of the site investigations at the cost of site characterization.

SKB has acquired a computer program to handle the systematic handling of requirements (design premises). SKI intends to follow the work on developing the database tool for the overall design premises and the use of the design premises for the design of the underground part of D2 as well as to continuously keep itself informed of SKB's work on a system for a digital drawing and document management system. It is important, particularly from the standpoint of safeguards, to have easy access to reliable documentation on the facility.

With respect to the control and verification of the design work, SKI fully agrees with SKB's plan that the design work should be conducted with clear interfaces (stepwise decision-making process), efficiency and traceability. SKI also agrees with SKB that it is important for all information of importance for the disposal project to be documented and retained. Furthermore, at this stage, SKI does not have any immediate objection to SKB's proposal for facility design concept with ramp, skip shaft, elevator shaft and three ventilation shafts.

SKI has no objection to make to the implementation of the disposal project as a stepwise (design) process. SKI also notes that the conditions are changing as new information successively becomes available. This means that the freedom of action for possible future changes in design will become increasingly limited and that early (ambiguous) choices will be difficult to rectify at a later stage.

4.5.3 Monitoring, Safeguards and Physical Protection

The ideal situation would be for the repository to be designed so that it is safe even without monitoring and/or maintenance, both during operation and after closure. However, international regulations, like Swedish regulations, recommend long-term observations during all disposal implementation stages with the limitation that the safety

of the closed repository should not be dependent on long-term observations or future maintenance. The steps and measures that are implemented to carry out long-term observations must either have a small but negligible impact on repository safety or result in improved safety.

Long-term observations and measurements are required to increase the scientific understanding of the site and the repository. Therefore, in the light of this, SKB has formulated guidelines for carrying out long-term observations (monitoring programmes) during the site investigation, construction and operating phases. Safeguards and physical protection requirements are also high.

SKB's Reports

SKB's specific objectives for long-term observations are: to obtain knowledge of undisturbed conditions in nature and their seasonal variations, to strengthen the understanding of the repository function, to monitor the environmental impact of the repository, to provide information for monitoring occupational safety and to demonstrate compliance with the safeguards requirements.

SKB's programme plan is to collect information during the site investigations on, for example, land use, surface ecosystems, geology, hydrogeology, rock mechanics and hydrochemistry. During the construction phase, detailed investigations of the rock from the surface will continue at the same time that the underground part will be built and the rock investigated. During the operating phase, long-term observations of temperature, microseismics, groundwater pressure etc. can be conducted as can the control of backfill resaturation and pressure buildup.

Sweden has accepted that all nuclear materials must be subjected to international safeguards. The safeguards are administered by Euratom and the IAEA, and on a national level, by SKI. The IAEA published a policy document in 1997 where the IAEA states that safeguards will be required for the repository as long as safeguards in general are applied.. Furthermore, international activities are in progress to develop mechanisms for safeguards. SKB observes that it must be possible to identify canisters and that some form of verification is needed to ensure that canisters that are placed in the repository remain unchanged after leaving the encapsulation plant.

SKB also emphasizes that it is important that it should be possible for the safeguards body/organisation to verify the deep repository design during construction, operation and closure to ensure that it corresponds to the reported design.

Finally, SKB states that the development of safeguards may result in the use of new methods, such as environmental sampling and satellite surveillance, which in turn can affect the design of monitoring requirements. SKB intends to follow international developments but does not itself intend to conduct any development work in the area.

Physical protection covers monitoring and other measures that are taken to protect fuel and other radioactive material from theft and sabotage.

Comments by the Reviewing Bodies

The Waste Network and Oss note that, for the local population and local politicians in the area where the repository is planned to be located, the question of image-related impact is important. Therefore, the Waste Network considers that SKB must, as soon as possible, describe how it intends to mark the repository site so that it deters people from intrusion and functions as a form of safeguards, as well as report how this can be achieved without the area becoming stigmatized.

The Swedish Anti-Nuclear Movement notes that once the repository is sealed, as far as it understands, long-term observations will cease. The only future monitoring and control activity will thereby be limited to possibly monitoring site access and safeguards which SKB believes can be carried out by satellite monitoring.

The Movement puts two questions to SKB:

1) Is it responsible and reasonable to cold-heartedly remove from future generations any possibility of monitoring the potential threat to their living environment that is represented by this long-term experiment?
2) Should not our responsibility instead require us to implement any possible means of following and monitoring the project as far into the future as possible and, thereby, minimize the risk to future generations and, at the same time, give them the possibility of gaining invaluable practical experience of this concept for nuclear waste disposal in rock?

The Swedish NGO Office for Nuclear Waste Review (MKG) considers that the issue of how repository monitoring is to be designed after closure and how such monitoring is to be financed must be resolved before decisions are made regarding method and siting. In MKG's opinion, the RD&D programme should seriously take this issue into account.

The Swedish Environmental Protection Agency considers that it is especially important for SKB to further develop its work on environmental impact studies during the planning, establishment and construction phases of the repository and, on a long-term basis, during the repository operating period. Furthermore, SKB should formulate a programme for environmental monitoring and continuously interpret collected data and report these findings for possible action.

SSI states that it may seem that issues relating to long-term monitoring after repository closure lie too far ahead in the future to require these issues to be explored in detail. However, SSI considers that these issues are of considerable interest to the public. A common view on this issue, shared by several actors, of which SSI is one, is needed. In SSI's view, it is reasonable for such monitoring which has similar aims to the environmental monitoring and release control described in articles 36 and 37 of the Euratom Treaty to be taken over by the Government through the relevant authority at some stage after closure. (SSI carries out this monitoring and reporting at present).

Furthermore, SSI states that it is obvious that information relating to safeguards should also be retained. SSI notes that international archives of safeguards information are, together with other reporting within the scope of the IAEA's International Joint Convention on the Safety of Spent Nuclear Fuel Management and on the Safety of

Radioactive Waste Management, a valuable component in a future archive on nuclear waste repositories.

The Swedish Defence Research Agency (FOI) is concerned that SKB is not planning to conduct any development or demonstration of equipment for physical protection (safeguards) during the period of 2005-2010, but only intends to follow international developments.

Moreover, FOI considers that SKB should study and develop methods to verify that the material that is received by the repository is identical to the material that was shipped from the encapsulation plant. SKI and other competent authorities should participate in this work.

Oskarshamn Municipality considers that it is important for forms of monitoring/control of possible leakage of radioactive substances from the repository to be investigated in good time before an application is submitted. This applies during the deposition phase as well as after closure. The possibility of long-term monitoring should be developed and consultation with the local population should be held on this issue. This consultation should also include the authorities who need to become more involved in the issue and conduct a dialogue with the public.

Furthermore, the Municipality notes that the local population has little knowledge of safeguards, of how they are structured and which authorities – national and international – are responsible for safeguards etc. This situation must be rectified by measures undertaken by the authorities. Documentation on the repository, in the long and short term, is also very important. Through the Misterhult Group, the local population has evinced an interest in participating in discussions on documentation/marking in a long-term perspective.

SKI's Evaluation

The authorities' regulations, particularly SSI's, recommend long-term observations at all stages of the development of the repository. However, the safety of the closed repository must not be dependent on long-term observations or on future maintenance.

SKI considers that it is reasonable for SKB to give a more detailed account of its plans for the type and frequency of future monitoring measures that are planned to be conducted during the construction phase and the initial operating phase.

SKI observes that long-term observations in the form of measurements are being conducted to determine successive environmental changes. One of the most difficult tasks of the monitoring work during the construction and operating phases is to determine different thresholds, alarm levels and measures in the event that limits and alarm levels are breached. SKI therefore recommends that SKI should continue its initial work in this area as the design work progresses.

SKI finds that Table 4-1 of SKB R-04-13 (Bäckblom and Almén, 2004), which describes possible monitoring activities for different phases of the repository development, lacks a monitoring system for deformation measurements in connection

with large fractures and planes of weakness. In SKI's opinion, the establishment of such a system is warranted.

SKI shares SKB's view that some form of institutional monitoring can be expected to occur even after closure if only for safeguards and physical protection-related reasons.

SKI also observes that SKB intends to take into account in the repository design problems relating to safeguards already at the design stage and to take into account the views of the supervisory bodies (IAEA, SKI) on, for example, the positioning of the monitoring equipment.

In SKI's opinion, SKB has adequately described the situation for international safeguards at the repository but observes that the description is general in nature, which is understandable since this is a new type of facility for which there is no established safeguards system. SKB points out that work is in progress in the area and that SKB is participating in several fora. This is important for knowledge acquisition and in order to be able to influence the safeguards so that they are realistic and feasible.

SKI considers that it is satisfactory that SKB has indicated the importance of verifying the design of the facility, but SKB should also have mentioned the work which is underway in Finland where the IAEA, the European Commission and STUK (Radiation and Nuclear Safety Authority of Finland) are being given the opportunity of following the design of the planned repository adjacent to existing nuclear reactors at Olkiluoto. SKI recommends that SKB should closely follow this process since this concept could set a precedent for repository safeguards.

SKB should also, in accordance with FOI's review statement, describe in greater detail how it will ensure that the material will arrive at the repository in an unchanged condition.

SKI's requirements on physical protection are stipulated in the forthcoming regulation on the physical protection of nuclear facilities (SKIFS 2005:1). The regulations were sent to SKB for review in spring 2005.

SKI would like to point out that it is important for measures for physical protection to be planned at an early stage and to be included in the basic repository design.

4.5.4 SKI's Overall Evaluation – Repository

SKI expects, with reference to the applicable legislation, that SKB will use the term "repository" in the future when referring to the repository for spent nuclear fuel.

If SKB is taking the requirements on limited impact on the rock seriously, SKB should decide that mechanical excavation of deposition tunnels and deposition holes will be conducted. This method entails the smallest damage zone around the openings, the best possible wall stability, the minimum rock reinforcement and probably the smallest need for tunnel plugging. Thus, SKI does not agree with SKB that there is freedom of action with respect to the excavation method up to the time of the excavation of deposition tunnels and deposition holes and after deposition is initiated.

If the research on developing non-cementitious material with good penetration into fine cracks and the development of cementitious grout which results in a leachate with a pH that is lower than 11 is not achieved, it is vital that all of the repository sealing should be carried out through systematic pre-grouting. The purpose of pre-grouting is to, as far as possible, avoid leakage which results in an increased groundwater flow through the repository and, thereby, increased leaching.

SKI observes that the grouting work has so far primarily focused on sealing individual small fractures and fracture systems. The work on developing the technology for sealing large fractures and fracture zones, which will be required during the construction phase, has beenneglected. In SKI's opinion, sealing of large fracture zones must also be included in SKB's grouting research programme.

In spite of SKI's positive view of isostatic pressing of bentonite blocks in its review of RD&D Programme 2001, SKI notes that SKB is late with its work. There are now considerable time constraints to conduct the outlined programme since an isostatic press for full-scale blocks is still not available.

SKI repeats its comment, from the previous RD&D programme review, that the backfill should be chosen in good time before an application for permission to construct the repository is submitted to SKI, which SKB plans to submit in 2008. In SKI's view, SKB needs to present an alternative for tunnel backfill which can be shown to have good prospects of meeting the requirements.

SKI now sees obvious difficulties for SKB to manage to conduct sufficiently comprehensive backfill tests before an application is submitted in 2008. This is also evident from the report written by Gunnarsson et al. (2004) where large-scale tests are planned to be conducted as late as 2008-2011.

With respect to horizontal deposition, there is concern for practical implementation as well as long-term safety such as a limited flexibility to avoid (water-bearing) fractures of varying size and falling blocks in the tunnel and their consequences for the sealing properties of the bentonite. Unfavourably high rock stresses can also lead to problems during the construction and deposition phases which can result in the need for reinforcement and grouting. SKI considers that other questions that SKB needs to answer include: What is the maximum borehole deviation that can be accepted for the introduction of the deposition container in the tunnel? Additional questions that need to be answered are: The function of the distance block in the event of uneven wetting, the thermomechanical evolution of the deposition container, the buildup of swelling pressure and the function of the bentonite in the interface between the deposition hole and the tunnel periphery.

SKI repeats its recommendation from its review of RD&D Programme 2001 that SKB should keep some form of respect distance between the borehole and the deposition hole.

SKI considers that it is important for SKB to provide a more detailed plan for which main and design documents it intends to submit as a basis for the application.

SKI considers that, for the design of layout D1, the design of the facility, in terms of the thermal properties of the rock, has not been given adequate attention since the thermal properties of the rock and the heat content of the fuel canisters play a very important role in the layout work. SKI would like to thereby emphasize the importance of giving greater priority to the thermal issues in the repository design in the remainder of the design work.

As mentioned above, SKB considers that the task of the design work is to adapt the facility to the information obtained on the site at the same time that the design is to result in requirements on how further site investigation work should be conducted bearing in mind the design needs. In SKI's opinion, this is a delicate task/balancing act for SKB since the design needs at an early stage in the site investigations must not dominate the site investigations at the expense of site characterization.

SKI considers that it is reasonable for SKB to give a more detailed account of its plans for the type and frequency of future monitoring that are planned to be conducted during the construction phase and the initial operating phase.

SKI shares SKB's view that some form of institutional monitoring can be expected to occur even after closure if only for safeguards and physical protection-related reasons.

SKI recommends that SKB should closely follow the process for the construction of Posiva's repository in Finland since this may involve concepts that set a precedent for repository safeguards.

SKB should also describe in greater detail how it will ensure that the material will arrive at the repository in an unchanged condition.

SKI would also like to point out that it is important for measures for physical protection to be planned at an early stage and to be included in the basic repository design.

4.6 Transportation of Encapsulated Fuel

In this section, SKI comments on Chapter 9 "Transportation of Encapsulation Fuel" of SKB's RD&D Programme 2004.

SKB's Report

In comparison with RD&D Programme 2001, SKB gives greater attention to fuel transportation in RD&D Programme 2004. SKB's description of how the transportation of encapsulated fuel will be carried out is based on the assumption that the encapsulation plant will be located adjacent to Clab in Simpevarp. SKB also deals with the possibility of siting the encapsulation plant adjacent to a deep repository at Forsmark.

Regardless of whether the deep repository is located at Simpevarp or Forsmark, overland transport will be limited to a few kilometers. Therefore, overland transport will be conducted using the terminal vehicles used to drive on and off the ship, Sigyn, or its

successor. Transport by sea will only be relevant if the repository is located at Forsmark. It will then be a question of at least twenty shipments per year, with up to ten transport casks per shipment. At least at the start of operations, these shipments must be added to the simultaneous transfers from the nuclear power plants to Clab and SFR. Currently, there will be about thirty shipments per year, on average.

SKB states that the design of the canister transport casks was started in 2004. SKB states that the future transportation activity will largely be based on known technology and is planned to be conducted in a manner similar to present-day transportation to Clab. A general description of current international and national radioactive material transportation regulations is provided.

Comments by the Reviewing Bodies

The reviewing body that has given most attention to transportation issues is the Swedish Defence Research Agency (FOI). In FOI's opinion, even if SKB shows that it will manage its task to dispose of the waste from the nuclear power plants in an environmentally safe manner, SKB is paying too limited attention to the risk of proliferation of nuclear material, and thereby nuclear weapons, to terrorists or criminals. In FOI's view, SKB should take three areas into account:

- analyze possible threats by developing a number of realistic scenarios
- evaluate technical protection systems in the form of equipment, technology and tactics for the monitoring of radioactive material in connection with transportation
- evaluate technical verification systems to check that the transport casks contain the same material at reception as at dispatch.

In the view of the Swedish Environmental Protection Authority, the liability issues in the event of accidents in connection with transportation must be reviewed. The Authority considers that it is particularly important to minimize the risks to man and the environment and to adopt the necessary safety measures to avoid unplanned events in connection with the transportation of radioactive material.

In the opinion of Oskarshamn Municipality, the transportation of nuclear waste must, as far as possible, take place outside the public road network. Furthermore, in the view of the Municipality, SKB should specifically examine and describe the alternative involving direct tunnel systems from the encapsulation plant to the repository.

SSI observes that the number of canisters that will be transported from the encapsulation plant to the repository will place completely new demands on the design of the transportation system. The sensitivity of the disposal system to unplanned events in the transportation of the waste must be taken into account.

Another issue that SSI raises is that the report to the authorities of a specific shipment should be made only after de facto sealing of the canister and the contents are definitively established.

SSI also mentions the difficulties of longer overland shipments which must be taken into account if the repository is located at another site than Simpevarp or Forsmark.

SKI's Evaluation

The task of designing, fabricating and certifying Type B transport casks involves extensive work. It is positive that SKB has started this work, but a timetable should be established for the entire fabrication and certification procedure to avoid a lack of approved transport casks becoming a bottleneck. At present, there are no casks on the world market that are designed for copper canisters with fuel.

The number of transport casks to be transported per year will be on the order of magnitude of three to four times higher than today. This is a sizeable transportation activity. Therefore it is an understatement for SKB to state that these shipments "do not entail any technical or organization difference compared with today." However, SKI shares SKB's view that it is mainly a question of expanding the current transportation system and that there should be no unknown technical barriers to doing so.

SKB's account of existing regulations in the transportation area is unclear and partly incorrect. For example, SKB refers to already defunct regulations. It is unclear what the regulations for the transportation of hazardous goods will require and what the Act on Nuclear Activities and the Radiation Protection Act will require. Furthermore, the account is based on the assumption that SKI will make the same stipulations for transportation as it does today, which is not self evident. In addition, when existing licence stipulations are mentioned, the issue of physical protection is completely neglected.

The need for a well-thought out system for the physical protection of nuclear material has, as is known, been highlighted in recent years. Therefore, SKI shares the view presented by FOI that SKB should raise its ambitions in this area. The analysis of possible threats and scenarios is primarily a task for regulatory authorities. However, equipment, technology and tactics for the surveillance of the fuel in connection with transportation is an area that SKB should investigate more deeply.

Transportation also includes loading and unloading. SKB should describe how these stages are to be performed, for example, what needs to be automated seeing that the radiation level is too high for people to be directly involved in this work.

5 Safety Assessment

In this section, SKI comments on Chapter 14, "Safety Assessment" of SKB's RD&D Programme 2004. SKI has taken into account the fact that the premises have changed somewhat after RD&D Programme 2004 was published.

SKB's Report

SKB mainly discusses three planned safety assessments:

- SR-Can, which will be completed in 2006. The assessment will be part of the supporting documentation for the application for permission to construct an encapsulation plant. However, according to SKB's modified plan of action, prepared in spring 2005, SR-Can will not directly be one of the documents in the application.

- Posiva's safety assessment for horizontal deposition (KBS-3H), which will be completed in 2007. The assessment will be prepared in co-operation with SKB and the methodology will be partly based on SR-Can. The assessment needs to specifically focus on the aspects where there are significant differences between the two disposal methods.

- SR-Site which will be completed in 2008. This assessment will be part of the documentation for an application to construct a repository and, in accordance with SKB's modified plan of action, also the encapsulation plant.

SKB has recently reported improvements in safety assessment in the interim report for SR-Can (SKB, 2004).

Within the area of integrated modelling, SKB has developed a system development model for engineered barriers in the near-field of a repository. This model contains a highly simplified representation of thermal, hydraulic, mechanical and chemical processes that affect the capabilities of the engineered barriers to isolate spent nuclear fuel. The purpose of developing this model is to improve the possibility of controlling the handling of individual processes, quality assurance as well as for probabilistic calculations. The simplified models are a complement to, rather than a replacement, for detailed process models.

The area of radionuclide transport and dose calculations can be roughly divided into the sub-areas of the near field, far field and biosphere. Groundwater flow calculations that are conducted separately provide data for all of these parts. For a long time, SKB has coupled the near field and the far field and performed probabilistic calculations using the Proper code package. In order to enhance flexibility prior to SR-Can, the Tensit code package, which can be used in a PC environment, has now been implemented. Tensit is based on Matlab. For probabilistic calculations, SKB will also use the @risk code. For the near field model, Comp23 is to be used as before. However, this code has been developed to handle advection and shared solubilities. In the case of the far field, Farf31 is to be used, as before. A new feature of biosphere calculations is the capability to take into account human exposure to radionuclides from several ecosystems at the

same time. Matlab/Simulink will be used for this type of calculation. Process models will supplement the compartment-based biosphere models that were previously used.

SKB has developed analytical/simplified versions of the near and far field models which will complement the detailed numerical models.

Comments by the Reviewing Bodies

The Swedish Anti-Nuclear Movement considers that the knowledge base for safety assessment is surprisingly uneven. This is expected to result in a lack of understanding of the interaction between sub-systems and, thereby, the evaluation of risk and safety will not be possible. The Movement also considers that it is difficult to obtain an overview of the RD&D programme and the Movement expresses the reminder that deficiencies have been identified in connection with the review of SKB's latest safety assessment for SFR (SAFE).

The Local Safety Group at Oskarshamn Municipality considers that SKB's account, which is limited to calculation methodology, is insufficient. The Safety Group would have liked to have seen an account of how the safety assessment work is structured to comply with the requirements of the Environmental Code and SKI's and SSI's regulations.

The Swedish NGO Office for Nuclear Waste Review (MKG) finds that a system analysis is lacking which deals with scenarios for events and incidents that can occur during the time that the waste is hazardous.

In the view of Oskarshamn Municipality, it is important for the regulatory authorities to state their opinion on how far SKB's programme needs to have come before an application can be processed.

Oskarshamn Municipality wonders why SKB has not discussed updated regulations (SKIFS 2004:1) and new general recommendations (to SSI FS 1998:1). SKB should show that it is prepared for the significant impact that these can have on the implementation of the safety assessment.

Oskarshamn Municipality also would like to see a methodology for dialogue about the safety assessment. In the light of this, the Municipality considers that it is unsatisfactory that Chapter 14 of the RD&D programme focuses on the details of calculation models. It would have been more important to present an overall methodology in such a way that it can be used by non-experts. A dialogue is needed, for example, concerning the choice of scenarios. Furthermore, the Municipality would like to see greater clarity concerning the link between safety assessment and the site investigations.

The Swedish Radiation Protection Authority (SSI) has some understanding for the fact that SKB has not fully described method development for the safety assessment in the RD&D programme, bearing in mind that such an account is included in the interim report for SR-Can. However, SSI considers that SKB should have included a short summary in the RD&D programme report.

SSI points out that there is a need to rectify the deficiencies in SKB's methodology that have been expressed during the consultation on system analysis and safety assessment. SSI is therefore positive to the fact that the regulatory authorities, in accordance with SKB's modified plan of action, will be given the chance to comment on SR-Can before SKB's safety assessment method is used as a basis for an application.

In SSI's opinion, it is positive that SKB is developing simplified methods for an integrated account of processes of importance for repository evolution and radionuclide transport. However, SSI would like SKB to clarify the use that these will have in the safety assessment. Furthermore, SSI would like SKB to describe how all of SKB's models are coupled to each other.

According to SSI, it is good that SKB has further developed COMP23 but SKB should, in its further work clarify the importance of conceptual simplifications for the near field model. SKB should specifically investigate the validity of the transport resistances used for the transition between a small hole in the canister and the buffer as well as the buffer and a fracture in the rock.

Stockholm University (Pereira) wonders which steps SKB must take in order to benefit from Posiva's safety assessment on horizontal disposal at Olkiluoto.

In the view of Östhammar Municipality, Chapter 14 of the RD&D programme does not give a good overview of safety assessment methods and purposes. Furthermore, the Municipality considers that a systematic review of how regulations and general recommendations will be handled is lacking. Even if this information may be available in other documents, the Municipality considers that the RD&D programme report should contain an overview of these areas.

SKI's Evaluation

In SKI's view, SKB has provided adequate information on the ongoing development of safety assessment, such as safety assessment methodology and its link to the regulations and general recommendations. The background to this is the activities that have been conducted in the ongoing consultation and system analysis and safety assessment with SKI, SSI, SKB and the municipalities concerned (which are participating as observers). A particularly important part of this work has been SKI's and SSI's joint review of SKB's interim report for SR-Can (SKI and SSI, 2005) and the international peer review that has been carried out (Sagar et al., 2005). Since SR-Can will not directly be a document (according to SKB's modified plan of action) in an application, there will be additional opportunities for the regulatory authorities to follow up SKB's interpretation of the regulations and general recommendations before they are applied in full. One issue which SKB should specifically pay attention to is the flexibility of its scheduling in order to take into account review comments prior to the finalization of SR-Site.

SKI has some understanding for the fact that several reviewing bodies consider that SKB's account of safety assessment in RD&D Programme 2004 is incomplete. It is not obvious why SKB has specifically chosen to focus on calculation models. SKI considers that a somewhat more detailed account of safety assessment methodology and future safety assessments would have been warranted. In this context, it is especially important for SKB to take into account the strong wishes of several reviewing bodies that safety

assessment issues should also be presented in a way that non-experts can understand. SKI considers that SKB should spend careful effort on preparing an accessible version of SR-Can and SR-Site so that both the problems and the possibilities that SKB must deal with are presented in a comprehensive manner.

With respect to computer code development, SKI considers that SKB should review its procedures and instructions for documentation since certain deficiencies have been previously identified (Hicks, 2005). In particular, if repeated updates and modifications have been made, it has been difficult to form an impression regarding the comprehensiveness and relevance of the documentation.

In SKI's opinion, SKB's simplified models for repository evolution and radionuclide transport will improve the conditions for flexibility, integration and quality assurance. However, SKI agrees with SSI that SKB should describe the limitations of the models and better describe the conceptual simplifications that are used. As SSI points out, transport resistances for the transition between the canister and buffer and the buffer and rock are very important parameters for the description of radionuclide transport.

SKI considers, as does SSI, that SKB needs to develop its safety assessment methodology prior to forthcoming applications. In their review of the interim report, the authorities reached the conclusion that many essential improvements had been made since SKB's latest safety assessment, SR 97. However, in certain areas, additional improvements or clarifications are required concerning, for example:

- methods for scenario selection and their application
- the selection of scenario variations and calculation cases for a complete risk assessment
- the handling of unfavourable FEPs, even those that are eliminated at an early stage
- the handling of discrepancies during the initial state and human error
- the handling of codes and their inherent relationships
- the mapping of the use of function indicators and preliminary evaluations
- iterative procedures in safety assessment
- the quality assurance of safety assessment
- the presentation of arguments for compliance with requirements.

For some of these items, additional reporting will be conducted within the consultation on the system analysis and safety assessment (for example, quality assurance, methods for scenario selection), while others will probably not have to be estimated until the complete SR-Can is available (for example, the comprehensive risk assessment calculation case, iterative procedures).

SKI agrees with Stockholm University (Pereira) that it is not completely clear how Posiva's safety assessment of horizontal disposal will be used by SKB. Does the assessment have to be modified with information from the Swedish site investigations before SKB can have an adequate basis for deciding whether to continue with KBS-3H? Are there site-specific conditions that can make implementation difficult and that have not been adequately taken into account in Posiva's assessment (for example, high rock stresses)?

SKI recommends that SKB, in the main report of the safety assessment, should handle the isolation phase of the repository in greater detail since it is a main feature of SKB's concept for the demonstration of safe disposal.

SKI intends to conduct an initial review after an application has been submitted. The aim is to assess whether there is a need for supplementary work to be done (scope or content not as expected). This does not exclude the possibility of the need for supplementary work being identified at a later stage of the review. For SR-Can which, according to current plants, will not be directly part of the application documentation, SKI has proposed that hearing should be held with SKB in 2007.

SKI is carrying out, in co-operation with primarily SSI, a series of activities to prepare for future reviews. Furthermore, these activities have given the authorities many possibilities for drawing to SKB's attention deficiencies in the available material. Examples are:

- workshops on specific themes that are of great importance for safety assessment (for example, SKI 2002, 2003, 2004, 2004a). On four of six occasions, hearings with SKB were conducted
- the development of independent modelling tools to evaluate SKB's safety assessment (Maul et al., 2003)
- a review of SKB's calculations (Maul and Robinson, 2005)
- a review of SKB's quality assurance of codes (Hicks 2005)
- a review of SKB's site investigations within the framework of INSITE (SKI's expert group) and OVERSITE (SSI's expert group).

SKI's intention is to continue all of these activities and, within the next year, it intends to prepare review plans for forthcoming safety assessments.

SKI's Overall Evaluation – Safety Assessment

In SKI's opinion, the safety assessment area is being well handled at present. The reviews that were recently conducted have highlighted the most important weaknesses for SKB to rectify, such as quality assurance and methods for scenario selection (SKI and SSI, 2005; Sagar et al, 2005). With the modified plan of action, SKB can further develop and test its method before it is used in connection with licensing.

Since SR-Can is no longer directly a supporting document for an application, SKB should take adequate advantage of the possibility of a new regulatory review before SR-Site is finalized. Certain remaining questions surrounding SKB's safety assessment method and the application of regulations and general recommendations should be dealt with in the consultation process for system analysis and safety assessment. SKI would like to remind SKB of the importance of preparing easily accessible and high quality versions of SR-Can and SR-Site.

6 Research on Long-Term Safety

In this chapter, SKI presents its comments on SKB's overall prioritization for research on long-term safety as reported in Part III of RD&D Programme 2004. Under the sub-headings of "Fuel", "Canister as Barrier", "Buffer", "Backfill" and "Geosphere", SKI comments on the corresponding chapters, 15 to 19, of SKB's RD&D Programme 2004.

Comments by the Reviewing Bodies

In SSI's view, SKB should more clearly present the most important remaining research-related issues based on an analysis of their importance for long-term radiation protection and the implementation of the disposal programme. For these issues, it should be made clear which goals need to be reached and when in order to obtain adequate information for the various milestones in SKB's programme for repository development. SSI also considers that SKB should present a specific analysis of the need for different types of long-term experiments to demonstrate the function of the engineered barriers. Whether this analysis is a part of the main report or part of a plan of action is of less importance. What is important is that the information should be included.

6.1 Fuel

In this section, SKI presents comments on Chapter 15 of RD&D Programme 2004.

6.1.1 Introduction

The characterization and description of all of the types of fuel that will be deposited in the repository are included in "Fuel". New features in RD&D Programme 2004 include the fact that SKB also includes other fuel types such as MOX. The research question that is dealt with in the greatest detail is what would happen when spent fuel in a damaged canister comes into contact with the groundwater. The major difficulty lies in extrapolating the relatively short measurement series that can be compared during different experiments to the very long time horizons involved in safety assessment. Other issues in the fuel area include the total radionuclide inventory, half-lives, criticality and inventories of instant release radionuclides.

SKB's Report

The most comprehensive part of SKB's report concerns the fuel matrix dissolution rate. One issue that is given particularly high priority is the importance of the redox conditions and the possible presence of oxidants. Under laboratory conditions it is difficult to completely eliminate atmospheric oxygen, which means that the fuel oxidizes and reacts more rapidly than in expected anoxic conditions in a repository environment. Furthermore, oxygen and other oxidants are formed due to alpha, beta and gamma radiation via radiolysis near to the surface of the fuel.

During the past period, SKB studied dissolution with fuel fragments and U-233-doped uranium dioxide. The latter material is used to isolate the impact of alpha radiolysis which is expected to be the only form of radiolysis that can be of importance in a long-term perspective. Major efforts have been made to avoid the impact of atmospheric

oxygen. Furthermore, experiments have been conducted under high hydrogen gas overpressure to simulate the expected environment in a damaged canister where the penetrating groundwater reacts with cast iron during hydrogen gas generation. SKB has studied fuel with different burnups, the importance of groundwater with different pH levels, salinities and carbonate concentrations.

The results show that the occurrence of a high hydrogen gas pressure counteracts the formation of oxidants from radiolysis, which prevents rapid dissolution caused by oxidation of uranium dioxide. The explanation is thought to be that the hydrogen which is slow to react is activated by oxidizing radicals and that this eventually has a catalytic effect on the surface of the uranium dioxide. Generally speaking, the experimental results show that very small quantities of actinides and fission products are released from the fuel under redox conditions. pH is considered to have very little importance for fuel dissolution. The impact of temperature and salinity will be studied during the forthcoming RD&D period.

Participation in EU projects has had an increasing significance for SKB's spent fuel programme. During the past period, several critical fuel issues have been studied in the SFS project (Spent Fuel Stability under repository conditions) and in InCan (In Can processes). These projects have been completed, but final reports have not been published. During the forthcoming period, several studies are expected to be conducted within the NF-Pro EU project.

SKB intends to continue to work on other fuel types, such as MOX fuel, in order to obtain complete material on all fuel types.

Experiments on spent fuel and hydrogen gas-saturated solutions for underpressurized matrix dissolution in order to obtain improved data for rapid or instantaneous nuclide release have proven to be more difficult than expected. SKB is testing methods and is hoping to be able to start a systematic study. SKB also intends to study the impact of non-radioactive fission gases.

Fuel experiments using the CHEMLAB probe have been delayed.

Comments by the Reviewing Bodies

In SSI's opinion, SKB needs to further study the impact of burnup on the nuclide inventory and the original materials composition of the fuel and its importance for the inventory of activation products.

SSI considers that SKB needs to conduct an overview of the importance of the burnup for the decay heat of the fuel. The conditions for meeting the criterion of 1,700W per canister with high burnup fuel need to be taken into account. SSI points out that MOX fuel affects the generated thermal energy of the canister.

SKI's Evaluation

SKI considers that SKB's experiments to investigate the matrix dissolution are suitable and largely successful. With respect to the planned continuation of the programme, SKI considers that it is positive for SKB to conduct new experiments within the framework

of the NF-Pro EU project. This project is considered to focus on issues that are important for SKB, such as the impact of salinity, temperature and the characterization of the mechanisms of hydrogen gas effects. However, SKI considers that SKB also needs to give an account of the importance of fuel dissolution under redox conditions but in the absence of high hydrogen gas pressure (which can primarily build up if there is a small hole in the canister). This is due to the fact that cases with a larger canister deformation (for example, due to earthquakes and shear movements in the rock) are currently a possible scenario to be included in future safety assessments.

SKB has recently published a report which presents useful literature-based data for determining parameters for safety assessment needs (Werme et al., 2004). SKI considers that this report is a good summary of the state-of-the-art in the area. However, prior to future safety assessments (such as SR-Site), there is a need for a systematic account of all assumptions and uncertainties needed to justify the handling of the reaction of the fuel with the groundwater. Werme et al. (2004) contains a limited selection of experimental data. SKI does not exclude the possibility that there are/should be other experimental studies that can strengthen the basis of the safety assessment as well as other information that can be used, such as natural analogues.

In connection with SR-97, SKB justified the rate of fuel dissolution on the basis of a mathematical model of radiolysis (Eriksen, 1996) of water at the fuel surfaces reactions between the radiolysis products in the water and oxidation of uranium dioxide ($UO_2(s)$). This model has been criticized for its deficient analysis of uncertainties and insufficient documentation (SKI & SSI, 2000). In spite of this, SKI considers that SKB needs to continue to develop and use process models as well as to report the results in safety assessments. The primary aim does not need to be the same as for SR-97 which was to specify a dissolution rate. The aim could be, for example, to demonstrate an understanding of processes for extrapolation using very long timescales and to provide a basis for sensitivity analyses and the characterization of uncertainties.

SKI considers that one of the CHEMLAB probes should be used for fuel experiments rather than for actinide experiments. Bearing in mind the reported difficulties of achieving representative conditions in a laboratory environment for the characterization of fuel dissolution, experimental in-situ measurements would be of considerable value. SKI has some understanding for all of the practical problems that must be solved but it would be valuable if the initial findings could be used in one of the forthcoming safety assessments.

In the safety assessment, the importance of a single barrier function will be affected by the extent to which there are traceable and quality-assured datasets that support a final choice of parameters in dose and risk calculations. A large part of the work on spent nuclear fuel has focused on the need to understand basic processes. However, SKI considers that, prior to future licence applications, SKB should devote more attention to quality, scope and traceability with respect to the experimental data that will be used. For example, there is a lack of data on the rapid release of certain radionuclides from fuel which, in the case of certain nuclides, can have a large impact on consequence calculations (for example I-129). Therefore, where suitable, SKB needs to strengthen the experimental basis of certain parameters. In other cases, it should perhaps be sufficient to review the documentation and traceability of already existing data.

SKI agrees with SSI that, for a limited number of nuclides, there are significant uncertainties in the fuel inventory, such as CI-36 and Se-79 (Grambow, 2000). This needs to be taken into account in connection with the selection of parameters for the safety assessment. SKI also agrees with SSI that SKB needs to give an account of expected variability in fuel properties as part of the description of the initial state. With respect to the impact of parameters such as burnup and linear power density, SKB may need to, for example, take into account the impact on the reactive surface of the fuel pellets in the choice of "instant release fractions". In the case of MOX fuel, there are more significant differences in the inventory and distribution of radionuclides. SKI recommends SKB to primarily follow the work being conducted in countries which have more extensive MOX programmes (for example, Loida et al., 1997).

In SKI's opinion, SKB needs to give an account of procedures to ensure that the placement of fuel elements is conducted in such a way that the thermal power for each canister remains within the specified limits. The total decay heat of the fuel is also of importance for the size of the repository, since the distance between deposition holes needs to be regulated to avoid too high temperatures. SKI comments more closely on SKB's temperature calculations in the sections on the canister, buffer and geosphere (sections 6.2.2, 6.3.4, 6.5.2).

6.1.2 SKI's Overall Evaluation – Fuel

In SKI's opinion, the fuel area must continue to be given a high priority in SKB's programme. A high confidence in the fuel's own barrier function will entail significant advantages for safety assessment. In SKI's opinion, the understanding of the fuel's reaction with the groundwater has improved considerably in recent years, with the reservation that the demonstration of this understanding in the form of quantitative model studies of mechanisms and processes needs to be better reported. There is also a certain lack of data for justifying the choice of several of the most important parameters for dose and risk calculations (for example, Werme et al., 2004).

6.2 Canister as Barrier

6.2.1 Initial State

The occurrence of possible initial defects in the sealing is part of the canister geometry variable. SKI's comments on this item are presented in the section on acceptance criteria, see Section 4.1.1. Comments on the materials composition variable are provided together with comments on materials choice, see Section 4.1.2.

SKB's Report

Under the "radiation intensity" variable, SKB states that the dose rate on the canister surface may not exceed 1 Gy/h. Werme (1998) states that this entails a minimum total wall thickness of 100 mm.

With respect to mechanical stresses, SKB states that the size and importance of possible residual stresses in sealing welds made by Friction Stir Welding should be investigated during the period.

Comments by the Reviewing Bodies

SSI points out that the RD&D Programme has not taken into account the viewpoints on the criterion for the maximum surface dose rate which were presented in SSI's review statement on RD&D Programme 2001. In SSI's opinion, the power that can lead to a high secondary electron flux right at the canister surface cannot be simply ignored when assessing radiation-induced effects such as radiolysis. In particular, SSI points out the risk of the dose rate in water cavities near the surface of the canister exceeding the dose rate criterion in a small area closest to the canister.

SKI's Evaluation

In SKI's opinion, the adequacy of the requirement on dose rate must be shown in the assessment of radiation protection during operation and in the assessment of long-term safety. The effect of radiolysis, including interface effects in the water cavities near the canister surface must be described and possibly further investigated. Updated calculations of dose rates must be based on the specific canister design.

SKI agrees that the occurrence of possible residual stresses in welds made by Friction Stir Welding should be investigated.

6.2.2 Temperature and Heat Transfer

SKB's Report

SKB discusses the temperature variable in Section 15.1.4 (under "Fuel"), and states that new results from measurements show a very low emissivity in the infra red area in copper. However, SKB states that this is only of importance before full water saturation has occurred.

Comments by the Reviewing Bodies

The Swedish Anti-Nuclear Movement points out, referring to the stated uncertainty related to the impact of the air gap on heat transport, that a small canister would mean a better heat transport and, thereby, increased safety.

SSI comments that SKB now, and even previously, has stated that the canister temperature may not exceed 100ºC, but that this is not in agreement with the discussion that SKB presented in the interim report on SR-Can, where SKB stated that the temperature can be allowed to exceed 100ºC before the system is oversaturated. SSI considers that it is important for SKB to clarify the plans that it has and to clarify what additional research a possible change would entail.

The Swedish Research Council points out that the heat capacity of the rock varies as a function of the mineral composition and that SKB has not stated what another value for the heat capacity of the rock would mean for the canister temperature.

SKI's Evaluation

In its review of RD&D Programme 2001, SKI stated that a more detailed description of the studies of emissivity and temperature evolution in the canister is lacking. SKI observes that individual emissivity measurement results have been presented as have calculations of temperature evolution with the system analytical model provided in Hedin (2004). However, as has been stated by SSI and SKI in the review of the SR-Can interim report (SKI, 2005), it is still unclear how the uncertainties relating to heat transfer are dealt with in the safety assessment. The uncertainties stem, for example, from the emissivity of surfaces, the content (air or vacuum, water etc.) of different gaps and the time that heat transport occurs in an unsaturated state. SKI and SSI also observed in their review that there is some lack of clarity in the statements regarding the maximum canister temperature between what was stated in RD&D Programme 2004 (a maximum of 100ºC, which is in agreement with previous requirements) and what was stated in the interim report for SR-Can that the temperature can be allowed to exceed 100ºC during the period before the system reaches full saturation. In the review, the authorities observed that this can be perceived to be a change in the basic functions of the KBS-3 method and that this should clearly be justified.

SKI recommends that SKB should present an updated overall description of temperature evolution in the canister, including the impact of uncertainties. This must be linked to clarified plans concerning the maximum permissible canister temperature (for all times and states). As SSI comments, SKB must also clarify how this will be handled in future safety assessments.

6.2.3 Deformation of Cast-iron Inserts

SKB's Report

Earthquake-induced rock shear calculations have been carried out for canister and insert (Börgesson et al., 2003). The calculations were conducted using the Abaqus finite element code and updated materials data for bentonite were used. The results show that the greatest influence is that of the buffer density and the shear plane position although the shear rate and the magnitude of the shear displacement are also important.

In 2003, SKB started a major programme for probabilistic analysis of canister strength. Materials data from fabricated canisters are obtained in this programme. The pressure testing of canister sections is also included.

Comments by the Reviewing Bodies

The Swedish NGO Office for Nuclear Waste Review (MKG) points out that extra loads from the continental ice sheet in connection with future glaciations must be carefully taken into account when choosing the method and, above all, SKB's description in the RD&D programme can be interpreted to mean that SKB sees glaciations as an extreme case for which no extra safety margins are required. In MKG's view, since it is probable that there will be glaciations in several thousand years, the risk assessment is dubious.

The Safety Group in Oskarshamn Municipality considers that, according to Section 16.2.4, the question of the strength of the cast-iron insert in connection with tectonic movements must be further analyzed. The Group points out the importance of ensuring that the consequences of earthquakes after a glaciation are given a satisfactory treatment in SKB's programme and of clearly communicating the results to the public.

SKI's Evaluation

In its review of RD&D Programme 2001, SKI stated that it is important to have new calculations of the mechanical strength of the canister and for both the materials data (for bentonite and cast iron, including defect descriptions) and possible loads to be updated.

SKI observes that SKB has performed new calculations of the effect on the insert of shear displacements (which can occur in connection with an earthquake) and that SKB has started a programme for probabilistic analysis of canister strength, including the pressure testing of a (shorter) canister.

SKI finds SKB's new calculations and ongoing studies on insert strength to be a positive step. Besides the calculations of shearing, few results from studies have been reported. SKI can therefore not give an opinion on whether the results from the strength studies will be sufficient. SKI considers the pressure testing of canisters with a full diameter but a shorter length to be valuable. The reporting of results should include the calculations which show how the results from the pressure testing of a shorter canister can be used for a full-length canister.

With respect to the bentonite, the sensitivity of the material parameters to alterations (illitization, cementation etc., see also Section 6.3.9) should be described, even in the shear calculations for the canister. SKB should also consider the possibility of verifying the shear calculations for the inserts through large-scale experiments, see also Section 6.3.7.

When describing the canister strength, the impact of the canister temperature on the materials properties should also be reported.

6.2.4 Deformation of the Copper Shell

SKB's Report

The copper shell is primarily subjected to mechanical loads through external positive pressure. The buildup of corrosion products between the cast-iron insert and the copper shell can lead to internal positive pressure. The difference in the coefficient of thermal expansion between the cast iron and the copper can lead to strains in the copper canister. According to SKB, the influence of the latter on strength is negligible.

SKB states that the creep testing programme will continue during the forthcoming three-year period. Modelling of creep deformation in the copper canister under slow loading is being considered.

The consequences of the buildup of corrosion products in the gap between the copper shell and the cast-iron insert have been studied in experiments although no pressure buildup could be proven. Archaeological analogues have also been studied, although no significant deformation has been proven.

SKI's Evaluation

SKI finds that an overall account of experiments and modeling of creep in copper as well as of how these results are to be used in the safety assessment is lacking.

Furthermore, RD&D Programme 2004 does not state how SKB intends to handle the experimental results that show that pressure buildup from corrosion products does not occur to the extent previously assumed.

6.2.5 Corrosion of the Cast-iron Insert and Evolution of the Damaged Canister

SKB's Report

SKB has carried out and is carrying out several studies to shed light on corrosion rates in the cast iron. SKB's conclusion is that corrosion rates decline when an oxide film is formed, but that this is independent of whether the material is completely or partly immersed in water as well as independent of the surrounding hydrogen gas pressure. The impact of the presence of bentonite has not been established. Experiments to study galvanic effects have also been conducted but no final report has been written.

In RD&D Programme 2004, SKB describes in very general terms how a damaged canister evolves through water penetration, gas evolution and cast-iron corrosion. Furthermore, SKB states that long-term experiments (5-10 years) using miniature canisters are to be started in the Äspö Hard Rock Laboratory.

SKI's Evaluation

Attention was given to corrosion of cast iron in the review of RD&D Programme 2001. SKI recommended SKB to carry out studies of corrosion rates and the impact of carbonate and sulphide on the water in the gap between iron and copper, radiolysis of water, metal coupling (galvanic corrosion), corrosion products with components of U (VI), as well as the impact of the transport properties.

However, as before, SKI considers that the specific work and the extent of the work needed in the cast iron corrosion area (including stress corrosion) and galvanic coupling between iron and copper, depends on the role that a canister with a penetrating hole in the copper (damaged canister) is given in the safety assessment. In SKI's view, this role is not clarified in RD&D Programme 2004.

6.2.6 Corrosion of the Copper Shell

SKB's Report

In RD&D Programme 2004, SKB states that studies have been conducted for copper corrosion in alkaline water. Work is underway to investigate grain boundary corrosion in welded material, to study corrosion in sodium chloride solution, to study the mechanisms for sulphide action on copper and to develop a model to predict the long-term behaviour for copper canisters in a deep repository environment. A programme for identifying the premises for bacterial corrosion of copper has been in progress for several years. The results continue to show that sulphate-reducing bacteria cannot be active in compacted bentonite. Furthermore, studies are being planned to shed light on the consequences of copper oxide films and, in particular, on the influence of chloride and sulphide ions.

According to SKB's description of the situation for stress corrosion, tensile stresses in the copper canister are a prerequisite for stress corrosion. Since the canister is subjected to external pressure, it is not probable that stress corrosion could lead to canister penetration. SKB also states that it has conducted studies involving electrochemical noise which turned out not to be applicable and that studies are being planned with acoustic emission from crack growth.

Comments by the Reviewing Bodies

The Swedish Anti-Nuclear Movement notes that SKB, in its calculation of the canister lifetime (King et al., 2001), specifies one million years whereas other international researchers have reported considerably higher corrosion rates than those reported in SKB's calculations. Furthermore, the Movement wonders what is the basis of SKB's assumption that the oxygen in the repository will be "consumed" already after 3000 years and what impact any supplied oxygen will have, for example, oxygen-rich water in connection with melting from future glaciations. The Movement also lacks corrosion studies on the weakest points of the canisters and on the weld joints for the lid and bottom. With respect to the weld joints, the Movement states that these joints contain dislocations and other defects in the crystalline structure which thereby result in higher corrosion rates.

Gothenburg University states that the planned experiments with microbial processes are of interest. The Geological Survey of Sweden considers it to be positive that so much attention has been paid to microbial processes.

In the opinion of Uppsala University, studies of corrosion attack on the waste containers should be elucidated also in the future.

SKI's Evaluation

SKI is pleased to see that SKB is continuing to conduct studies on copper corrosion. The new knowledge obtained needs to be systematically compiled in order to obtain an overview of the information which can be used in the safety assessment. In connection with RD&D Programme 2001, SKB and Posiva compiled and published a state-of-the-

art report on copper corrosion (King et al., 2001). It is therefore desirable for SKB to update this report to include new knowledge acquired.

The more specific need for further studies of copper corrosion depends on how copper corrosion is handled in the safety assessment. The question of when additional studies can be ready, particularly in relation to the future safety assessments, SR-Can and SR-Site, is also linked to the issue regarding what needs to be studied.

However, SKI would like to continue to draw SKB's attention to deficiencies in the material relating to stress corrosion and the importance of the oxide layer for different types of corrosion, especially in chloride and sulphide-rich water. There are also deficiencies in the material concerning the ability of microbes to survive in the bentonite, especially with respect to sulphate-reducing bacteria. SKI would also like to remind SKB about the importance of other boundary conditions besides corrosion mechanisms and water environment, such as materials properties and available oxygen. The Swedish Anti-Nuclear Movement has also pointed this out. Light also needs to be shed on the impact of a possible heterogeneity of properties.

Stress corrosion cannot be immediately excluded by referring to the fact that the canister is subjected to external pressure, since this pressure can also result in tensile stresses in the shell when the lid is compressed. Instead, all of the necessary factors (tensile stresses, potential and water environment) must be judged in time and space if stress corrosion is to be excluded.

As knowledge of the survival capabilities of microbes increases, it seems to be increasingly difficult to exclude microbial activity through environmental factors. Therefore, SKI considers that it is necessary to show to effects of microbial activity in the safety assessment. In the case of copper corrosion, it is not sufficient to study the processes in most of the bentonite, even the interface processes must be analyzed, such as the possibility of the occurrence of a biofilm on the canister surface.

6.2.7 SKI's Overall Evaluation of the Canister as Barrier

In SKI's view, SKB's programme for obtaining knowledge about the canister as a barrier iswell adapted to the needs. However, SKI would like to point out that SKB needs to clarify the work and projects that must be carried out (to a certain point) and reported in order to be used in the basis for the application for the encapsulation plant.

SKI considers that it is necessary for SKB to present an updated and overall description of temperature evolution in the canister, including the impact of uncertainties. This must be connected to clarifying plans concerning the maximum permissible canister temperature. Correspondingly, an overall account of experiments and modeling of creep in the canister must be prepared.

In several areas, SKB still has to show how the results from experiments and calculations are to be used in the safety assessment and whether the existing knowledge is adequate. This applies to the above mentioned areas of temperature evolution and creep in copper and the corrosion of cast iron and copper. In the case of copper corrosion, SKI still sees deficiencies in the material for evaluating canister corrosion,

the importance of the oxide layer for different types of corrosion, especially in chloride and sulphide-rich water and the capability of the microbes to survive in the bentonite.

6.3 Buffer

6.3.1 Introduction

In this section, SKI comments on Chapter 17, "Buffer", of SKB's RD&D Programme 2004 as well as on certain parts of SKB's plan of action which describe long-term experiments connected to the buffer. To a certain extent, SKI has taken into account results from ongoing experiments that have been obtained after the publication of RD&D Programme 2004.

The buffer comprises rings and blocks of compacted bentonite clay that are placed in deposition holes with the main aim of protecting the canister mechanically and chemically and, thereby, contributing to the isolating function of the barrier system. A secondary purpose of the buffer is to limit the dispersion of radionuclides in the event of a breach in the integrity of the isolation. As SKI previously pointed out (SKI, 2002), SKB has had a tendency to consider the buffer as subordinated to the canister and the rock. This is a not relevant approach since all three are equally necessary components of the KBS-3 system.

6.3.2 Requirements on the Buffer

SKB's Description

In RD&D Programme 2004, SKB describes the requirements on the buffer that must be met, which have largely already been specified in, for example, SKB (2002). The requirements are also connected to several of the function indicators that SKB introduced in connection with the SR-Can interim report (SKB, 2004). Examples of requirements that must be fulfilled include:

- the groundwater flow through the buffer (hydraulic conductivity) must be negligible (transport must only be possible through diffusion)
- the dimensions of the buffer must be stable
- the buffer must have a self-healing capacity
- the physical and chemical properties of the buffer must be stable in a long-term perspective
- the buffer's deformability must be adequate so that minor rock movements cannot damage the canister
- the buffer's deformability must not be so great so that the canister sinks through the buffer
- the buffer must be permeable.

Furthermore, SKB states that it is desirable that the buffer should prevent microbial activity from occurring and that the buffer should filter colloids.

For certain requirements/preferences, SKB specifies quantitative criteria, for example, that bacterial growth is only possible for a density that is lower than 1,700 kg/m3 whereas, in other cases, it is more difficult to specify, for example, that compacted bentonite must retain its favourable properties under a number of different chemical and thermal conditions.

Comments by the Reviewing Bodies

The Waste Network Association points out that toxic metals bound to bentonite clay will gradually enter the geosphere and biosphere.

Oskarshamn Municipality considers that the requirement on the buffer is extensive and that the importance of this component for repository safety is greater than the public perceives. The Municipality would like answers to the question that it previously asked regarding whether criteria have been determined for water availability in the rock as a result of buffer saturation.

In SSI's view, from SKB's account, it is difficult to obtain an impression of the most important remaining R&D issues as well as what knowledge and data SKB considers that it needs prior to critical points in the programme, such as the application for permission to start operation.

In SSI's opinion, SKB should have described the plans to prepare acceptance criteria for the buffer in a better manner.

SKI's Evaluation

In SKI's view, the requirements on the buffer are more multi-faceted and are partially more difficult to interpret than the requirements for other engineered barriers. The above-mentioned requirements partly overlap with the function indicators that SKB presented with the SR-Can interim report. The report stated that the criteria do not necessarily have to be met, but that a breach in criteria would primarily indicate the need for a more extensive analysis. SKB should therefore be cautious in its specification of requirements in order to draw a distinction between what are requirements which, with considerable certainty, must be shown to be fulfilled throughout the entire period covered by the safety assessment and what are to be considered ideal conditions for the buffer. A report of the data and theories justifying these requirements is required for the specification of buffer requirements. The importance of the requirements can vary and exceeding the requirements may result in more or less serious damage to the canister and rock, which should be illustrated.

In SKI's opinion, SKB should strengthen the basis for determining the limits and criteria for the requirements. In SKI's and SSI's review of SKB's interim report for SR-Can (SKI and SSI, 2005), a similar comment was presented regarding the criteria for function indicators. There are examples in RD&D Programme 2004 where the requirements are formulated in such general terms (such as long-term stability, gas conductivity) that it can be difficult to decide whether or not they can be considered to be met. It is therefore important for SKB to clarify the requirements and make them more specific.

SKI notes that certain buffer properties (such as the occurrence of microbial activity) have been formulated as preferences rather than requirements. SKI wonders whether this means that cases where the property is not met will be given greater weight in the safety assessment (for example, the analysis of the importance of microbial activity in the buffer for corrosion). One issue that should have been discussed in this section is the requirement that the buffer may not be frozen/defrosted. Previously, SKB preliminarily stated that the favourable properties of the buffer and backfill cannot be guaranteed after such a process.

6.3.3 Initial State of the Buffer

SKB's Report

RD&D Programme 2004 specifies variables for the description of the initial state of the buffer, for example:

- the geometrical dimensions of the buffer
- the mineral composition of the buffer and its link to the choice of material
- the density and pore structure of the buffer
- hydrovariables
- impurity levels.

SKB has studied alternatives to the reference material that was used for a long time, MX-80 (from Wyoming, USA), including material from Milos (Greece) and Buj (India). Favourable laboratory results show that the alternative materials also show similar swelling properties and can, therefore, be considered to be used as a buffer. However, SKB still has to evaluate the alternative materials in more large-scale experiments (LOT experiments in the Äspö Hard Rock Laboratory) as well as to show clear relationships between mineralogical and chemical/physical properties. The chemical long-term stability of the alternative materials and the content of accessory materials will have to be investigated in greater detail. The objective of this work is to obtain an adequate basis for deciding which material could be relevant in connection with future procurement.

SKB intends to study the composition of montmorillonite and its impact on the key properties of the buffer (for example, swelling pressure). On the other hand, accessory minerals, where they occur, are not considered to be a problem. SKB does not intend to specify a concentration range for accessory minerals in the same way as for montmorillonite.

SKB intends to study isostatic pressing more closely with the aim of investigating the suitability of higher and larger blocks.

Comments by the Reviewing Bodies

SSI considers that SKB is conducting systematic work on the characterization of the initial state of the buffer. SKB's account contains an open description of the processes that could lead to a deterioration in the buffer function. However, SSI considers that it is a deficiency that the importance of the different variables for long-term safety is not fully described.

In SSI's opinion, SKB should have described the further work to be conducted after 2008 with respect to other materials besides MX-80.

SKI's Evaluation

In SKI's opinion, SKB's studies of alternative buffer materials provide the necessary conditions for more reliable deliveries and better cost-efficiency. In order to obtain an adequate basis for future decision-making, SKB needs to investigate these alternatives in good time and to have time to conduct long-term experiments (such as LOT experiments). However, there is no requirement that these alternative materials should be fully investigated prior to the applications which soon have to be submitted. SKI therefore considers that, in the immediate future, SKB should primarily prioritize the demonstration of a reference concept with a reference material (probably MX-80) that meets requirements on long-term safety. With respect to alternative materials, caution is warranted bearing in mind the comparatively small number of tests that have so far been carried out (SKI, 2004).

SKI considers that RD&D Programme 2004 lacks detailed accounts on the optimization of the properties and fabrication of the buffer. Although a discussion on the influence of the size of the bentonite block is presented, issues remain concerning, for example, the fabrication method for bentonite blocks, handling as well as combinations of density and water ratio. At an SKI workshop on fabrication issues arranged by SKI (SKI, 2004a), it was observed that SKB could not yet evaluate its own reference method (isostatic pressing) for the fabrication of full-scale bentonite blocks, which must be considered to be a deficiency. When selecting its reference methods, SKB should take into consideration the information that exists for the evaluation of feasibility.

In SKI's opinion, prior to future applications, SKB needs to describe the steps in the practical handling of bentonite blocks in greater detail since there is reason to assume that fabricated bentonite blocks may be sensitive to impact from the handling environment. Possible inspections and quality assurance need to be illustrated. SKB also needs to, in the same way as in the development of the copper canister, evaluate the risk of critical parameters ending up outside the preferred range in routine and large-scale handling. Furthermore, SKB needs to describe the consequences that this could lead to.

SKI still considers that more work is required to investigate impurities and accessory minerals. Certain components are more reactive than others and minerals with low concentrations can also have a great impact on the geochemical evolution in the buffer (such as sulphides and carbonate minerals). For all components (even less reactive), a qualitative account of the way in which they can affect long-term safety is needed.

6.3.4 Heat Transport

SKB's Report

SKB states that the understanding of heat transport through the buffer is good for water saturation conditions. However, in the case of unsaturated conditions, this process is more difficult to handle. SKB states that the primary criterion in the evaluation of heat transport is the fact that the surface of the canister may not exceed 100ºC to avoid boiling. Examples of factors that affect temperature evolution are:

- the decay heat of the fuel
- the heat conductivity of the buffer and as a function of water content, density etc.
- the time to full resaturation
- the temperature offset across the air-filled canister-bentonite gap which is below buffer resaturation (currently assumed to be less than 17ºC)
- the thermal conductivity of the rock (which can be inhomogeneous in different scales)
- the distance between the deposition holes and deposition tunnels.

To a certain extent, the choice between KBS-3V and KBS-3H will affect the analysis of heat transport.

SKB intends to follow up the experiments in the Äspö Hard Rock Laboratory (the Prototype Repository) and investigate in detail whether the temperature offset between the buffer and canister can be limited to 10ºC. SKB will also develop the calculation models to be able to take into account variable canister distance and inhomogeneities in the thermal conductivity properties of the rock.

Comments by the Reviewing Bodies

SSI considers that SKB has provided a good account of the area in RD&D Programme 2004 and that SKB has a suitable programme for temperature modeling and field experiments. However, SSI would like SKB to clarify the effects on the buffer at temperatures above 100ºC, since SKB has not excluded the possibility that a limited number of canisters can be exposed to such temperatures.

SKI's Evaluation

In SKI's opinion, the area of heat transport is well established in principle and it should be possible to limit new work to adapting calculations to the specific design and site-specific properties. The possibility of affecting the distance between the canister positions and the decay heat for each canister means that it should be possible to handle the issue without any problem. However, the question is what safety margins are necessary bearing in mind uncertainties, such as the temperature offset between the buffer and canister. In SKI's view, when designing the repository, SKB should take into account the possible practical difficulties of handling a small gap between the canister and buffer during routine handling.

SKB has previously proposed that the upcoming safety assessments may assume a somewhat larger distance between canister positions in order to increase the safety margins and to limit the need for detailed calculations. In SKI's opinion, this is a suitable method of handling the remaining uncertainties linked to the as yet limited knowledge of the rock as well as the impact of the air gap. This method does not exclude the possibility of limiting the canister distance at a later stage if more accurate data and calculation models can be obtained.

SKB has also previously proposed (SKB, 2004) that the temperature criterion for the canister surface (100ºC) should only apply after the canister comes into contact with the groundwater and not to the initial phase directly following disposal. SKI has certain reservations regarding this modified interpretation of the temperature criterion since conditions and consequences for this initial phase have not been reported. In the case of dry deposition holes, uncertainties surrounding this phase and the evaluation of compliance with requirements may therefore be rendered difficult. Therefore, SKI considers that SKB should either decide to apply an unambiguous temperature criterion or present detailed material in support of the time that the criterion does not need to be met. Analyses of buffer transformation, the possible impact on the canister surface and other possible negative effects need to be presented.

6.3.5 Water Transport

SKB's Report

Water transport is handled in different ways, depending on whether the buffer is saturated or unsaturated. As for heat transport, the process is more complex to handle for unsaturated conditions where the negative capillary pressure drives water uptake from the surrounding rock. The saturation process for the buffer can be limited by the supply from the rock and, for this reason, the hydraulic conditions in the near field are decisive.

SKB has studied water uptake in connection with several different experiments:

- The Prototype Repository at the Äspö Hard Rock Laboratory.
- The Canister Retrieval Test.
- The Temperature Buffer Test (TBT), for which higher temperatures are used which leads to a greater dryout near to the canister surface.
- Scale tests for KBS-3H (on a scale of 1:10).

SKB has also acquired a new code, Code Bright, which supplements the previously used Abaqus code. Calculations of water uptake and flows in the above experiments have been conducted, as they have in the Spanish Febex Experiment and the planned Lasgit Experiment. The evaluation of results is underway.

In the case of water saturated conditions, there is a minor risk of liquefaction occurring in connection with an earthquake. SKB intends to study this phenomenon in a simulated deposition hole (on the scale of 1:40).

Comments by the Reviewing Bodies

SSI would like to see a better basis for the evaluation of the risk of liquefaction and preparations for handling this in the safety assessment.

Furthermore, in SSI's view, SKB should have compiled the most important remaining problems of achieving an even saturation of the buffer under realistic conditions.

SKI's Evaluation

In SKI's evaluation, the saturation process and the early evolution of the engineered barriers should be dealt with in greater detail in forthcoming safety assessments, compared with, for example, SR 97 (see also THMC modeling). In normal conditions, the resaturation process can be considered to be a short transient phase of minor importance for long-term repository evolution. On the other hand, in the case of relatively dry deposition holes without large water-bearing fractures, resaturation can occur for a long period of time (SKB, 2003) which partially coincides with the thermal phase of the repository. These drier conditions must be taken into account in particular detail if it is a matter of siting a repository in the fracture-poor Forsmark lens. One uncertainty is the extent to which the groundwater in the rock matrix, independently of the flow in water-bearing fractures, can contribute to the resaturation of the buffer and the backfill.

In connection with previous RD&D programme reviews and in other contexts, SKI has indicated that the consequences of a slow water saturation phase must be evaluated. At different workshops that SKI has organized (such as SKI, 2004), SKB has stated that placing the deposition holes closer together and a slow resaturation do not have a negative impact but rather can be considered to provide an advantage in terms of safety. In SKI's opinion, SKB should support this thesis by systematically identifying the differences in the system development compared with the deposition holes with more normal water inflow. Some differences may include the possibility that a more extensive dryout is possible for the innermost layer of the buffer, that the development of a homogeneous swelling pressure and the sealing of gaps and cracks will be slower, that a more significant accumulation near the canister surface can occur, that the backfill will be resaturated more quickly than the buffer and that moisture will be supplied from above etc. Possible advantages should also be considered, such as slower radionuclide transport, a smaller supply of corrodants in the groundwater etc.

In SKI's view, SKB has high ambitions with respect to model development. It is particularly positive that SKB has obtained a broader set of modeling tools through its acquisition of Code Bright. SKI considers that this code should be very useful in the interpretation of SKB's long-term experiments, such as the Prototype Repository. However, according to RD&D Programme 2004, fairly extensive experimental studies are necessary in order to provide adequate input data to Code Bright.

6.3.6 Gas Transport

SKB's Report

If the groundwater enters a damaged copper canister, it must be possible to transport the hydrogen gas generated from the corrosion of the cast-iron insert through the buffer. One question that must be answered is the extent to which hydrogen gas pressure and gas transport can damage the buffer and the surrounding rock SKB is currently analyzing this phenomenon through:

- laboratory-scale experiments
- full-scale experiments
- the development of mathematical models for gas transport in bentonite.

Based on results so far obtained, in SKB's opinion, the buffer will not be damaged by gas transport. However, SKB considers that existing experimental data are not sufficient to provide an unambiguous view of how gas transport occurs. SKB has therefore started an extensive project to study the phenomenon in the Äspö Hard Rock Laboratory (Lasgit).

SKI's Evaluation

SKI is very positive to the fact that SKB has decided to conduct the experiment on a full scale. SKI has some understanding for the fact that the practical challenges are considerable, but considers that it would be of great value if the initial results could contribute to the material for SR-Site. SKB should naturally continue to work on the mathematical modeling and the theoretical understanding of the process in order to be able to interpret, in the best manner possible, experimental data that eventually becomes available.

6.3.7 Swelling/Mechanical Interaction

SKB's Report

Several of the favourable properties of the buffer (density, self-healing capacity, deformability, low water activity) are connected to the buildup of a suitable swelling pressure and to the fact that the density of the buffer can be maintained in a long-term perspective. Comments are presented below on the following examples of processes that are of considerable importance for safety assessment:

- impact of the surroundings on swelling pressure (groundwater composition, temperature)
- swelling of the buffer into backfilled deposition tunnels
- possible sinking of the canister through the buffer
- shear movements over the buffer caused by earthquakes.

SKB has worked with laboratory experiments using different buffer densities and sodium chloride concentrations. The experimental results can be explained by a

theoretical model based on immobile ions with different charges (Donnan equilibrium). The effects of a high salinity over long time periods have been studied through a natural analogue (Barra Project). During the next period, experiments will focus on other counter ions besides sodium, the effects of buffer density, the effects of an increased temperature as well as other materials besides MX-80.

SKB has investigated the compression properties of the Friedland clays with the aim of evaluating its suitability as backfill material. Results show that the buffer will swell towards the backfill to a greater extent than is desirable. This requires a considerably greater buffer cover. SKB intends to study the compression properties of other backfill materials and to study this process in the field when the prototype laboratory is excavated.

Based on models for creep in clay, the movement of the canister in the bentonite buffer is expected to only be a few millimeters. However, SKB considers that an uncertainty exists since the results must be extrapolated over longer time-scales than normal. The effects of rock shear have been simulated in laboratory experiments (measurement of deformability and shear strength) as well as finite-element calculations using the Abaqus code.

Comments by the Reviewing Bodies

In SSI's opinion, SKB's programme on mechanical interaction contains a good description of processes although, in other respects, it is difficult to evaluate. SSI considers that an account is lacking of the status of knowledge and remaining uncertainties (for example, concerning uneven resaturation, rock shear, canister sinking). According to SSI, SKB should have described the status of knowledge on the mechanical interaction between the buffer and a backfill consisting of a crushed rock/bentonite mixture (reference design).

SSI considers that an overall description is lacking of the impact of salinity on the resaturation and long-term function of the bentonite clay, with respect to the natural variations in the groundwater (contact with saline deep groundwater or ion-poor glacial meltwater).

Stockholm University (Pereira) raises the problem of buffer deformation and of the swelling of the material towards the backfill. In the opinion of the University, this phenomenon should be investigated through calculations in the safety assessment which should specifically include the risk of an increase in hydraulic conductivity.

SKI's Evaluation

SKI considers that the impact of groundwater with a high salinity should be studied further, especially taking into account the coastal location of the candidate sites. Prior to future safety assessments, the aim should be to obtain a good theoretical understanding and solid experimental data. Therefore, it is good for SKB to study the impact under as realistic conditions as possible and for SKB to include temperature increases as well as the impact on a buffer after ion exchange with calcium. The issue of high salinity is linked to chemical alterations of the buffer as well as ion exchange with calcium. In

SKI's opinion, the criterion for maximum salinity (100 g/dm^3) needs to be based on more detailed information.

Saline groundwater could have a significant impact on repository design and, thereby, have significant economic consequences. This issue can also affect the need for understanding the geochemical evolution of the candidate sites. However, both of these aspects primarily concern the backfill which needs to be handled in larger volumes and which is more greatly affected by the ion strength of the groundwater (see Section 6.4).

SKI is not convinced that it is sufficient to merely take into account the highest salinity in the design premises. Therefore, SKB should also evaluate whether significant losses of mass during periods with highly diluted groundwater can occur (see buffer erosion) and whether any effects arise from a gradual variation between fresh and saline groundwater (based on an evaluation of climate evolution at the pertinent sites).

In SKI's view, the difficulty of showing that a homogeneous and high buffer density can be maintained should not be underestimated. One issue concerns the time-scales for which the buffer density and swelling pressure are homogenized, for example, depending on initial defects in the buffer or uneven groundwater supply. The link with the backfill, which is due to the swelling of the buffer towards the deposition tunnel, increases the difficulty of the analysis. Another issue relates to the extent to which erosion and/or chemical alterations can introduce heterogeneities in the system (see sections 6.3.8 and 6.3.9).

In SKI's opinion, SKB should present tangible measures for improving the understanding of the movement of the canister in the buffer on very long time-scales. One uncertainty is indicated by the fact that the SR-Can interim report did not have a limit for the lowest buffer density. In principle, the process could affect the corrosion process in all canisters. Therefore, SKI considers that it is particularly important for SKB to have a convincing strategy for handling this uncertainty in the safety assessment, even if, in principle, it is highly unlikely that a canister could sink right down to the bottom of a deposition hole. SKB would need to investigate the density at which serious problems could arise in order to evaluate the safety margins for the current concept of a density of around 2,000 kg/m^3.

SKI's opinion, with respect to the impact of shear movements in the rock on the protective roles of the canister and bentonite, is that a large-scale experimental validation of calculation results (such as Börgesson et al., 2003) would provide a valuable basis for future safety assessments. However, it should be pointed out that the need for and possible design of such an experiment should be evaluated on the basis of an assessment of the type of earthquake that is possible at the sites in question. There are many practical issues that have to be resolved for such an experiment, such as issues relating to the representativity of expected results.

6.3.8 Buffer Erosion

SKB's Report

Buffer erosion can occur: 1) in the short term during the resaturation phase due to the groundwater flow in the gap between the buffer and rock 2) in the long term, for example, as an effect of highly diluted glacial saline meltwater. The first erosion process was discovered in connection with the evaluation of KBS-3H while the second has been known for a long time. SKB has studied buffer erosion in laboratory experiments and in the Äspö Hard Rock Laboratory (Colloid Project). The results indicate that some form of technical modification of KBS-3H must be considered in order to prevent buffer erosion. No long-term erosion is expected to occur if the calcium concentration exceeds 1 mM. SKB is planning to continue the experiments with KBS-3H and to develop a model to quantify the removal of bentonite.

Comments by the Reviewing Bodies

The Swedish Anti-Nuclear Movement considers that bentonite is a poor choice of material since it spontaneously forms colloids which can transport radionuclides.

Stockholm University (Pereira) emphasizes that SKB should pursue piping and erosion of the buffer in particular detail and should discuss calculation cases in the safety assessment that take this issue into account.

SKI's Evaluation

In SKI's opinion, prior to submitting an application for the construction of a repository in 2008, SKB should, primarily, investigate the importance of buffer erosion and piping for KBS-3V. The potential for initial buffer erosion is perhaps less than for KBS-3H, although SKB needs to decide whether any specific criteria or engineering measures are required to resolve the problem for the reference concept. SKI cannot exclude periods of significant long-term erosion if a sufficient quantity of diluted glacial groundwater reaches repository depth. SKI assumes that SKB is preparing a solid basis of data for future safety assessments.

6.3.9 Chemical Alteration of the Buffer

SKB's Report

Chemical processes in the buffer can involve the main component montmorillonite and minerals that occur in small quantities (accessory minerals). Chemical alterations may have anything from a very strong to a mere marginal impact on buffer function. With respect to the issue of montmorillonite alteration, SKB has studied the effects of cement pore water in the Ecoclay Project. The results show that a substantial deterioration occurs at a pH of 13-14, whereas a lower pH is more favourable. SKB intends to continue this work with further modeling studies, experiments with bentonite of a lower quality and specific studies of how reactions with iron affect the bentonite.

SKB has studied chemical processes in the bentonite with a temperature gradient (LOT tests) and has also conducted experimental studies of ion-exchange processes (sodium to calcium). Over the next few years, SKB will terminate further LOT tests to study the redistribution of minerals (gypsum, calcite and silicon compounds etc.) and to develop equilibrium constants for bentonite at high temperatures.

Comments by the Reviewing Bodies

The Swedish Anti-Nuclear Movement points out that cement leads to a deterioration in bentonite properties.

In SSI's view, SKB should assume an increase in the hydraulic conductivity of the buffer in the event that illitization cannot be excluded.

SKI's Evaluation

SKI observes that it is not yet possible to decide whether low-alkaline cement can completely resolve the problem of bentonite alteration due to a high pH. SKB needs to specify which additional studies are needed in order to provide a basis for a more definitive choice of cement type. To start off with, low-alkaline cement must be shown to have sufficiently good construction properties for the specific applications. Furthermore, experiments should be conducted to study the reactions between cement pore water with different pH levels (corresponding to the leaching phases from the particular type of cement) and bentonite. Model simulations for relevant time-scales are also required (for example, Benbow et al., 2004). This type of data is needed to justify the assumptions concerning the long-term alteration of bentonite. Cement may be needed for several important functions in the repository and, prior to designing the repository, SKB needs to take into account whether cement should be avoided/limited in the near field surrounding the buffer and canister.

SKI's consultants (Arthur et al., 2005) consider that SKB should implement a method for bentonite modeling which explicitly takes into account the thermodynamic properties of complex clay minerals. The authors of this report consider that models that are solely based on ion exchange, surface complexation and illitization do not provide an adequate basis for excluding the significant conversion of the structure of the smectite clay on time-scales of one million years.

In SKI's opinion, additional studies of how the initial phase with increased temperatures affect the buffer properties are needed. The fact that SKB has not been able to note any significant cementation of bentonite during the LOT tests is positive, but this does not necessarily mean much on a time-scale of several thousand years (a period of increased temperature) if the observations cannot be linked to the modeling results. It is important to show that initial cementation and/or alteration into non-swelling clay mineral do not lead to a tangible deterioration in buffer properties.

With respect to the above comments, SKB should carry out a survey and external review of the strategy for handling buffer alteration processes presented in the interim process report for SR-Can (SKB, 2004). For example, the modeling strategy may have to be supplemented so that it contains a combination of scientifically based approaches

for demonstrating the scientific understanding and simpler and more robust models, for example, in order to show the limited mass exchange with the surrounding groundwater.

In SKI's opinion, it is possible for mineralogical changes in the buffer to be taken into account in the very long time-scales for the safety assessment (up to one million years). The complete alteration of smectite clay is probably extremely improbable but alteration processes could occur near to the canister (which has been exposed to the highest temperature) and in the outer boundary in contact with the surrounding groundwater. This would result in the buffer assuming a stratified structure which might mean that a certain deterioration of buffer properties must be taken into account.

6.3.10 Field Experiments for the Evaluation of Coupled Process in the Buffer

SKB's Report

Ongoing experimental studies of THM processes consist of the Prototype Repository, the Canister Retrieval Test and TBT (THM processes at higher temperatures than normal, about 130ºC). No specific results are reported in RD&D Programme 2004, although SKB intends to compare modeling results with measurement results and observations in connection with the demonstration of experiments with modeling results. The external part of the Prototype Repository and the Canister Retrieval Test will be concluded in 2007-2008.

On a smaller scale, laboratory studies are under way in order to enhance the understanding of the evolution of swelling pressure at different pore water pressures. SKB has carried out measurements in a KBS-3H experiment on a reduced scale (1:10). In this experiment, the spacer blocks and the perforated steel containers were evaluated. A Czech laboratory experiment with a somewhat different buffer material has also been started. SKB intends to continue with laboratory experiments focusing on an improved understanding of THM processes for unsaturated bentonite. An almost full-scale laboratory experiment for KBS-3H will be established and the wetting process will be followed.

Comments by the Reviewing Bodies

SSI points out that the ongoing experiments in the Äspö Hard Rock Laboratory will provide very limited statistical data for the evaluation of coupled processes. SKB should therefore consider expanding its programme for field experiments at Äspö. SKB should also prepare a table showing which processes, including uncertainties such as ongoing experiments, are expected to provide information and when this information is expected to be available.

In SSI's opinion, in the area of coupled processes, SKB has an ambitious programme for laboratory experiments, in general.

According to SSI, it is also of considerable importance for SKB to investigate the cementation of the buffer due to long-term heat exposure. Studies of natural analogues can provide valuable data for this purpose.

Furthermore, in SSI's opinion, SKB provides too brief a description of the area of long-term experiments. SSI would like to see a clearer description of expected results, an evaluation of the adequacy of existing experiments and criteria for evaluation.

SKI's Evaluation

In SKI's opinion, in general, the set of experiments that SKB is conducting at the Äspö Hard Rock Laboratory is good. The experiments have provided and will probably provide much valuable information on individual processes under in-situ conditions. Furthermore, they provide a good opportunity for evaluating the integrated function of the repository in the initial phase and for testing the coupled models that SKB has developed for many years.

However, SKI has noted the technical problems that have recently occurred with the Prototype Repository (electrical heaters for one of six canisters malfunctioned in connection with the pressurization of the Prototype Repository in the latter part of 2004). There is a risk that it may not be possible for the long time series with results from the Prototype Repository to be delivered to an adequate extent and at times when the results are needed. This would be the case particularly if additional technical problems were to arise. Therefore, SKI considers that SKB needs to be prepared to start supplementary and modified long-term experiments pending the outcome of new experiments in the Prototype Repository (such as blocked drainage). It should be pointed out that these problems concern instrumentation and artificial heating of the Prototype Repository. The problems are therefore not directly relevant to an actual KBS-3 repository.

SKI considers, as does SSI, that, independently of the above-mentioned technical problems, it would be valuable for SKB to review its programme at the Äspö Hard Rock Laboratory. SKB should consider whether the ongoing experiments may need to be supplemented in order to provide a basis for future reporting. The 15 years minimum that remains of SKB's current timetable should provide SKB with a good opportunity for obtaining results prior to submitting an application for permission to start operations, which SKB should use if need are identified (SKI, 2004). If SKB is to continue the projects on horizontal deposition, SKB should analyze which field experiments can provide information on the issues that are specific for this concept and how long such experiments should be conducted (for example, for studies of piping/erosion, the spacer plugs and the function of the perforated steel cylinder). SKB should also consider whether there are any experiments that may have to be repeated after a site has been identified in 2008. This would be most relevant if the repository is to be located in the Forsmark lens where the hydrogeology is more different from Laxemar, compared with the Äspö Hard Rock Laboratory.

SKI's view, which SSI shares, is that it would be valuable if SKB were to prepare a more detailed account of expected results from ongoing long-term tests (there are certain data in SKB's plan of action which was attached to the RD&D programme report) which can be used as a basis for future applications. Such a basis would facilitate regulatory review planning by the authorities and independent evaluations of work. For this reason, detail plans are required of the measurements which will be conducted when dismantling the external canister positions prior to submitting an application in 2008. It would also be valuable if SKB could specify the expected use of experimental results

from long-term experiments within other nuclear waste programmes (which are described in RD&D Programme 2004). These can essentially increase the experimental basis for testing coupled models. However, particular attention must be paid to the possibility that the conditions for these experiments may differ substantially from KBS-3 which can reduce their usefulness as a direct basis for decision-making.

In SKI's view, it is probably unrealistic to experimentally verify the long-term evolution of the barrier system for all phenomena that need to be taken into account. These variations can be expected to be large, for example, with respect to hydraulic conditions near to deposition holes. This emphasizes the importance of SKB having access to well-developed simulation tools, which can provide answers to questions concerning the importance of phenomena that cannot be tested through experiments.

6.3.11 Integrated Modelling of THMC Processes

SKB's Report

SKB has used Code Bright to study THM processes in the ongoing TBT test and has modeled the water saturation process for KBS-3V. In the future, SKB will conduct experiments to develop material parameters for Code Bright. An extensive co-operation is being planned also with respect to the modeling of tests conducted under the auspices of Andra and Enresa. As the implementation of Code Bright and Abaqus are further developed, the tests being conducted at the Äspö Hard Rock Laboratory will be simulated. SKB has also planned to simulate large-scale tests in Canada and Switzerland.

Comments by the Reviewing Bodies

SSI is positive to SKB's development of coupled models.

SKI's Evaluation

In SKI's view, SKB's plans to continue modelling work on coupled processes in the buffer are detailed and suitable. However, extensive work remains to be done. SKB should therefore primarily concentrate on the studies with the best premises for providing a useful basis for future applications.

SKI considers that an account is lacking of how chemical processes are to be integrated into SKB's work with coupled processes. SKI also finds that RD&D Programme 2004 lacks a description of modelling tools that can handle chemical processes and relevant applications. An obvious example is the analysis of how precipitation reactions driven by the temperature gradient can affect the long-term properties of the buffer.

SKI would like to see a structured modelling of possible processes that could result in discrepancies in relation to SKB's central assumption that buffer homogeneity will be guaranteed by the swelling properties of the smectite clay. Some examples include:

- uneven saturation due to the distribution of cracks in the deposition holes or the supply of groundwater via the backfill

- dryout in parts of the buffer nearest to the canister surface in dry deposition holes and its importance for continued heat transport
- evolution of buffer density near to the backfill due to the interaction between the buffer and backfill and its impact on saturation
- possible changes in the mechanical and hydraulic properties of the buffer near the canister and in the interface with the rock, for example, the closure of cavities after piping/erosion
- the importance of processes in cracks and gaps and the time to closure of these cracks and gaps.

SKB needs to determine how important it is for the long-term safety of the repository that buffer homogeneity is achieved in a specified time. The determination of this factor will determine the extent to which tests and model studies are needed which can provide information on discrepancies that can cause heterogeneities. The necessary scope of the studies of buffer evolution also depends on how well the environment of the buffer can be specified (rock and groundwater).

6.3.12 Other Processes

SKB's Description

SKB has studied the mechanical interaction between the buffer and near field rock for the KBS-3H alternative. Corrosion of the external perforated steel cylinder is not expected to lead to any problems in this respect. In tests, SKB has also studied the swelling of bentonite through the perforated steel container. SKB intends to continue with a full-scale test to study how the swelling pressure builds up in the case of KBS-3H alternative (Big Bertha test).

Microbial processes may be of importance for the formation of sulphides near the canister. However, based on previous tests, SKB's evaluation is that microbial activity in the buffer is negligible thanks to the limited access to water, nutrients and space. SKB intends to conclude a 5-year buffer test at the Äspö Hard Rock Laboratory (Lot tests) in 2005, which is expected to provide information on this issue.

Radionuclide transport via diffusion is faster for certain positively charged ions (alkaline metals, alkaline-earth metals). This is known as surface diffusion and is due to the interaction with negatively charged mineral surfaces. The opposite phenomenon, anion exclusion, involves long-term anion transport. Surface diffusion and anion exclusion decrease in importance at high ion strengths and a lower surface density. SKB has studied these processes in situ (Chemlab probe and Lot tests) and has found that pertechnate ions (TcO_4) are transported faster than expected due to the slow reaction. With respect to the transport of other ions (Sr^{2+}, Cs^{+}, Co^{2+}, I^{-}), there is agreement between in-situ conditions and laboratory conditions. SKB plans to evaluate the description of the diffusion process in bentonite with ion equilibrium which, from a theoretical perspective, could be a more practicable method compared with the current method. SKB also plans to experimentally study transport resistance between bentonite and water-conducting fracture.

SKB has studied the diffusion of certain organic colloids (humic acid) and found that these are not prevented by compacted benonite in the same way as certain inorganic colloids. These organic substances bind certain metal complexes and accelerate their transport (Eu(III), Co(II). SKB intends to conduct further work in this area.

SKB provides a brief description of processes such as radiation attenuation, thermal expansion, advection, diffusion, radiation-induced montmorillonite alteration and radiolysis of pore water. Knowledge is considered to be adequate and no substantial work has been planned.

Comments by the Reviewing Bodies

The Waste Network Association points out that organic colloids have been found to pass through compacted bentonite and considers that this is highly unsatisfactory. In the view of the Association, this could be a reason to eliminate the alternative of disposal in water-bearing crystalline bedrock.

SKI's Evaluation

In SKI's opinion, SKB has a sound programme for studying microbial activity in the buffer. Even if SKI considers that there are arguments to exclude significant microbial activity, there is a need to continue the studies bearing in mind the considerable importance of the issue for the analysis of copper corrosion. There may be a need to better define the safety margins taking into account the fact that a certain deterioration in the buffer cannot be excluded on a time-scale of one million years. For example, it would be valuable to know what impact microbial activity in the buffer could have if it is theoretically assumed to be possible. What would limit the activity of, for example, sulphate-reducing bacteria in such a situation? The question is connected to the risk of cavities arising in the buffer (due to, for example, erosion or unsuitable emplacement of bentonite blocks) although it can also be considered as a purely hypothetical case in order to understand this buffer function.

SKI considers that a description is lacking of the work that will be conducted to better understand how the buffer is affected by freezing/defrosting. According to SKB's current handling of this process in the safety assessment (that the buffer loses all of its favourable properties after a period of permafrost), considerable demands must be made on the basis for excluding permafrost. SKI recommends that SKB should consider conducting experimental studies to see how the favourable properties of the bentonite (buffer and backfill) change after a cycle with freezing/defrosting. This particularly applies in the case where more than insignificant uncertainties remain after the analysis of maximum permafrost depth.

In SKI's opinion, SKB has a good programme for studying radionuclide migration in the buffer, especially through the possibility of conducting in-situ tests in the Äspö Hard Rock Laboratory (Lot tests and the Chemlab probe). The priority of further enhancing the understanding of specific phenomena such as surface diffusion, anion exclusion and complex formation with organic substances seems to be correct. In general, SKI considers the need for further knowledge relating to radionuclide migration to be considerably less than the need for knowledge concerning the buffer's capacity to protect the canister.

6.3.13 SKI's Overall Evaluation - Buffer

In SKI's opinion, SKB has a good programme for buffer issues and a commendably clear account of these issues is provided in RD&D Programme 2004. Significant progress has been achieved in recent years in terms of model studies and code development (Code Bright, Abaqus) as well as experiments. However, in SKI's opinion, SKB should evaluate the need for supplementary long-term experiments, especially taking into account technical problems relating to one of the canister positions in the Prototype Repository. Prior to submitting future applications, there is a clear need to demonstrate, through comparisons with practical experiments, that SKB's knowledge and modeling tools for the buffer are adequate. If the horizontal deposition programme is to be pursued, SKB must decide which long-term experiments may be needed for this purpose. In the long term, SKB must also decide whether additional long-term experiments are needed at the final repository site.

SKI observes that SKB, compared with the work on the copper canister, has not made as much progress in the development of fabrication technology and procedures for practical handling. For example, SKB has not yet been able to test its reference method for full-scale bentonite block compaction (isostatic pressing). SKI is not aware of any major practical difficulties that have to be solved, but it is nevertheless important that future safety assessments should be based on information that is as well-founded and realistic as possible. For example, during future routine operating conditions, poor quality bentonite blocks or an unsuitable block emplacement may occur. It is not clear to SKI whether SKB intends to take into account such practical problems explicitly in connection with the description of the initial state of the repository or whether they will be completely excluded and, if so, on what grounds.

In recent years, SKB has made progress in broadening its concept to include more buffer materials and a different buffer design for KBS-3H. In SKI's view, this work has been successful and, in the long term, it is well justified, since it will result in greater freedom of action and possibly conditions for improved cost-efficiency. However, SKI would like to see clearer priorities set regarding the concept upon which future applications are to be based (2006 and 2008, according to the current timetable). Without clear priorities, there is a risk that the limited competence and resources available in Sweden will become too fragmented.

SKI observes that the specification for the buffer (SKB, 2002) is multifacetted and partially difficult to interpret. SKB needs to continue its work on the clarification and determination of detailed requirements in the specification and on ensuring that there is a basis that can justify requirements and criteria. It is obvious that SKB's premise has been that all of the criteria will be met during a period of one million years and that no deterioration of the buffer needs to be taken into account. SKI is not convinced that all possible deterioration/changes (maintenance of density, homogeneity, mechanical properties etc.) can be totally excluded. However, this does not mean that all deterioration/changes need to have a decisive impact on long-term safety. In SKI's view, SKB needs to illustrate the effects of potentially unfavourable buffer features, events and processes (FEPs) if these cannot be dismissed on solid grounds. The preparation of information for future safety assessments which justify the handling of unfavourable FEPs for the buffer should be given a high priority.

In SKI's opinion, SKB needs to start planning the basis that will be needed for submitting an application for permission to start operation in around 2020. This planning needs to cover the handling of practical issues related to the fabrication, handling procedures, testing, documentation and quality programmes as well as long-term experiments.

Unlike a copper canister, a bentonite buffer is a component that is included in the nuclear waste programmes of most other countries. SKB has previously stated that the need for research and long-term demonstration can partially be satisfied through knowledge transfer from other programmes and RD&D Programme 2004 contains several examples of this. SKI supports these plans and considers that they are examples of efficient resource utilization. However, there are questions related to the extent to which these experiments are actually used in SKB's safety assessments. In order for SKI to judge the value of an exchange of experimental information from international long-term experiments, SKB must specify the relevance of the information to a KBS-3 repository, any critical differences that must be taken into account in the interpretation as well as whether the time of the experiment allows for information to be a part of the decision-making basis for the Swedish programme.

6.4 Backfill

In this section, SKI presents comments on Chapter 18, "Backfill", of RD&D Programme 2004.

6.4.1 Introduction

In its review of RD&D Programme 2001, SKI pointed out that the backfill is a necessary condition for the buffer to function as intended and so that the near field rock does not short circuit as a barrier against groundwater flux. SKI recommended SKB to determine the requirements and criteria that must be made with respect to the backfill material. Prior to licensing, data and methods must be available which show how these requirements can be met, such as method choice, application technology and control methods. A suitable backfill material should also have been made at that time.

SKB's Report

SKB's requirement on the backfill is that it:

- must have a stiffness that minimizes buffer expansion upwards in the tunnel (this allows the buffer density to be maintained)
- must have a hydraulic conductivity that is comparable to that of the surrounding rock (otherwise the deposition tunnels may act as pathways for groundwater flow in the repository)
- must exert a given swelling pressure against the roof (to maintain a swelling capacity that can seal possible effects of piping and creep movements in the backfill).

SKB states that groundwater salinity is of considerable importance for the backfill properties such as swelling pressure and hydraulic conductivity. A number of uncertainties remain for a bentonite-mixed backfill with respect to these parameters.

SKB considers that, for the existing compaction results, there is a risk for considerable deterioration in the backfill function, already at a relatively low groundwater salinity (a few per cent TDS). SKB also states that existing compaction techniques for backfill material in a deposition tunnel do not provide a sufficiently high montmorillonite density to meet the safety margins for seawater conditions. The bentonite-mixed backfill in the Backfill and Plug Test at the Äspö Hard Rock Laboratory provides a measured permeability that is generally higher than the theoretically calculated permeability. The measured hydraulic conductivity for the section with 100 per cent crushed rock is far too high (about 10^{-7} m/s) and, for the 30/70 bentonite/crushed rock mixture, the conductivity is about 10^{-8} to 10^{-9} m/s. SKB considers that the latter is at the limit of the acceptance criterion and therefore considers that further tests are justified/required.

Results from laboratory experiments and field tests on Friedland clay indicate that there are difficulties in achieving an adequate compressibility in the field tests to prevent considerable swelling of the buffer in the deposition holes.

SKB's studies of the backfill will continue to focus largely on three different projects: the Backfill and Plug Test, the Prototype Repository and Backfill and Closure of Tunnels and Rock Caverns.

In the phases of the Backfill and Closure of Tunnels and Rock Caverns that have so far been completed, SKB, which is conducting the project together with Posiva, has reached the conclusion to continue the project using three alternative concepts for backfill:

- in-situ compacted 30/70 bentonite/crushed rock (reference concept)
- in-situ compacted Friedland clay
- pre-compacted blocks.

The project will be carried out in four phases where phase two will continue until 2005 and where phase four, according to SKB's plan of action, will be completed in 2012.

Comments by the Reviewing Bodies

With reference to SKB's account of completed and planned backfill tests, the Waste Network Association states that, throughout the entire test process, the backfill technology seems to have presented difficulties. The difficulties have been so great that, so far, it has not been possible to consider the method to be functional. The Association questions whether the backfill will ever function on the basis of the conditions that exist since many different backfill materials have been tried and tested.

With respect to the backfill and closure, the Waste Network and the Opinion Group for Safe Disposal (Oss) indicate the absolute necessity of ensuring that all safety solutions that are linked to the selected KBS-3 method are tested and reported before the licence application for the method is accepted. Therefore, it is not acceptable that so much

remains to be investigated and reported when the method account, according to the company, must be ready by autumn 2005.

The Waste Network and Oss also consider that SKB must more clearly describe how it will prevent access tunnels and different shafts from evolving into capillary systems that lead radioactive substances up to the ground surface when the barriers around the canisters no longer function as intended.

In SSI's opinion, it is good that SKB has now intensified its R&D programme to obtain a working concept for tunnel backfilling. However, in SSI's view, a number of critical uncertainties remain to be investigated, for example, concerning the mechanical interaction between the buffer and the backfill, the importance of saline groundwater and the risk for piping during deposition. Furthermore, bearing in mind that SKB has not yet selected the final concept for the backfill and that reporting of the continuation of the programme is vague, SSI is not convinced that SKB will obtain adequate results in time for a licence application for a repository in 2008. Therefore, SSI considers that SKB should prepare a detailed plan of action which describes what needs to be achieved prior to selecting a reference concept in the licence application in 2008 as well as which additional full-scale tests for the selected concept may be needed before an application for initial operation is submitted.

Stockholm University (Pereira) observes that with respect to the backfilling of tunnels, the experience of sealing is still deficient. Therefore, in the view of the University, a line of reasoning is required regarding how the safety assessment will handle scenarios or variant calculations which take into account long channels in the tunnel ceilings which result in higher conductivity than in the remaining parts of the tunnels.

With respect to completed and ongoing experimental work in the Äspö Hard Rock Laboratory, Stockholm University (Pereira) would like a new document (in addition to annual reports) to be published with an overall description of the knowledge that has so far been gained and that is desired, focusing on both national and international activities.

The Safety Group, Oskarshamn Municipality states that, much work and testing remains to be conducted at the Äspö Hard Rock Laboratory for the backfill. The Group raises the relevant question in this context of whether salt water in the system can impair clay swelling which would degrade backfill function. The Group wonders what importance this effect has and how it can be counteracted.

SKI's Evaluation

Like SKB, SKI's conclusion is that pure crushed rock is eliminated as backfill in deposition tunnels while the alternative involving the 30/70 mixture of bentonite and crushed rock needs to be further investigated. Bearing in mind the fact that no unambiguous results have been obtained for this concept, SKI supports SKB's plans to also investigate the Friedland clay and compacted block alternatives. However, the most important factor prior to future applications is that SKB should be able to present an alternative to the backfilling of tunnels that can be shown to have good prospects of meeting the criteria.

In SKI's view, SKB needs to prepare material that better justifies the backfill criteria. To more easily put the backfill into a safety context, more detailed analyses of the implications of a spectrum of possible properties are needed. SKB needs to analyze both the importance of the backfill for other barrier components as well as for dose and risk calculations. Previous safety assessments, such as SR 97, did not deal with any details for this component of the repository. A criterion for the hydraulic conductivity of the backfill needs to be justified on the basis of groundwater flux simulations. These simulations should, for example, shed light on the importance of the backfill properties for very dense rock such as the Forsmark lens.

In SKI's opinion, just as for the buffer, SKB needs to systematically analyze FEPs that can cause a deterioration in long-term function, such as:

- high salinities that lead to reduced swelling pressure against the surrounding rock (SKB should more clearly justify the criterion for the highest salinity that is currently set at 35 g/l)
- piping/erosion after the closure of a repository tunnel, leading to a loss of material
- erosion during periods when highly diluted groundwater can reach repository depths, leading to a loss of material
- reduced swelling pressure due to chemical alterations such as illitization of the bentonite component of the backfill
- impact of cement primarily on the bentonite component of the backfill.

Since none of these processes can probably be completely excluded, SKB needs to prepare analyses which show that the scope of these processes is limited and does not have a decisive impact on the long-term safety of the repository. SKB needs to investigate the importance of heterogeneities which these processes can cause.

SKI considers that, in the description of the initial state of the backfill, SKB should take into account the possibility that the quality of material, handling, application etc. can vary during the long period of time that the repository needs to be in operation. SKB should also describe the function that quality assurance and inspections can have in this context.

SKI observes that, in the Prototype Repository experiment where Milos bentonite (sodium-converted calcium bentonite) is the clay component in the backfill, adequate density is not achieved in relation to the criteria. SKB considers that this is due to compaction problems relating to the quantity of instruments and cables in the backfill. This means that additional tests will be necessary before Milos bentonite can be considered to be an alternative to MX-80.

6.4.2 SKI's Overall Evaluation – Backfill

SKI supports SKB's ambitions to evaluate alternative backfill designs over the next few years. The most important factor prior to future applications is that SKB should be able to present an alternative to the backfilling of tunnels that can be shown to have good prospects of meeting the criteria.

In SKI's view, SKB needs to prepare material that better justifies the backfill criteria. To more easily put the backfill into a safety context, more detailed analyses of the implications of a spectrum of possible properties are needed. In SKI's opinion, in the description of the initial state of the backfill, SKB should take into account the possibility that the quality of material, handling, application etc. can vary during the long period of time that the repository needs to be in operation.

SKI considers that, just as for the buffer, SKB needs to systematically analyze FEPs that can cause a deterioration in long-term function.

SKI considers that SKB needs to show how results from the Backfill and Plug Test and the Prototype Repository will be used prior to the submission of an application in 2008 for permission to construct the repository.

6.5 Geosphere

In this section, SKI presents comments on Chapter 19, "Geosphere", of SKB's RD&D Programme 2004.

Some of the reviewing bodies have submitted comments of a general nature on the geosphere chapter. These comments are therefore reported at the beginning of this section.

General Comments by the Reviewing Bodies

Gothenburg University (GU) considers that SKB has largely assumed its responsibility for the geoscientific issues that are relevant for the siting of a repository. In GU's opinion, SKB needs to describe in greater detail what it means by "granitic composition" and why granitic rock types in particular are the most suitable for repository siting.

The Swedish NGO Office for Nuclear Waste Review (MKG) considers that certain parts of the content of the chapter on the geosphere are highly specialized and that the content is probably only understood by specialists in the particular subject areas.

Stockholm University (Pereira) wonders whether the timetable of 2006/2008 is realistic seeing that several issues cannot be considered to be trivial. In the opinion of the University, even if SKB can meet its timetable by working twice as hard, the quality of the review of the work must be maintained and this has to be achieved within too constrained a timeframe.

The Geological Survey of Sweden (SGU) considers that Chapter 19 of RD&D Programme 2004 provides a general and pedagogical account of the geosphere.

Östhammar Municipality considers that a clear link to the site investigation and environmental impact statement is missing.

The Local Safety Committee at the Nuclear Facilities at Forsmark is particularly positive to the newly acquired knowledge that is reported in the chapters, “Geosphere” and “Biosphere”.

6.5.1 Initial State of the Geosphere

SKB’s Report

SKB starts off by defining the initial state of the geosphere and how it is affected by different processes during the repository lifetime. SKB underlines the importance of results from the site investigations which are the most important basis for determining the state of the geosphere after closure (initial state). SKB refers to other reports apart from RD&D Programme 2004 which present the programme for ongoing site investigations.

Comments by the Reviewing Bodies

SGU is satisfied that good work has been put into increasing the knowledge of structural geology with a focus on new formation, dating of fracture systems and reactivation of existing fracture systems. Knowledge obtained together with results from the site investigations are an important basis for optimally determining the initial state of the geosphere before the construction of a repository.

SKI’s Evaluation

The section that describes the initial state of the geosphere completely focuses on describing the disturbances in the geohydrological and geochemical situation at the site of a future repository. In SKI’s opinion, it is at least as important to take into account the disturbances that occur through the blasting of the repository, which affect the rock mechanical and thermal initial state.

SKB should also have been clearer in stating what resources and what preparedness and flexibility exist to take into account site-specific issues that require some type of research work. The lack of preparedness concerning the acquisition of knowledge can impact on future applications since the timetables for the application do not allow greater delays in knowledge acquisition. In SKI’s view, the link between research work and ongoing site investigations must be clarified.

Furthermore, in SKI’s opinion, a clear link is lacking to the ongoing site investigations and the problems at each of the sites can have (such as high rock stresses, saline groundwater etc.). In SKI’s view, in the RD&D programme, SKB should discuss in greater detail how it intends to meet and handle problems that are now known. SKB should also have been clearer in describing which resources and preparedness exist to handle these site-specific issues which require some type of research work.

6.5.2 Heat Transport

SKB's Report

SKB will increase and better co-ordinate the analysis work in order to determine the distance between canisters, calculate the effects of displaced canister positions and, on different scales, investigate numerically and analytically how the thermal properties of the rock affect canister distance.

The work on developing, calibrating and verifying methods for determining thermal properties is continuing as is the work on converting results into thermal models on different scales.

A thermal model for the Prototype Repository at the Äspö Hard Rock Laboratory will be prepared with the aim of testing and evaluating the accuracy and reliability of the thermal model.

The Prototype Repository and the Canister Retrieval Test are modeled using coupled THMC codes. According to SKB, the aim is to evaluate and verify models which, at the same time, describe the transport of heat, water, steam, gas and dissolved salts in the partially unsaturated buffer.

Comments by the Reviewing Bodies

Stockholm University (Pereira) states that the expected evolution of the sealing process, which is due to the high temperature of the canister surface (80ºC) and water saturation is unclear. The University considers that this should be analyzed with the help of modeling that is based on ongoing full-scale tests, the Prototype Repository, the Canister Retrieval Test and TBT. In the view of the University, information from these tests should allow the modeling to be refined using the Abaqus code.

The Swedish Research Council considers that enough calculations of heat transport using heat conductivity models seem to have been performed and that the work to be done in the continuation of the programme appears to be well justified. The Council also discusses various assumed values for heat capacity and other parameters and how these can affect, for example, the surface temperature of the canister. The Council also puts forward an alternative explanation to the 25-per cent difference between measured K values and the K values measured in the laboratory.

SKI's Evaluation

SKI finds that SKB has modified its research work in relation to RD&D Programme 2001. SKI considers that SKB, with the now partially conducted and increased work, has a better level of ambition in its programme to resolve important remaining issues in the heat transport area.

With respect to heat transport in the rock, SKI's advisory group on site investigation issues, INSITE, previously pointed out the importance of SKB studying the impact of

anisotropy and of SKB actively continuing to develop a field instrument which can determine the thermal properties of the rock mass in boreholes.

SKI would also like to emphasize the importance of continuing with the ongoing temperature measurements in the Prototype Repository in order to provide the opportunity for the calibration of the thermal model calculations now used and of exploiting/using the thermal parameter values from the laboratory tests at the Swedish National Testing and Research Institute (SP).

6.5.3 Groundwater Flow

SKB's Report

SKB points out that development work in the groundwater flow area mainly relates to the development of calculation tools (Connectflow and DarcyTools), but that certain studies have been conducted to obtain greater knowledge of specific issues such as near-surface groundwater flow and large-scale groundwater flow in order to better understand the problems surrounding recharge and discharge areas.

With respect to the problems surrounding recharge and discharge areas, SKB has conducted and reported two modeling studies, one for Eastern Götaland (Follin and Svensson, 2003) and one for Northern Uppland (Holmén et al., 2003). SKB has also presented a comprehensive report where it discusses the importance of groundwater flow conditions and salinity for repository siting (SKB, 2003a). According to SKB, these studies show that local flow patterns caused by the relationship between local and regional gradients dominate the groundwater flow down to typical repository depths and that the occurrence of saline groundwater at depth may serve as a floor for the groundwater flow.

Comments by the Reviewing Bodies

The Waste Network and Oss would like RD&D Programme 2004 to be supplemented by an overall and comprehensible description of groundwater flow and the recharge and discharge problems in the areas in question. Furthermore, in accordance with environmental legislation, SKB should compare these areas with interior siting alternatives where the environmental conditions can be expected to be better.

Gothenburg University finds that the planned programme for groundwater flow is satisfactory, but points out the importance of obtaining detailed geological information.

The Local Safety Committee at the Nuclear Facilities at Forsmark notes that SKI and SSI have pointed out to SKB that additional analyses are needed to improve the understanding of the regional groundwater flow and that SKB has started a project in order to respond to the regulatory authorities' comments. Furthermore, the Committee considers that SKB has a high level of ambition for raising the level of knowledge in the area.

The Swedish NGO Office for Nuclear Waste Review notes that SKB's account lacks a discussion of the problems of recharge and discharge and how these problems are related to siting.

With respect to the problems concerning recharge and discharge and how these problems are related to the issue of coastal or interior siting, Oskarshamn Municipality writes in its statement that the Municipality sees a great need for clarification with regard to two points: (i) A clear and unambiguous account of regional groundwater modeling for Småland and (ii) An overall account of all factors affecting an interior and a coastal siting of a repository and an explanation of how SKB will take into account these factors in site selection.

The Swedish Radiation Protection Authority (SSI) is positive to the fact that SKB is further developing its hydrology models in order to be better able to evaluate the importance of heterogeneities on different scales. SSI also emphasizes the importance of SKB verifying and documenting the newly developed models before they are used for future licence applications. Furthermore, SSI considers that it is positive that SKB is planning different studies to shed light on the time-dependent development of groundwater salinity.

With respect to SKB's reports which study the problem of recharge and discharge areas, SSI refers to the conclusion that it reached in its review, namely that the results of the study are insufficient to exclude the possible advantages of an interior siting and that SKB should carry out a more thorough analysis. SSI then notes that SKB has now started an additional modeling study for Eastern Götaland.

SGU notes that studies and models of groundwater/groundwater flow have been conducted on different scales and at different depths and points out that it is important for these to be compiled so that, together with studies and models of radionuclide transport and adhesion processes, they can provide a consistent view where both the area closest to the repository and the region as a whole are adequately represented. SGU also points out that it is necessary to carry out many realizations with the analytical models in order to obtain different possible outcomes and thereby take into account the uncertainties that remain. SGU also considers that the importance of large discontinuities in the rock as well as the impact of differences in permeability along individual fractures on the flow should be described. The modeling should also cover the transition to the soil layer and the importance of layers with greater permeability in soil. SGU further points out that it must be clarified whether restrictions are needed for drilling and, in that case, within which area and at which depth.

The Swedish Research Council points out that, in groundwater flow modeling, not only is it important for minor fractures to be approximated to continuum models on a large scale but that large fracture zones that exist in the rock are also important.

SKI's Evaluation

SKI considers that SKB's account in RD&D Programme 2004 provides a good summary and status report of the modeling tools used to describe the groundwater flow. In SKI's opinion, SKB describes a well thought out and ambitious programme for the development of the Connectflow and DarcyTools calculation codes and that it is an

advantage for SKB to use and test these codes in the site modeling projects and in the safety assessment work.

However, as in its review of the SR-Can interim report (SKI and SSI, 2005), SKI would like to point out that it is vital that SKB should set aside enough time to evaluate and document the different models before applying them in SR-Can and eventually in SR-Site.

SKB's calculations of the groundwater flow are based on a number of simplified assumptions concerning the natural system (for example, concerning boundary conditions on the surface and lake bottoms as well as the heterogeneity structures of the rock and the Quaternary deposits). SKI does not consider these assumptions to be justified and confirmed yet. For this reason, SKI considers that RD&D Programme 2004 lacks a plan for how SKB will obtain data to test and verify the above-mentioned models. Without such data, the model results should not be used as reliable predictions.

In RD&D Programme 2001, SSI and SKI both requested that SKB should present an account of the recharge and discharge problem. In response to the authorities' request, SKB has now carried out and reported two model studies (Follin and Svensson, 2003 and Holmén et al., 2003) as well as a summary (SKB, 2003a). In turn, the authorities have presented their comments and criticism of these studies (SSI, 2004 and SKI 2004b). For this reason, SKB is now planning to conduct an additional model study for Eastern Götaland in order to respond to the authorities' comments. SKI notes that these planned activities are not reported in RD&D Programme 2004 since the decision to carry out the study was made after RD&D Programme 2004 had been written. However, SKI was informed in advance and is positive to these plans and is awaiting the results of the study.

6.5.4 Gas Flow/Dissolution/Formation

SKB's Report

SKB observes that the need for research in this area is limited. Nevertheless, SKB intends to investigate whether the conditions can exist which would cause a free gas phase to form in the geosphere. If so, experimentally verified models for bubble flow are needed. Another question that needs to be investigated is whether two-phase flow (namely groundwater and a gas phase) need to be incorporated into the analysis of repository saturation.

SKB intends to build up the database for dissolved gases in the groundwater using data from ongoing site investigations and data from the Äspö Hard Rock Laboratory. New methods for the extraction and analysis of gases have been developed.

SKI's Evaluation

In SKI's opinion, gas flow in the geosphere probably has minor consequences for repository safety. However, gas flow in the repository near field might affect the engineered barriers, which needs to be investigated. In SKI's view, SKB would be well served by having tools for performing scoping calculations available for the data

handling, for example, in the process report. SKB should also investigate whether there may be a link between gas flow and colloid transport (colloids can accumulate in the interface between two phases).

In SKI's opinion, SKB needs to continue its research into the interaction between dissolved gases and microbial processes in deep groundwater.

SKI also considers that it is positive that SKB intends to take into account two-phase flow in the analysis of repository resaturation, since this phase occurs during the time when a relatively detailed analysis of the repository evolution is required (for example, the first thousand years, according to SSI's regulations, 1998:1).

6.5.5 Movements in Intact Rock

SKB's Report

SKB has developed a strategy to prepare a site-descriptive model for the basic issues concerning the characterization of the mechanical properties of the rock. The strategy is applied and developed in connection with ongoing site investigations. SKB has also carried out a general survey of methods for rock stress measurements and how these are to be evaluated.

In the ongoing APSE experiment at the Äspö Hard Rock Laboratory, a detailed characterization and modeling of stresses and deformations was carried out. In 2005, a complete evaluation of the test is being conducted and this will then provide the basis for an in-depth analysis with the aim of comparing predicted properties in the rock mass with experimental results.

SKI's Evaluation

In connection with its continuous followup of ongoing site investigations and with the support of SKI's advisory group, INSITE, SKI has presented its views on SKB's site-descriptive rock mechanics models and methods for rock stress measurements. In this case, SKI considers that routines for providing feedback to SKB have worked well.

In SKI's opinion, SKB's account of the APSE experiment in RD&D Programme 2004 is very brief, which makes it difficult for SKI to judge the feasibility, the ultimate objective and final results. However, in view of the information that SKI has been given on the APSE experiment in another context, SKI considers that the evaluation and in-depth analysis of the test should most likely be very useful in the continued work.

Furthermore, SKI considers that the ongoing APSE project is important for SKB's assessment of future rock breakout over time. However, SKI would like to point out that the results depend on the geology and the situation could be different at any of the other sites (Forsmark and Laxemar). The different rock stress situations in Simpevarp (very low magnitudes) and Forsmark (very high magnitudes), seen in relation to the normal rock stress situation in Fennoscandia, underlines the importance of further shedding light on these issues and finding a reasonable explanation. Therefore, in SKI's view, the

site-specific aspects relating to rock stresses and rock strength need to be further analyzed.

6.5.6 Thermal Movement

SKB's Report

SKB considers that the risk of canister damage due to thermomechanical loads is zero in practice. This assumes that no canister deposition holes can be expected to be intersected by fractures with length greater than 700 metres in the dip direction.

SKB is planning to continue with analyses of the thermally generated movements and stress changes within the framework of the APSE experiment. Within the framework of the site investigations/design, thermomechanical numerical analyses are also being conducted where site-specific data are being used.

SKI's Evaluation

SKI would like to stress that SKB has not yet shown that canister holes will not be intersected by fractures with a length greater than 700 metres in the dip direction. In SKI's view, SKB still has some work left in order to also demonstrate that fractures of a shorter length do not need to be taken into consideration in the analysis.

With respect to thermally-induced movements, SKI would like to point out that SKB should take advantage of any thermal movements occurring in the rock masses at the Prototype Repository for calibration and possible modification of the coupled calculations and simulations planned for each site within the framework of the site investigations.

Finally, SKI observes that there are still a number of ongoing experiments that need to be concluded and analyzed before definite conclusions can be drawn concerning thermally-induced movements in the rock mass.

6.5.7 Reactivation – Movements along Existing Fractures and New Fracturing

SKB's Report

In RD&D Programme 2004, SKB specifies the new knowledge that has been gained since 2001. For example, SKB mentions work that has improved knowledge of the role of the fracture system for deformations in the near field in connection with tunnel excavation and the drilling of deposition holes. SKB states the conclusion that the role of the fracture system for deformations in connection with the excavation of the Zedex tunnel in the Äspö Hard Rock Laboratory could be less important than previously assumed which, in SKB's view, is confirmed by the results from the tunnel blasting for the ASPE experiment and other results.

Seismically-induced shear movements in fractures have been analyzed dynamically unlike the approach used in SR 97 (non-dynamic analysis). According to SKB, the

results indicate that the static contribution to the induced fracture movement dominates, which could mean that, for the deep repository, it is sufficient to carry out purely static analyses as those conducted in the analyses presented in SR 97. According to SKB, this would simplify continued work, especially with respect to the analysis of the impact of large earthquakes.

Thermohydromechanical effects of future glaciations on a repository have also been studied in the Decovalex project.

The continuation of SKB's programme in this area also contains issues that have been discussed in different contexts between SKI and SKB: For example, the interaction between minor fractures, the respect distance, the analysis of the mechanisms for postglacial fault movements, the risk that the repository itself may function as a plane of weakness and spalling. SKB intends to continue the work on developing models to judge fracturing and fracture propagation and the APSE experiment is an important source of knowledge on these issues.

Comments by the Reviewing Bodies

Gothenburg University (GU) considers that SKB should verify the reactivation of existing fractures through detailed mineralogical studies of secondary minerals and alterations around fractures. According to GU, such studies should be conducted on the basis of a fracture zone (and at several places alongside such a zone) with the aim of also estimating how far from such a fracture zone the repository should be located. This is important in order to be able to determine the respect distance.

Stockholm University (Pereira) states that, in view of existing knowledge on paleoseismic earthquakes in connection with the last glaciation, SKB's earthquake scenario should be revised. The University also considers that the respect distance that SKB mentions should be revised.

Uppsala University (UU) emphasizes the importance of ensuring that fracture zones and their properties are thoroughly investigated in the areas which are being considered for repository siting. UU also stresses that the effects of any tectonic movements, including earthquakes, need to be assessed. Since these movements are slow and episodic in nature, long-term measurements of any deformations are necessary.

The Safety Group at Oskarshamn Municipality emphasizes the importance of giving the consequences of earthquakes after a glaciation satisfactory treatment in SKB's work. This is particularly important since the Municipality observes that SKB's account does not provide clear answers to the question of the consequences of major earthquakes and there seems to be uncertainty regarding the size of the earthquakes (larger than a magnitude of 6) that must be analyzed due to calculation-related difficulties.

SKI's Evaluation

The fault movements that could occur in connection with an earthquake with a magnitude of 6 at a distance of 200 metres from the epicenter of the earthquake are estimated to be 6.5 cm. If SKB intends to continue with this type of analysis, SKI proposes that the maximum displacements that can occur should be reported in diagram

form where the magnitude of the earthquake, the distance from the epicenter and the displacement are presented graphically. In SKI's view, it will then be easier to judge how these parameters vary and how they are dependent on each other. Furthermore, SKB should carry out this type of analysis bearing in mind the probable stress state both with respect to magnitude and direction.

SKI observes that SKB's conclusions concerning fracture movements in connection with earthquakes of a magnitude of 6 and more are still associated with uncertainties. This can be seen in the way SKB has formulated its account, for example, "the results now available indicate", "this might mean that". In SKI's opinion, further work is required in these areas before the results can be turned into a feasible concept and how these issues may be dealt with in future safety assessments must be described. SKB's programme states that SKB plans further work on these issues. These will also be dealt with in SSI's and SKI's ongoing project (autumn 2005) concerning expert judgements about earthquake problems. Certain issues have also been raised by Stockholm University (Mörner) which questions SKB's assumptions and analyses.

SKI also finds that studies are lacking which shed light on and determine the strength and deformation characteristics of the large fractures and fracture zones. Such studies are important, especially in the light of the regional and local modeling required for the analysis of stress state, rock mass strength and issues relating to coupled processes.

In this section, SKB does not deal with the issue of the disturbed zone (EDZ) around different openings in a future facility. In SKI's opinion, this is still an open question which needs to be taken into account in future analyses. If fracturing occurs in the near field of tunnels and deposition holes, the permeability could increase by several orders of magnitude. SKI considers that SKB needs to further develop methodology that indicates the possible existence of flowpaths in the disturbed zone along the tunnel length and develops methods to minimize/prevent increased flows. SKB should therefore present its view of the disturbed zone and its possible effects as well as its importance for the safety of a repository in a single account.

In SKI's view, the sections of RD&D Programme 2004 that concern fracturing are important. SKB intends to carry out further analyses and modeling, applying the Fracod and PFC codes. SKB's account includes rock creep but says nothing about sub-critical fracturing, namely, fracturing occurring over long periods of time and at loads that are far below the normal rupture limit.

SKB should analyze the impact of creep on both fractures and intact rock and describe the importance of sub-critical fracturing and its contribution of new microfractures as a function of time (Atkinsson 1984 and 1987). The contribution of microfractures over long time periods is important for the assessment of the changes in permeability around deposition holes and tunnels. The impact of sub-critical fracturing is probably greatest in sites with high rock stresses, as is the case in Forsmark. This is further commented on by SKI in the next section which discusses time-dependent deformations.

In SKI's opinion, SKB's plans which are presented under the heading "Programme" are reasonable with the addition of the comments presented above. The programme will contribute valuable knowledge on issues that are raised in the continuous contact

maintained between SKI and SKB and which require more exhaustive answers than have so far been given. SKI shares SKB's view that the APSE test has an important role to play in that it will contribute data and new knowledge in several of the activities that SKB is planning to conduct during the next three-year period.

6.5.8 Time-dependent Deformations

SKB's Report

Since RD&D Programme 2001, SKB has conducted work on handling and controlling slow creep movements in the host rock surrounding cavities, such as tunnels and deposition holes that are backfilled in different ways. A literature survey of creep in rock masses has been compiled and this indicates that the stress-strength ratio must exceed certain threshold values for creep to occur.

The aim of RD&D Programme 2004 is to be able to limit the stress changes that the rock may be exposed to over time as a result of slow tectonic movements. Furthermore, SKB would like to be able to limit the convergence of tunnels and deposition holes that could occur over thousands of years as a result of the inherent time-dependent materials properties of the rock mass.

SKI's Evaluation

SKI considers that SKB's proposed programme is reasonable.

However, in SKI's view, the high stress magnitudes at the proposed deposition levels in Forsmark indicate that sub-critical fracturing could occur. Sub-critical fracturing is related to the rate at which fracturing occurs and is often reported in diagram form as the fracture rate as a function of the fracture mechanics parameter, fracture toughness (propensity to break). In the case of rock material, the fracture toughness decreases with a decrease in the deformation rate. The slower the deformation, the more probable is the rupture. As far as SKI knows, these relationships have so far not been studied and tested by SKB.

SKB has so far conducted a literature survey of normal creep in rock masses (only a preliminary report is available) and this is a different issue which requires different analyses. Therefore, in SKI's opinion, SKB should investigate whether sub-critical fracturing might be important for micro-fracturing around openings in a repository and, if so, how this issue should be dealt with in SKB's continued work.

6.5.9 Erosion

SKB's Report

SKB has prepared an estimate of the scope of glacial erosion. SKB observes that the most extensive erosion of the bedrock is assumed to arise in connection with glaciations.

SKI's Evaluation

SKB refers to its Climate Programme which handles issues relating to erosion. However, SKI finds that specific studies concerning this process are lacking in SKB's Climate Programme. Therefore, the need still exists for SKB to study/report the possible importance of the process for the repository function. SKI would also like to remind SKB about the comments that SKI made in its review of RD&D Programme 2001.

6.5.10 Advection/Mixing – Groundwater Chemistry

SKB's Report

SKB has developed a model, the M3 code, for mixing calculations based on different types of typical waters (such as precipitation, glacial meltwater, deep highly saline groundwater). This code has been used with groundwater chemistry data for many sites in the country. SKB has also participated in an international task force for modeling groundwater flow based on hydrological and geochemical information.

SKB intends to upgrade the M3 code over the next few years. Mixing calculations will be performed with data from the ongoing site investigations. The purpose is to investigate the salinity evolution over long time periods with extensive climate changes. SKB will also continue to work on improving the integration between hydrochemistry and hydrogeology within the framework of the ongoing site modeling.

SKI's Evaluation

In SKI's opinion, through previous groundwater characterization of several sites in the country, SKB is well prepared for the ongoing interpretation of groundwater chemistry data from the site investigations. The M3 code has been found to be a valuable tool for understanding how groundwater of different compositions contribute to the complex groundwater chemistry, especially at certain coastal sites. However, it is necessary for SKB to be cautious in its interpretation since the uncertainty for what is basically a statistical method rapidly increases when there is a deficiency in primary data. Interpretation problems can be related to an uneven distribution of data points in the bedrock and to discontinuous change instead of incremental change.

SKI observes that if the extensive geochemical information that is prepared within the site investigations is to be useful, an extensive integration is required between different disciplines. Even if SKB states that it is possible to integrate the handling of hydrological and chemical data, to a certain extent, there are still difficulties in excluding alternative interpretations of the groundwater flow situation which can have different implications for safety assessment. SKB needs to continue the work on expanding the data and developing better models for advection/mixing so that, for example, the paleohydrological interpretations are more credible and quantifiable. These interpretations can then be useful in justifying intervals, for example, for future salinity changes. SKB's expertise in geochemistry needs to be applied, not only to the establishment of groundwater flow models but also for the choice of scenarios and variants in safety assessment.

6.5.11 Reactions with the Rock

SKB's Report

SKB has studied matrix water composition which, to a greater extent than water in fractures, is expected to be determined by chemical weathering processes. However, in the Matrix Experiment at the Äspö Hard Rock Laboratory, the conclusion was reached that most of the matrix water has a relatively rapid turnover via diffusion and only a small component is dominated by slow reactions with the rock. Since the rock in the Äspö Hard Rock Laboratory has a relatively high permeability, the conditions may be different at other sites. The Matrix Experiment will therefore be repeated as a part of the ongoing site investigations.

SKB presents an account of the problem with oxygenated water which occurs in connection with the construction and operation of the repository and which could occur in connection with melting of a continental ice sheet. SKB considers that it is unfortunate that confirmed cases of glacial meltwater at great depths are interpreted to mean that oxygen also occurs at great depths. Based on results for the Rex Project, SKB's assessment is that microbial processes rapidly consume the available oxygen. The buffer's capacity for oxygen consumption can be estimated for inorganic reactions whereas unresolved questions remain with respect to the capacity of microbes. During the most recent research period, SKB has studied the weathering of the mineral, chlorite, since this process can consume oxygen.

SKB has worked within EU projects with indicators of existing and previous groundwater chemistry (Equip and Padamot). Calcite appears to be the most useful mineral although sulphides and iron hydroxide are of interest. The paleohydrogeological conditions at Äspö/Laxemar have been determined and zones with different geochemical conditions for reactions with calcite have been identified. In the future, the iron oxides at Äspö will be studied. SKB also intends to continue several studies of iron-containing fracture-filling minerals and new calculations for the penetration of oxygen will be performed.

Comments by the Reviewing Bodies

Gothenburg University considers that an understanding of the evolution of groundwater chemistry, reactions with fracture-filling minerals and the age of fracture-filling minerals is very important.

The Swedish Research Council emphasizes the importance of ensuring that the repository remains anoxic and wonders about SKB's preparedness for handling an oxygenated repository. Information is also lacking about the importance of unintentional chemical releases.

The Swedish Research Council points out that epidote contains trivalent iron and can therefore not contribute to redox buffering.

SKI's Evaluation

SKI considers that the impact of the matrix water on the barrier system could be of importance for a repository in the Forsmark lens since few water-bearing fractures exist. SKB's planned work should be viewed as important. SKB also needs to evaluate the usefulness and representativity of the matrix water that is extracted from borehole cores for different geochemical parameters.

The conceptual understanding of the exchange between the rock matrix and groundwater-bearing fractures can also have other applications. New information may need to be taken into account in the modeling of matrix diffusion. Factors that may be of importance include the impact of microfractures as well as the difference between laboratory and in-situ conditions.

SKI does not consider that the occurrence of glacial meltwater at repository depth is proof of the fact that oxygen has also occurred at this depth. On the other hand, this observation demonstrates the need to evaluate or exclude potentially unfavourable effects of groundwater with glacial origin on the repository function, such as the effects of oxygen and possible buffer and backfill erosion. SKI would like to remind SKB that SKB's own study showed that the penetration of oxygen was in principle possible if only for high groundwater flow rates (Guimera et al., 1999). It can be pointed out that the authors of this study could not exclude the possibility that the geochemical model was optimistic. In the light of this, SKI would like to emphasize the importance of a new modeling study which can be used as a basis for SKB's forthcoming safety assessments. Site-specific information should, if possible, be used in this modeling work, since it cannot be excluded that differences exist between different sites. SKB should also evaluate the usefulness of other geochemical information for this issue such as results from fracture-filling mineral characterization.

In SKI's opinion, SKB should also prepare more accurate estimates of the quantities of oxygen that could remain after construction/operation. The resistance to and chemical impact of construction material is another issue for which data is needed for the safety assessment. It has been suggested that cement pore water can change the conditions for matrix diffusion.

6.5.12 Microbial Processes

SKB's Report

SKB has studied the impact of microbes on redox processes in the Rex Project. Microbes contribute to the consumption of oxygen and when oxygen is not available, sulphate ions, dissolved iron (III) and manganese (IV) are used. Certain microbes break down organic carbon compounds while others live on hydrogen and methane. Calculations show that microbial oxygen consumption is largest in the beginning while inorganic reactions take over in the long run. SKB intends to go on to study the activity of methane-oxidizing microbes.

SKB is studying biological iron oxides (Bios) and has found that they contribute significantly to the retardation of trace metals. They are expected to concentrate on mobile radionuclides more than inorganic radionuclides.

The opposite effect of microbes is that certain organisms emit complexing agents which accelerate radionuclide transport. Experiments have so far been conducted in an aerobic environment but SKB will now go on to study the effects under anaerobic conditions, such as with anaerobic biofilms. SKB is studying the microbial processes in-situ in the Äspö Hard Rock Laboratory at a depth of 400 metres.

SKB is currently performing calculations of sulphate reduction near to deposition holes.

SKI's Evaluation

In SKI's opinion, SKB has a sound programme for studying microbial processes. Microbial processes for which a negative impact on a barrier function is expected are of particular importance. SKB should therefore primarily evaluate processes such as sulphate reduction near to deposition holes, the impact of complexing agents from microbial activity, the limitation of matrix diffusion due to biofilms etc. However, in SKI's view, credible results exist that are coupled to microbial effects that have a positive impact on repository safety, such as oxygen consumption, use of reducing capacity from hydrogen and methane, biosorption of metals. The degree to which these are used in the safety assessment must, as for all other processes, be evaluated on the basis of the available data, such as the understanding of the processes, the availability of conceptual mathematical models and the available data for calculations.

6.5.13 Colloid Turnover – Colloids in the Groundwater and the Impact on Radionuclide Transport

SKB's Report

SKB has measured background concentrations of colloids at Äspö and has found that the concentrations are low and decline with increased depth. Special reactors have been installed to study the possible release of bentonite colloids. The results show that colloid production is small.

SKB intends to possibly carry out a field-scale tracer test with colloids.

SKB has developed a numerical variant of Farf31 which uses the same conceptualization of colloid transport that SKI previously reported (Klos et al., 2002). Simulation results show that colloids may be of importance for certain parameter combinations. It was found to be important to obtain information on the filtering rate in particular.

Comments by the Reviewing Bodies

The Swedish Anti-Nuclear Movement considers that SKB in its report has completely neglected the problem of rapid colloid leakage.

Stockholm University (Pereira) considers that the sealing of tunnels and boreholes is an engineering problem which requires more research and development and points out that colloid formation is an important issue in this context. The University also notes that SKB, in its report, mentions that additional work will be required with respect to the understanding of colloid properties in bentonite but that this work is not specified or described.

The Swedish Research Council considers that experiments with colloid-transporting radionuclides are vital. The Council also wonders whether the impact of salinity on transport mechanisms also included colloid transport.

SKI's Evaluation

In SKI's opinion, SKB has a more comprehensive and well-developed understanding of colloids compared with the situation a few years ago when only measured colloid concentrations were used as an argument. The results from the bentonite experiments are valuable, but studies of lower ion-strength groundwater can also be required. Cement could also be important for the formation of colloids in the near field of a repository.

In SKI's opinion, field-scale tracer element experiments with colloids can provide a valuable contribution to the understanding of colloid migration. SKB should design its experiments so that critical parameters can be evaluated and so that recently developed models (Cvetkovic, 2003) can be tested.

One of the greatest uncertainties in connection with the evaluation of the importance of colloids is their interaction with radionuclides. Unlike conventional radionuclide transport, a completely reversible sorption has a negligible colloid impact while a more irreversible process can give a greater dose contribution (Klos et al., 2002). SKI recommends that SKB should carry out studies of the interaction between radionuclides and colloids to better understand this aspect.

6.5.14 Methane Ice Formation and Salt Exclusion

SKB's Report

SKB observes that, at a low temperature and high pressure, methane ice can be formed under permafrost conditions.

SKB also notes that when saline water freezes slowly, the solutes (salts) are forced out into solution. The process could be important in connection with cold climate, for example during a permafrost period.

SKB has studied both of these processes in the Lupin Mine in Canada but has not been able to demonstrate any of the processes/effects. However, the investigations in the Lupin Mine are expected to continue.

Comments by the Reviewing Bodies

Stockholm University (Mörner) states that explosive dehydration of methane ice could be a new factor which requires research work.

SKI's Evaluation

SKI shares SKB's view that knowledge of these processes needs to be improved. On the other hand, SKI cannot form an opinion whether the Lupin Mine is the best place/way of achieving this.

6.5.15 Integrated Modelling – Hydrogeochemical Evolution

SKB's Report

The aim of SKB's programme for groundwater chemistry is to provide the necessary information for the safety assessment and repository design. The understanding of the variations in the groundwater system at repository depth is important both for an understanding of the isolating function of the barrier system and for radionuclide transport.

Hydrochemical modeling is based on the distribution of both the main components of the groundwater and stable and radioactive isotopes. Statistical processing of data is performed using the M3 code (see Section 6.5.10). Discrepancies between the calculated and measured concentrations are interpreted for certain components as a result of chemical processes. The reasonableness of the results is checked using other codes which explicitly represent these processes, such as PHREEQEC.

An important issue is how representative groundwater samples are for conditions at the depth where they are taken. Studies of fracture-filling minerals can provide supplementary information on previous and current groundwater chemistry at different depths.

SKB states that current conditions are expected to prevail in a 1,000-year perspective, while land uplift will be of considerable importance in a 10,000-year perspective. In a 100,000-year perspective, SKB states that climate changes will be the completely determining factor.

No further method development is being conducted specifically in this area. Instead, all work is being conducted within the framework of the ongoing site investigations.

SKI's Evaluation

It is difficult for SKI to evaluate the work in this area since the most intensive phase of site-specific modeling and integration with safety assessment is still underway. For the time being, how the interpretation of the geochemical information will be satisfied in the safety assessment must be considered to be an open issue. There should be good reason to reach conclusions concerning the evolution of the groundwater chemistry and

hydrology over long time-scales if new data can gradually eliminate uncertainties/alternatives in the interpretation of the actual specific rock volumes.

SKB needs further develop the application of other tools besides M3 to enhance its understanding of processes involving reactive components in the groundwater, e.g. PHREEQEC. SKI is unsure of SKB's ambitions in this area, since no details are provided in RD&D Programme 2004. SKI also considers that an important issue, which is not discusses, is how geochemical data can be used to reach conclusions concerning recharge and discharge areas and groundwater flow direction on a local and regional scale.

6.5.16 Integrated Modelling – Radionuclide Transport

SKB's Report

SKB states that work is in progress to study how different models based on data from short-term field experiments can predict radionuclide transport when extrapolations are made to the temporal and spatial scales that are relevant for safety assessment. Work is also underway to show which types of investigation data are useful and decisive in modeling work.

A development of the methodology for analyzing flow and transport through backfilled tunnels is being carried out and transport calculations where detailed information from discrete network models of cracks and flows on a canister scale are being transferred to the codes for nuclide transport in the near and far field.

SKB has also developed a numerical variant of Farf31 which can be used to study more complex conditions than those that are possible in the standard Farf31. SKB states that one study shows that the effect of a one-dimensional Farf3 approximation compared with a two-dimensional solution is relatively small, for example, with respect to the resulting transport resistance.

Comments by the Reviewing Bodies

In the view of the Nuclear Waste Secretariat of the Environmental NGOs, the vital question concerning how fast the leakage via the shafts and tunnels sealed with clay and crushed rock is estimated to occur remains unanswered.

SSI is positive to the fact that SKB is further developing models to be able to take the heterogeneity along the transport routes in the rock into account but notes that the heterogeneity and variability of the retention parameters are not included in the study due to the lack of data. SSI therefore considers that SKB should investigate the extent to which such data can be obtained in the site investigations as well as, in the cases where site-specific data cannot be obtained, the uncertainties this leads to and how this will be taken into account in the safety assessment. Finally, SSI considers that SKB should investigate the effects of the simplifications that the radionuclide transport models are associated with.

As far as the sealing of tunnels and boreholes is concerned, Stockholm University (Pereira) considers that the models for nuclide transport in the near field must take into account inhomogeneous conductivity. Furthermore, the University considers that the results from SKB's planned experiments to investigate transport resistance for radionuclides in the interface between bentonite and water-bearing fractures are important. This particularly applies if it is found that the use of transport resistances in the mathematical models is optimistic.

SKI's Evaluation

In SKI's opinion, SKB's programme for radionuclide transport models is suitable and SKB has an ambitious programme with respect to field studies. SKI also observes that SKB's activities in the area of geosphere transport agree with the results from the RETROCK EU project (SKB, 2004a).

Like SSI, SKI considers that it is positive that SKB is developing models to take into account heterogeneity along the transport routes in the rock. Furthermore, SKI agrees with SSI that SKB should investigate the extent to which data can be obtained in the site investigations which enable heterogeneity and variability of the retention parameters to be included. In the cases where site-specific data cannot be obtained, SKI, like SSI, considers that SKB should describe the uncertainties that this will result in and how these uncertainties will be handled in the safety assessment.

In SKI's opinion, the work conducted in the framework of the Äspö Task Force (Task 6) provides a valuable contribution to increasing knowledge within the area. Furthermore, SKI is positive to the fact that SKB has developed a more flexible numerical variant of Farf31 to investigate alternative assumptions and conceptual models.

6.5.17 SKI's Overall Evaluation - Geosphere

SKI finds that a clear link to the ongoing site investigations and the problems that are associated with each of the sites (such as high rock stresses, saline groundwater etc.) is missing. In SKI's opinion, SKB should discuss, in greater detail in the RD&D programme, how it intends to confront and deal with the problems that are now known. SKB should also have been clearer in describing which resources and preparedness exist to handle site-specific issues that require research work.

SKI observes that SKB's conclusions concerning fracture movements in connection with earthquakes of a magnitude of 6 and more are still associated with uncertainties. This can be seen in the way SKB has formulated its account, for example, "the results now available indicate", "this might mean that". In SKI's opinion, further work is required in these areas before the results can be turned into a feasible concept and how these issues may be dealt with in future safety assessments must be described. SKB's programme states that SKB plans further work on these issues.

The contribution of microfractures over long time periods is important for the assessment of the changes in permeability around deposition holes and tunnels. Therefore, in SKI's opinion, SKB should investigate whether sub-critical fracturing

might be important for micro-fracturing around openings in a repository and, if so, how this issue should be dealt with in SKB's continued work.

SKI considers that RD&D Programme 2004 provides a good summary and status report on the modeling tools used to describe groundwater flow. Like SSI, SKI considers that it is vital that SKB should set aside enough time to evaluate and document the different models before applying them in SR-Can and SR-Site.

With respect to the recharge and discharge problem, SKB has now conducted and reported two model studies and a summary report. In turn, the authorities have presented their comments and criticism of these studies. For this reason, SKB is now planning to conduct an additional model study for Eastern Götaland in order to respond to the authorities' comments.

In SKI's opinion, SKB's programme for radionuclide transport models is suitable and SKB has an ambitious programme with respect to field studies.

7 Biosphere

In this chapter, SKI comments on Chapter 20, "Biosphere" of RD&D Programme 2004.

7.1 Introduction with General Comments

7.1.1 Background

The biosphere is the part of the earth where flora, fauna, humans and other organisms live and procreate. The biosphere does not only comprise the soil and sea, it also extends up into the atmosphere and down below the earth's surface. Radioactive releases from a repository must be assessed on the basis of knowledge of the biosphere, not only with respect to how the biosphere is affected radiologically but also with respect to how the dispersion of radioactive substances is affected by living and dead organisms. The assessment of the protective capabilities of a repository is therefore based on an analysis of how radioactive substances are transported from the transition from the geosphere to the biosphere and their transport pathways in different ecosystems which can lead to humans and other life forms becoming exposed to ionizing radiation.

7.1.2 SKI's Evaluation

SKI has carried out an overall evaluation of SKB's biosphere account, primarily with respect to its links to other areas within safety assessment. SKI has generally based its review statement on SSI's review of SKB's biosphere programme. This approach is naturally justified by the fact that the biosphere lies within SSI's area of responsibility and by the fact that SKI does not have any independent expertise or research programmes in this area. Therefore, SKI recommends SKB and other participants in the decision-making process for the disposal programme to consult SSI's review statement for more detailed comments.

SSI's General Comments

SSI observes that, for some years, SKB has been conducting significant work in the biosphere area. However, at the same time, SSI observes that the account provided in RD&D Programme 2004 does not reflect this. For example, SSI considers that the section on model development is difficult to interpret. How models and calculation tools will be linked is unclear. A plan of future work based on research findings and on a description of remaining central issues is lacking.

General Comments by Other Reviewing Bodies

Östhammar Municipality wonders whether SKB's data from the biosphere investigations will provide answers to questions concerning the short-term impact of the construction of a repository or whether answers will relate to the impact over thousands of years or both.

The Swedish Anti-Nuclear Movement criticizes the lack of references and a summary. In Section 20.11, SKB has devoted 15 lines of text to "Newfound knowledge since RD&D 2001" and refers to no less than 24 background reports.

7.2 Understanding and Conceptual Models

SKB's Report

SKB has started to compile process descriptions for the biosphere in a similar manner as for the barriers in the repository. A process report will be prepared for SR-Can. SKB has also continued to adapt the systems ecology approach to describe the cycling of radionuclides in the biosphere.

SSI's Comments

SSI supports the methodology that SKB has chosen to conceptually describe ecosystems and points out the need for a complete documentation of the processes in the biosphere. However, SSI is concerned about the timetable for SKB's development work and emphasizes the importance of the conceptual analysis for the site investigations. SSI has previously indicated the need for a detailed investigation programme which is linked to radiation protection requirements and safety assessment. However, SKB has failed to present such a programme before making the transition to complete site investigations or in its plan of action.

SKI's Evaluation

SKI agrees with SSI's comments and considers that it is surprising that SKB has not followed SSI's recommendations to present the plans that SSI requested.

7.3 Model Development

SKB's Report

SKB intends to develop and use process-based models which are based on transport in ecosystems where flows of radioactive substances are coupled to flows of primarily organic material. SKB intends to further develop the systems ecology models for lake and land. Models for wells, irrigation and dose to man will also be developed as well as methods for using site-specific data. The aim is for SR-Can to have a fully functional simulation environment.

SSI's Comments

In SSI's opinion, the systems ecology models are a good complement to the compartment models that have so far been developed. At the same time, SSI points out that uncertainties remain which mean that the process-based models do not necessarily mean an essential improvement in prediction capabilities. The total uncertainty in the consequence calculations may be significant and, with biosphere modelling as a dominant factor.

Furthermore, SSI considers that it is unclear how the modelling tools (Biomat and Tensit) which SKB intends to develop will be used in SKB's continued work. According to SSI, a comprehensive description is lacking of all of the models to be used in the safety assessment and this makes it difficult to understand the relationship between them. Descriptions of how well the models represent relevant ecosystems are also lacking.

SKI's Evaluation

SKI supports SSI's evaluation and has no comments to add to this evaluation.

7.4 Transport Processes

SKB's Report

SKB provides an overall description of a number of projects that mainly focus on transport processes where the discharge from a repository is assumed to occur via the seabed. Among these projects, SKB also refers to a modelling study where a more general conclusion is reached that discharge occurs in low points in the terrain, such as lakes and watercourses, independently of the conditions near to the ground surface. SKB reaches the conclusion that this supports the use of the dispersion models used so far. SKB intends to evaluate this conclusion with the help of hydrology models which include both near surface and deep groundwater flow in the same model. Model studies will be conducted where dispersion in the biosphere is affected by particle-bound transport. Furthermore, SKB intends to carry out a study of how humans can themselves contribute to dispersion over larger areas through the transport of foodstuffs and materials.

SSI's Comments

SSI points out that, in previous evaluations, it had criticized SKB for having neglected important process for radionuclide dispersion in the transition from geosphere to biosphere, for example, the accumulation of radioactive substances in sediment. SSI is therefore positive to SKB's planned work in this area.

With respect to the modelling study referred to above, SSI recommends caution in interpreting the results with reference to possible differences in groundwater and surface water-divides as well as the limitation of the model in surface and depth. SSI also sees a need for co-ordination between modelling work and site investigations.

Furthermore, SSI emphasizes the importance of the near surface hydrology for the dispersion of radioactive substances from a repository and the importance of the Quarternary deposits in this respect. SSI is still missing a clear plan of how SKB intends to conduct research in this area. SSI is positive to SKB's planned studies of the size of populations that can be affected by a contaminated area, but finds that a timetable is lacking. SSI emphasizes that such results are needed already during the site investigation phase to be able to compare sites from this perspective.

SKI's Evaluation

SKI completely shares SSI's view regarding SKB's work on transport processes in the transition between the geosphere and biosphere. Like SSI, SKI is concerned about the fact that SKB paid attention to this area late in its programme and is concerned that this could lead to delays in future decision-making processes. In SKI's opinion, it is more than likely that the accumulation of radioactive substances in sediment and organic deposits (such as peat and bottom sludge) will appear to dominate with respect to the exposure of individuals in a future population, above all, as a result of human impact. This is also the conclusion that SKB itself presented in SR 97. For this reason, SKI wonders why SKB has kept this account separate from the account of the terrestrial ecosystems (see next section).

In this context, SKI would also like to underline the need for SKB to develop its transport and accumulation models so that they can be used in the application of complementary safety indicators in terms of concentrations and flows of radionuclides. This area is currently being rapidly developed and a consensus concerning the useability of such indicators for very long time perspectives (> about 10,000 years) is being developed in international fora. The possibility of using such indicators is also advocated in both authorities' general recommendations for their disposal regulations (in SSI's case, it is so far only a question of draft general recommendations). SKI would like to emphasize that indicators are so far the only tool that can, to any credible degree, replace dose and risk as safety indicators for the remote future since we cannot actually imagine what the actual environmental conditions or future human civilization will be like. As far as can be seen, SKB's programme does not include any plans in this area and, in SKI's opinion, this is a serious deficiency.

7.5 Terrestrial Ecosystems

SKB's Report

In general, SKB considers that forests in depressions, for example swamp forests, as well as mires and wetlands are particularly important recipients for the repository sites that may be relevant. SKB describes how models of such areas of wetlands will be developed based on studies of wetland hydrology and their utilization by humans.

SSI's Comments

SSI considers that SKB's studies in this area are well justified and SSI also points out that the highest radiation doses are to be expected in these ecosystems, primarily when, for example, sediment goes over to wetlands and then goes over into forest. SSI emphasizes that this is in accordance with what SSI has called for in previous reviews.

SKI's Evaluation

SKI agrees with SSI that this is an important research area, especially with respect to what SKI has stated in the previous section.

7.6 Aquatic Ecosystems

SKB's Report

SKB considers that knowledge of transport processes in aquatic systems (watercourses, lakes and sea) is relatively good. Work is focusing on developing models and collecting data for use in the models. Site investigations are expected to provide knowledge of sediment distribution and accumulation rates. According to SKB, other important areas are the development of a systems ecology model for lakes and for sorption processes in small streams.

SSI's Comments

In SSI's view, SKB's planned research comprises several important areas. SSI considers that the studies of the importance of sediment to the exposure of man and environment are particularly positive. However, SSI considers that it is unclear how this research fits into a larger perspective.

SKI's Evaluation

SKI shares SSI's view that aquatic ecosystems are an important area. Like SSI, SKI also wonders how this research area can be distinguished from certain other areas, for example, that presented by SKB under the heading of "Transport Processes" (Section 20.5 of RD&D Programme 2004), cf SKI's evaluation in Section 6.4 and 6.5 above.

7.7 Safety Assessment

SKB's Report

The aim of SKB's programme for the biosphere is to be able to handle time-dependent and coupled ecosystems in future safety assessments. Important features of the programme are how processes and site-specific data can be handled in the system assessment. Methods will be developed which are based on results obtained in the EU projects, Erica and Fasset.

SSI's Comments

In SSI's view, SKB has raised its level of ambition in recent years with the aim of improving the analysis of the biosphere as an important part of safety assessment. Therefore, SSI considers that it is surprising that the biosphere is not included in the overview which describes research on long-term safety.

In its review of RD&D Programme 2001, SSI requested an explanation of how results from Fasset and other projects would be used in safety assessment and in the site investigation programme as well as how the environmental protection aspects will be satisfied in the site investigations. In SSI's opinion, SKB's claim that data that have already been collected from the site investigations far exceed the needs in accordance with Fasset should be justified.

Comments by Other Reviewing Bodies

The Waste Network and the Opinion Group for Safe Disposal (Oss) consider that SKB's one-sided focus on the construction and operational phase means that the discussion of the biosphere is limited to areas near to the repository site. The Waste Network and Oss consider that, as a result of the dilution principle of the method and the coastal siting, the biosphere must be expanded to also encompass diffuse releases to the Baltic Sea.

The Swedish NGO Office for Nuclear Waste Review (MKG) raises the issue of dilution in the sea as one of the principles of the KBS method. A coastal siting which, in the event of leaching, leads to a rapid dilution in the sea would result in the exposure of many people and organisms to ionizing radiation and the collective dose could be very high. In MKG's view, in order to facilitate an ethical (including economic aspects) weighing of safety measures and future damage, descriptions are needed of expected future collective doses and the number of fatalities and injured in different scenarios.

SKI's Evaluation

SKI has nothing to add to SSI's evaluation.

However, in this context, SKI would like to raise the issue of the role of the biosphere in the selection of a disposal site and method. It is SKI's firm opinion that it is unreasonable to assign to the biosphere the role of a barrier in the disposal system. At the same time, it is inevitable that different types of biosphere should result in different types and magnitudes of environmental and human exposure. The dilution of radioactive substances in the biosphere is often advantageous while accumulation may be disadvantageous from this standpoint. In SKI's opinion, SKB should develop its strategy concerning how these issues are to be handled in the site selection process for different time scales, both within the framework of safety assessment and more overall assessments.

7.8 Supportive Research for the Site Investigation Programme

SKB's Report

According to SKB, most of the data collection will be conducted in SKB's organization for site investigations. During the forthcoming period, efforts are therefore necessary to support the analysis of collected data and to measure process rates in situ. Co-ordination is necessary between research, safety assessment and site investigations. Furthermore, information will be exchanged through workshops and meetings.

SSI's Comments

SSI has previously pointed out the need to co-ordinate biosphere model development and site investigations, most recently in connection with its review of RD&D Programme 2001. SSI is therefore positive to SKB's account which describes a close relationship between research, safety assessment and site investigations. However, SSI lacks a clear plan of action for this area and documentation of the tangible connection between model development and the site investigations.

Comments by Other Reviewing Bodies

The Swedish Anti-Nuclear Movement (FKK) regrets that interest in the biosphere was awakened at such a late stage in the RD&D programme. FKK considers that it is illogical to show an interest in the factors that determine the impact of a deep repository on the biosphere only once a site has been selected. The interaction of a repository with the biosphere should be a criterion for site selection.

The Movement demands a re-evaluation of the authorities' approval SKB's referral of its biosphere research to the site investigations and the report of the research to the licensing-related EIA work. Furthermore, the Movement demands that the site investigations should be interrupted until the findings from the ecological research are available.

SKI's Evaluation

SKI has nothing to add to SSI's evaluation.

7.9 The Authorities' Overall Assessment - Biosphere

Bearing in mind the premises for SKI's evaluation which were reported in Section 6.1 above, SSI's overall evaluation of SKB's biosphere programme is provided here in full. SKI's own comments are then provided.

"In recent years, SKB's research in the biosphere area has been conducted more methodically and with a higher level of ambition than has previously been the case. SSI considers this to be positive. Unfortunately, RD&D Programme 2004 does not provide an adequate description of the research that is being conducted on the biosphere.

The connection between data from the site investigations and the requirements made by the site-specific systems ecology models must be clear. For example, it is not clear when critical R&D results and models must be developed with respect to the needs of the site investigations.

In SSI's opinion, a comprehensive documentation must exist of the processes involved in the interaction matrices for the biosphere that are used as is the case for other repository parts. Furthermore, a comprehensive description of all models to be used in the safety assessment and accounts of how well they represent the identified processes in relevant ecosystems are necessary.

SKB should clarify how environmental protection will be taken into account in model development and in the site investigations. SKB's claim that data already collected from the site investigations far exceeds the needs specified in the EU Fasset project must be justified."

SKI supports SSI's opinion, as presented above. In addition, SKI would like to particularly emphasize that SKB's account does not clearly specify how the different parts of the programme are to be co-ordinated with each other on the basis of the needs of the safety assessment. This may be due to an unsuitable structuring of material in RD&D Programme 2004. Unfortunately, it may also be a reflection of the need for

better internal co-ordination of SKB's biosphere programme. If this is the case, SKB needs to clarify its programme in these respects so that the authorities can decide whether the programme can, within a reasonable time in relation to SKB's overall plan of action, meet the goals that have been set. SKI assumes that these viewpoints will be taken into account already in the improved plan of action that SKB is to present before it submits an application for the encapsulation plant.

SKI would also like to remind SKB that biosphere modelling should include elements that can be used in connection with complementary safety indicators for disposal such as radionuclide concentrations and flows.

8 Climate

In this chapter, SKI comments on Chapter 21, "Climate", of RD&D Programme 2004.

Climate changes can be expected with considerable certainty in the perspective for which the repository safety must be assessed which entails a time scale of more than a hundred thousand years. A good understanding and a good description of possible climate changes are therefore necessary. Furthermore, in order to apply this knowledge in a safety assessment, the impact of these changes on the repository function must be quantified. Knowledge of what a suitable site for a repository has undergone during previous climate cycles is an important piece of information for understanding possible future climate changes. It is important to compile and use this knowledge in the description of the climate's impact on a repository.

In its review of the previous RD&D Programme, SKI found that a clear plan for how SKB intended to conduct research on climate was lacking. In addition, the importance of shoreline displacement was emphasized in the light of the fact that two coastal areas, Simpevarp/Laxemar and Forsmark are being studied as possible sites for a repository. SKI and SSI also emphasized the need for further investigating the importance of the greenhouse effect on climate evolution. Furthermore, SKI pointed out that SKB should investigate the importance of meltwater production at the base of a continental ice sheet for hydrology and groundwater composition.

SKB's Report

SKB is focusing its climate research on identifying and understanding conditions and processes within three different climate domains (glacial, permafrost and temperate/boreal) which are of importance for the repository and its safety. SKB states that the extent of the continental ice sheet is decisive for the prevailing climate domain. Consequently, simulations of the Scandinavian continental ice sheet, using numerical modelling, are a key project. A well-supported description of the latest glacial period – Weichsel – is necessary in order to interpret and understand prevailing conditions and to study several of the climate-related processes that are important for the state and safety of a repository (in a long-term perspective).

Issues that are particularly important for SKB to investigate are, for example, the occurrence of water pressure and water flows, the possible penetration of glacial (oxygenated) meltwater and the upward transport of deep saline groundwater during periods of glacial conditions. In addition to this, SKB is also planning to investigate the importance of the basal conditions and meltwater production for both thermal and mechanical conditions, of which hydromechanical modelling is already reported in this RD&D programme.

SKB's programme for the glacial domain is divided into the following sub-programmes: Scandinavian continental ice sheets, stress states in the earth's crust and shoreline displacement. The aim of each sub-programme is to be able to evaluate site-specific data. This means that data obtained in the site investigations can at the same time support the continental ice sheet project and are interpreted in the light of the results of the project.

SKB observes that knowledge of the occurrence of permafrost in Scandinavia in a long-term perspective is limited. The occurrence of permafrost affects the hydrological conditions and the groundwater composition. SKB is now conducting a study (numerical modelling) to determine the extent to which permafrost and frozen ground can occur in Simpevarp/Laxemar and Forsmark in the future.

In SKB's opinion, shoreline displacement is the process that has the greatest importance for the repository within the current temperate/boreal domain.

Comments by the Reviewing Bodies

In the opinion of Swedish NGO Office for Nuclear Waste Review (MKG), extra loads from continental ice sheets during future glaciations must be thoroughly taken into consideration when choosing a method. SKB's report can be interpreted as though glaciations are considered to be an extreme case for which no extra safety margins are required. MKG notes that, since glaciations within several thousand years are probable, this risk assessment seems to be dubious.

The Nuclear Waste Secretariat of the Environmental NGOs considers that, with reference to Mörner (2003), SKB must immediately review the earthquake scenario and safety distance to faults. An additional issue is the consequences of methane gas explosions in connection with a deglaciation.

With respect to climate, SSI refers to the review version of its general recommendations to the SSI FS 98 regulations. The recommendations assume that SKB will choose to describe: "the most important and reasonably predictable sequences of future climate domains and their impact on the protective capabilities of the repository and environmental consequences" (SSI, 2004). SSI notes that this is also SKB's strategy: "If it can be shown that the repository will remain safe during the different possible climate domains, the actual climatic evolution is of less importance" (RD&D Programme 2004, p. 292). In SSI's view, this is a significant improvement from the previous account in RD&D Programme 98 Supplement, where dilution in marine environments was a central component.

SSI also supports SKB in delimiting the issues that are of particular interest in connection with glaciation and observes that, on the whole, SKB's ambitions represent a comprehensive effort.

SSI further notes that it is important to describe future sea level changes, since SKB is focusing on two coastal sites in its programme for reasons relating to the radiological consequences of a release. SSI has previously pointed out the importance of SKB improving the depth of its knowledge of the possibility of the dilution of a release into the Baltic Sea and the importance of such a dilution.

SSI also reiterates the importance for the radiological consequences of, for example, a radionuclide release which has previously accumulated in sea sediment. This is an issue that concerns a general component of ecology, the importance of ecosystem changes, but which should have a natural place in studies of shoreline displacement.

The Safety Group at Oskarshamn Municipality emphasizes the importance of ensuring that the consequences of earthquakes, after a glaciation, receive a satisfactory treatment in SKB's programme and that the results are communicated to the public in a clear manner. The Safety Group notes that there are also other issues (besides earthquakes) which are related to future climate changes, such as the depth of the permafrost, the largest size of a continental ice sheet and the upward penetration of deep saline water, which require more sound knowledge for safety assessment to be credible.

SKI's Evaluation

SKI finds that SKB has largely taken heed of the viewpoints put forward in the review of RD&D Programme 2001 (see introduction above). In SKI's view it is positive that SKB, as a first step, is focusing on the simulations on the Weichsel glaciation. A well-grounded description is available for this period, for which modelling can be calibrated and validated against comprehensive geological information. The results should provide input data for shoreline displacement studies, the occurrence of post-glacial earthquakes, studies of erosion and of the hydrological systems of continental ice sheets. It should also be possible to obtain input data for the modelling of both periglacial and subglacial permafrost.

However, it is important to point out that this is only one example of a possible evolution. Even if SKB bases its assumptions on and uses knowledge of the paleoclimate, there will be significant uncertainties regarding future climate evolution, especially due to the impact of the greenhouse effect. SKB therefore needs to at least provide a general description of some climate evolution alternatives. SKB needs to credibly demonstrate that these evolutions will not have an essentially different impact on the long-term safety of the repository.

SKI and SSI observed in their review of SKB's RD&D Programme 2001 that in coastal areas, the future position of the shoreline and its importance for groundwater conditions and the biosphere is an important issue. Therefore, SKI is satisfied to note that SKB has initiated several projects to understand the causes of climate variations and shoreline position within different time periods. As a result, SKB can thereby postulate the development of a future shoreline in the areas where site investigations are currently being conducted.

However, it is worth noting that a future temperature increase of three degrees could mean the melting of Greenland ice. If the ice in the Western Antarctic were to melt, this would mean a total elevation in the sea surface of about 10 metres. The melting of these ice masses and the consequences for the repository sites need to therefore be described in future safety assessments and RD&D programmes.

SKI has observed that the description of permafrost is brief and corresponds to those descriptions that can be found in any normal reference book. SKB should have presented a more detailed description of permafrost, particularly since SKB considers that permafrost can have a decisive impact on the safety functions of the buffer. SKI notes that continuous permafrost is considered to occur down to a depth of about 300 metres (Figure 21-4 in RD&D Programme 2004). The uncertainties in this prognosis should be carefully quantified, especially for a repository in Forsmark at a depth of about 400 metres.

SKI has observed that SKB only provides a short description of how changes in hydrology in permafrost and glacial domains will be handled. The most important goal should be to identify differences between a future climate domain compared with modelling the existing climate and analyzing its consequences (such as salt exclusion and groundwater flow channelling).

Furthermore, in SKI's opinion, SKB should more clearly describe the way in which it will ensure that the selected climate evolution alternatives shed light on the most important climate-related stresses on the engineered barriers in particular (for example, hydrostatic pressure, groundwater chemistry, groundwater flows, rock movements due to earthquakes). SKB should be able to demonstrate the importance of processes such as buffer erosion, the impact of a high salinity on the buffer, the penetration of glacially oxygenated meltwater which can all seriously jeopardize the basic barrier functions. This applies even if site-specific data indicate that these processes have probably not occurred.

SKI finds that feedback to the chapters on the biosphere, geosphere and safety assessment is lacking. Future changes in the biosphere and geosphere are not adequately taken into account in calculations of how groundwater flow, water chemistry, rock stresses etc. around a future repository can change.

SKI observes that important results can be expected from the glacial-hydrological project which has started and which is partly reported. Together with ice extension scenarios, these results can generate new water pressure and gradient models for groundwater flow in the contact between ice and earth underground that SKB needs to take into account.

SKI's Overall Evaluation – Climate

In SKI's view it is positive that SKB, as a first step, is focusing the simulations on the Weichsel glaciation. However, it is important to point out that this is only one example of a possible evolution. Even if SKB bases its assumptions on and uses knowledge of the paleoclimate, there will be significant uncertainties regarding future climate evolution, especially due to the impact of the greenhouse effect. SKB therefore needs to at least provide a general description of climate evolution alternatives.

Furthermore, in SKI's opinion, SKB should more clearly describe the way in which it will ensure that the selected climate evolution alternatives shed light on the most important climate-related stresses on the engineered barriers (for example, hydrostatic pressure, groundwater chemistry, groundwater flows, rock movements due to earthquakes).

SKI and SSI observed in their review of SKB's RD&D Programme 2001 that in coastal areas, the future position of the shoreline and its importance for groundwater conditions and the biosphere is an important issue. Therefore, SKI is satisfied to note that SKB has initiated several projects to understand the causes of climate variations and shoreline position within different time periods. As a result, SKB can thereby postulate the development of a future shoreline in the areas where site investigations are currently being conducted.

SKI finds that feedback to the chapters on the biosphere, geosphere and safety assessment is lacking. Future changes in the biosphere and geosphere are not adequately taken into account in calculations of how groundwater flow, water chemistry, rock stresses etc. around a future repository can change.

9 Alternative Methods

In this chapter, SKI presents the evaluation of Chapter 23, "Alternative Methods" of RD&D Programme 2004.

9.1 Introduction

In its introduction to the evaluation of "Alternative Methods", Chapter 12 of RD&D Programme 2001 (SKI, 2002), described in detail the background and reasons for the report on alternative methods in SKB's programme. The legislation has three requirements regarding the reporting of alternatives, one in accordance with the Act on Nuclear Activities and two in accordance with the Environmental Code. One of the later requirements concerns the zero alternative whereby the planned measure is not implemented. The zero alternative is handled in the framework for ongoing consultation and EIAs. The account of alternatives, in accordance with the Act on Nuclear Activities originates from the requirement on the comprehensiveness of the programme for research and development that is needed to dispose of nuclear waste and spent nuclear fuel. Also, in accordance with the Environmental Code, the chosen design must be justified by comparing it with alternatives in an EIS.

SKB starts off by stating that Sweden has already prioritized geological disposal of spent nuclear fuel as a disposal method. However, at the same time, SKB will follow up and support the development of alternative methods. The methods of greatest interest are Partitioning and Transmutation (P&T) and disposal in deep boreholes.

Comments by the Reviewing Bodies

The Swedish Anti-Nuclear Movement has, in its previous review statements on the RD&D programmes, repeatedly indicated weaknesses in the KBS-3 concept, and repeats these weaknesses in its review statement. The Movement therefore once again recommends that SKB should investigate in depth the possibilities that may exist for dry disposal, namely, siting the repository above groundwater level. In the Movement's opinion, dry disposal has so many advantages above disposal in groundwater that not investigating dry disposal more closely must be seen as a grave omission.

The Swedish NGO Office for Nuclear Waste Review (MKG) considers that the level of ambition of the RD&D Programme with respect to alternative methods is far too low. Only two alternatives are mentioned – deep boreholes and P&T. The deep borehole alternative is dealt with far too briefly and the zero alternative is not discussed. MKG states that SKB has focused in a one-sided manner on developing only one method, the value of which, in relation to other methods, has never been investigated seriously.

Oskarshamn Municipality states that, in accordance with the Government's decision, the question of which alternative methods should be reported in the EIS will be the subject of detailed consideration in the EIA. Since the EIA is now making the transition into more detailed discussions on alternatives and other issues, the Municipality expects that how this will be handled by SKB and other stakeholders in the consultation process will become clearer. Furthermore, in the view of Oskarshamn Municipality, SKB's level of ambition is too low with respect to the description of alternative methods. The

methods should be described in greater breadth and depth than is SKB's intention and suggests that this should be done in SKB's system analysis.

In the view of Stockholm University (Mörner), the DRD (Dry Rock Deposit) method offers many advantages above the KBS-3 method, including availability and the possibility for monitoring in combination with reliable protection, and that the cost of such a repository is considerably cheaper.

According to SSI's interpretation, the overall purpose of the description of alternatives is to support the conclusion that the main alternative has a good possibility of meeting the requirements and that, as a whole, other alternatives do not have any tangible advantages, in terms of radiation protection, in comparison with the main alternative. Therefore, the level of the description of alternatives should be such that a comparison between the basic protective functions of the alternatives can be made.

Umeå University recommends that developments in alternative methods should be followed also in the future. The University is primarily thinking of P&T and, possibly, of elements of reprocessing. Following developments in different parts of the world and, especially progress in the EU member states, roughly to the same extent as has so far been the case, should allow advancements and any breakthroughs to be noted.

9.2 Partitioning and Transmutation (P&T)

P&T can be briefly described as aiming to convert long-lived nuclei into short-lived nuclei through neutron irradiation, thereby substantially reducing the radiological toxicity of the radionuclides in spent nuclear fuel. However, waste will still be generated and this waste will have to be disposed of in deep geological formations. P&T can be carried out in nuclear reactors or in accelerator-driven systems. The surplus energy from the nuclear fission could be used for energy production, for example. Before P&T can be carried out, the long-lived substances in spent nuclear fuel must be separated from uranium and fission products. This can be achieved by first reprocessing the fuel and through subsequent additionally refined separation processes. The separation must be very efficient and only very small quantities of the long-lived nuclides may accompany the waste if anything is to be gained from P&T from the standpoint of radiation protection.

SKB's Report

SKB begins by presenting the conclusions from the review of RD&D Programme 2001 and the findings from a number of studies (from the OECD/NEA, the USA and the EU) which have been available since 2001. This is followed by a description, in separate sections, of research conducted on P&T in the EU and Sweden. Since 1991, SKB has financed research on partitioning at the Department of Nuclear Chemistry at Chalmers University of Technology. The research conducted at the Department of Nuclear and Reactor Physics at the Royal Institute of Technology, Stockholm mainly focuses on accelerator-driven systems and has been supported by SKB since 1993. At the Svedberg Laboratory and the Department of Neutron Research at the University of Uppsala, measurements of cross-sections for high-energy neutrons are underway. This research has been financed by grants from SKB, the nuclear power companies and SKI.

SKB also describes future developments internationally and states the obvious difficulties that exist due to the fact that the nuclear industry in most countries is showing limited interest in the area (with the possible exception of France where there is a statutory requirement on P&T research). It is difficult to obtain a unified view on which systems should be prioritized in the research.

SKB states that the objective of research on P&T is to evaluate how the technology is developing and to judge whether, how and when it could be used in a system for the management of spent nuclear fuel from Swedish nuclear power plants. SKB refers to the handling of the question of a reasonable scope of Swedish work in this area in connection with the review of RD&D Programme 2001. In recent years, SKB's work has corresponded to about SEK 5 million a year. SKB considers that this is a moderate level and that this does not need to be increased, bearing in mind the planned feasibility study for an experimental facility for Accelerator-Driven Systems (ADS) within the EU's Sixth Framework Programme as well as the evaluation of the French programme in 2006.

Comments by the Reviewing Bodies

The Swedish Anti-Nuclear Movement and the Opinion Group for Safe Disposal do not consider that P&T is an alternative to the KBS-3 method. This is an issue that must lie outside the nuclear waste process so that it does not detract attention from the account of truly alternative solutions. RD&D Programme 2004 devotes just over 12 pages to P&T, compared with 2 pages devoted to deep boreholes.

In the view of Oskarshamn Municipality, according to the researchers in the EU who are working on the alternative, P&T is not a method that can be realized at present. It may be justifiable to focus on this alternative in the long-term perspective, when society is faced with a decision to close a repository, perhaps in fifty years' time. Development of the method requires international co-operation and is, therefore, not an alternative that Sweden could develop on its own.

In SSI's opinion, P&T entails alternative methods for minimizing long-lived waste from the nuclear fuel cycle. However, it cannot completely replace the need for a repository for long-lived waste. Nevertheless, the method entails both reprocessing of the fuel and some form of reactor for the conversion of the long-lived radionuclides into more short-lived nuclides. In SSI's view, it is natural for SKB to follow the work on P&T, but SSI does not consider P&T to be a reasonable alternative to disposal.

The Swedish Research Council considers that it is important to channel more resources into the area of P&T since even international research conducted in a number of countries has led to new progress in the past few years. Accelerator-driven systems used for the P&T of nuclear waste can offer a substantial additional energy supply alongside conventional thermal reactors, especially if existing nuclear waste is used. The Council also considers that it is desirable for SKB to focus on research relating to nuclides and reactions involved in new, advanced fuel cycles.

SKI's Evaluation

SKI agrees with the reviewing bodies, and SKB, that P&T will not be a realistic alternative for the management of Swedish spent nuclear fuel in the foreseeable future. SKI thereby agrees with the reviewing bodies, including the Waste Network and the Opinion Group for Safe Disposal, that consider that the description provided of SKB's programme in the area has taken a disproportionately large share of the reporting of RD&D Programme 2004. In SKI's view, this is however partly compensated for by the fact that the account provides a good overview of a complex research area.

However, in SKI's opinion, it is justifiable for the research conducted by SKB and Sweden in this area to maintain its current level. This is necessary so that international developments can be followed. This is also necessary in order to maintain and develop scientific and technical expertise in areas of importance for nuclear safety, including disposal, such as reactor physics, neutron physics and nuclear chemistry.

9.3 Deep Boreholes

In connection with the disposal of spent nuclear fuel in deep boreholes, canisters containing spent nuclear fuel are deposited at a depth of between two and four kilometres where the groundwater conditions are probably very stable. The rock is the most important barrier for isolating the waste, while the function of other possible barriers, such as the clay buffer and canister, will be more difficult to predict due to the high rock pressure, high temperature and saline groundwater.

Already in its review of SKB's supplement to RD&D Programme 1998, SKI pointed out the difficulties that focusing on the deep borehole alternative would entail, for example, the choice of system design, conditions at repository depth and the need for technology development for barriers, boring and deposition methods.

In its review of RD&D Programme 2001, SSI stated that an account which included a safety assessment of deep boreholes could correspond to the requirement on an account of alternatives, stipulated by the Environmental Code. In its review of the same programme, SKI considered that the need for and scope of a safety assessment for deep boreholes should be discussed in the framework of the EIA consultation between SKB and the authorities. SKI can now observe that such a consultation started in autumn 2004 and was almost completed in spring 2005.

In its review of RD&D Programme 2001, KASAM considered that an adequate justification for implementing the R&D programme for deep boreholes which had been outlined was lacking and proposed that SKB should, instead, continue its development work, focusing on direct disposal in accordance with the KBS-3 method.

SKB's Report

SKB states that, in practice, Sweden has already prioritized deep geological disposal as a disposal method for spent nuclear fuel and that Sweden is following a main line with a system based on deep disposal in accordance with the KBS-3 method. SKB refers to previous studies conducted (Harrison, 2000), which show that the deep borehole

alternative would take just over 30 years to implement and would cost SEK 4 billion to reach the same level of knowledge as KBS-3.

SKB's opinion of deep boreholes is that there is nothing to indicate that safety would increase or that costs would decrease if spent nuclear fuel were instead deposited in deep boreholes and, therefore, there is no reason to implement the programme.

Since the previous RD&D programme, SKB has conducted a literature survey (Smellie, 2004) to supplement previously compiled geoscientific information on the conditions deep in the earth's crust. SKB observed, after the survey was completed, that the simplified view of what conditions at great depths should be like is not fully supported by the studies conducted in the deep boreholes on the Kola Peninsula in Russia and in Germany.

SKB notes that the literature survey summarizes the most recent findings and reaches a series of general conclusions concerning what this would mean for deposition in deep boreholes. Among other things, it is difficult to estimate temperatures and thermal conductivity in heterogeneous rock types at great depths. From a hydraulic standpoint, it would appear that almost stagnant conditions exist in groundwater at great depths as a result of the high salinity. However, there are indications that solutions could be relatively rapidly transported even in environments with concentrated saline solutions (brines). The claim that flows and transport occur over large distances at depths of kilometres could therefore be difficult to disprove. The occurrence of bacteria at a depth of four kilometres at estimated temperatures of less than 115ºC could be entirely possible, which does not indicate a sterile environment at these depths.

Comments by the Reviewing Bodies

The Swedish NGO Office for Nuclear Waste Review (MKG) notes that the deep borehole method entails locating a repository for nuclear waste at a depth of about 4 kilometres. Over the years, SKB has conducted surface studies of the deep borehole method within its alternatives programme and has consistently emphasized the possible disadvantages of the method and has not paid attention to the advantages. In MKG's view, an impartial evaluation of the deep borehole alternative is necessary in order to be able to conduct the descriptive comparison between methods for nuclear waste disposal required in the Environmental Code. Unless this is done, statutory requirements will not be met.

In the view of the Nuclear Waste Secretariat of the Environmental NGOs (MILKAS), no comprehensive information or diversified data for nuclear waste disposal methods is available. MILKAS states that only the KBS-3 method exists. Furthermore, MILKAS considers that the description of alternatives prepared by SKB is inadequate and incomplete.

Oskarshamn Municipality would like to see a more detailed description of deep boreholes – especially with respect to the fact that SSI has previously requested a safety assessment of this method.

SSI is positive to the fact that SKB, in accordance with SSI's request, is planning to carry out an investigation into the deep borehole alternative and to submit a report in

autumn 2005. At the consultation meetings that have been held, SSI stated that the comparison between deep boreholes and KBS-3 should be based on the different possibilities of the different methods to comply with the radiation protection requirements and that the comparison should be illustrated with simple calculations.

SKI's Evaluation

SKI agrees with the reviewing bodies which consider that the deep borehole alternative has been described too briefly in relation to P&T in the RD&D Programme.

SKI observes that the only barrier that can be assumed to work in the case of the deep borehole concept is the rock, providing that the rock type at repository depth is relatively homogeneous. Short and long-term properties of the bentonite or other buffer material in the borehole, in terms of protecting the canister against major rock movements and chemical attack, are difficult to assess at great depths. Similarly, the integrity of the canister, even for short periods of time, is difficult to predict due to the high rock pressure and, from all appearances, the aggressive chemical environment at repository depth.

Consequently, SKI still upholds its opinion from its review of the supplement to RD&D Programme 1998: the deep borehole alternative is associated with such large uncertainties that it should not be considered to be a realistic alternative to the KBS-3 method.

Based on available knowledge, already from deposition time, it may be difficult to count on anything else besides the rock as a barrier. SKI would like to express the reminder that, if this is the case, it would be in breach of SKI's regulations (SKIFS 2002:1) on safety in connection with the disposal of nuclear substances and nuclear waste. SKI thereby repeats the question that it posed in its review of RD&D Programme 2001 concerning how well a main alternative to the chosen design in an EIS should be shown to comply with basic requirements and regulations. The question of the extent to which such an alternative should be available and tested at a reasonable cost also remains.

However, in SKI's view, a clarification of the description of deep boreholes prior to the ultimate choice of a method and prior to licensing under the Environmental Code is still warranted. SKI consequently shares SSI's view that a more thorough comparison should be made with the KBS-3 method. In SKI's opinion, such a comparison should be made in a systematic manner which is based on the same principles that SKB has developed for the safety assessment for other repositories. SKI also agrees with SSI that it would be sufficient if the comparison were to be illustrated with simplified calculations.

In this way, SKI fully supports SSI's proposal, which means that SKB should carry out a limited safety assessment with existing data as a stage in a broader discussion of different alternatives as is assumed in the Environmental Code. As SKI previously pointed out, it may still not be a question of presenting a comprehensive safety assessment in the sense associated with repositories based on the KBS-3 concept.

9.3 SKI's Overall Evaluation of Alternative Methods

In SKI's view, it is justifiable for the research conducted by SKB and Sweden in the area of P&T to maintain its current level. This is necessary so that international developments can be followed. It is also necessary in order to maintain and develop scientific and technical expertise in areas of central importance for nuclear safety

In SKI's view, a clarification of the account of deep boreholes prior to the ultimate choice of a method and prior to licensing under the Environmental Code is warranted. SKI shares SSI's view that a more thorough comparison should be made with the KBS-3 method. In SKI's opinion, such a comparison should be made in a systematic manner which is based on the same principles that SKB has developed for the safety assessment of other repositories. SKI also agrees with SSI that the comparison can be illustrated with simplified calculations.

10 Decommissioning

In this chapter, SKI comments on Chapter 24, "Decommissioning", of SKB's RD&D Programme 2004.

10.1 Introduction

The facilities covered by SKB's RD&D programme are the Swedish nuclear power plants and SKB's own facilities. Waste from Studsvik, Westinghouse's fuel factory, the Ranstad plant and the Ågesta reactor will be included in radioactive waste management.

In this case, SKB is only responsible for co-operating with the other actors for ensuring that an optimum management of the Swedish decommissioning waste is achieved. All of the holders of licences under the Act on Nuclear Activities need to work together to ensure that only one repository for decommissioning waste is constructed which is the only effective solution, from a socioeconomic standpoint, for the anticipated volumes of decommissioning waste from nuclear power plants and nuclear facilities in Sweden.

When and how nuclear power plants are to be dismantled is affected by a number of different factors. SKB states that the dismantling of a nuclear power plant can be conducted in a safe way a short time after closure, but that there are arguments that also indicate that dismantling at a later stage would be advantageous (SKB, 2004, 2000, 2004a). The earliest date for dismantling is currently determined by the completion of facilities for radioactive waste management and licensing actions as well as by the fact that the dates for the closure of the different reactors are more or less unknown.

From the time that the reactor is shut down until the time that dismantling starts, fuel is removed, decontamination is carried out to remove radioactive substances from surfaces and preparations are made for dismantling (SKB, 2004). The period of time when the fuel is still in the facility is called shutdown operation by SKB and the period of time afterwards is called service operation. SKB states that the length of service operation will vary depending on the expected dismantling date. SKB points out that, during the time of service operation, the personnel force will be limited. SKB estimates that the actual dismantling work will take five years per reactor unit and will employ about two hundred people on average (SKB, 2004, 2004b).

Radioactive waste from the dismantling work consistently comprises low and intermediate-level waste. It is assumed that the waste with the highest level of activity, namely the reactor pressure vessel internals, can be stored before being deposited in the repository for long-lived and intermediate-level waste (SKB, 2004). It is assumed that other radioactive decommissioning waste can be transported directly to a repository for decommissioning waste and deposited there. SKB considers that a large quantity of decommissioning waste can be released for unrestricted use, possibly after decommissioning. SKB calculates the reference scenario in PLAN calculations using a conventional cost estimate method. This is a deterministic method which means that each item is allocated a calculated or estimated cost in Swedish kronor (SEK). These calculations are then evaluated by an expert group which determines expected values and limits for the best or worst case (SKB, 2004c, 2004d, 2000a).

SKB describes the situation as it was at the time when RD&D Programme 2004 was submitted in September 2004. Since then, the Swedish Government has decided that Barsebäck's second reactor (Barsebäck 2) is to be closed down permanently. Studsvik Nuclear AB intends to permanently close down the R2 and R2-0 reactors in June 2005. The consequences of the closure of Studsvik's reactors have not been reported. These changed conditions mean that there are certain grounds for the assessment that exist and that were, for reasons that can be explained, could not be included in the report. The timetable for the dismantling of the Swedish nuclear reactors is based on a probable operating time of 40 years or more (SKB, 2004, 1999, 2000b, 2001, 2002, 2003). Power uprates are planned to be carried out over the next few years at several reactors resulting in a considerable increase in the quantity of nuclear waste.

The licensees for the nuclear facilities are responsible for the decommissioning of their own facilities. SKB's role is to carry out general decommissioning studies and to ensure that technology and competence is available. SKB is responsible for the management of the waste.

The funds needed for decommissioning Swedish nuclear power plants are accumulated in the Nuclear Waste Fund and are regulated through the Financing Act and the ordinance to the Financing Act[1]. The system involves every reactor licensee, in consultation with other reactor licensees, preparing an estimate, once each year, of the cost of the management of spent nuclear fuel and other radioactive waste from nuclear reactors and of decommissioning these facilities. This work is carried out every year within the framework of the PLAN report that SKB co-ordinates together with the reactor licensees. The account presented in RD&D Programme 2004 under the heading of "Decommissioning" is in principle a general summary of the material included in the PLAN report. The latest estimates are presented in PLAN 2004, "Costs for the Management of the Radioactive Waste from Nuclear Power Production" from June 2004 (SKB, 2004).

10.2 Historical Background

A change in the timetable was launched by SKB in PLAN 99 (SKB, 1998, 1999) and contained a new scenario for decommissioning nuclear power plants. According to this scenario, there would be a period of 15 years between closure and the start of decommissioning. SKI calculated and proposed fees based on a scenario where this period was limited to 5 years after the removal of the reactor fuel and system decontamination was carried out (SKI, 1999). Previous years' studies had not included calculations performed at this level of detail. SKI decided to use a planning assumption in its calculations where a repository for decommissioning waste would be ready for operation by 2010 (SKI, 1999, 2000). The calculation, which is based on a planning assumption of a 15-year period, is called Case A, while the calculation based on a 5-year period is called Case B. The same principles for the calculations were used in PLAN 2000 (SKB, 2000b).

[1] The Act (1992:1537) on the Financing of Future Charges for Spent Nuclear Fuel etc. (called the Financing Act) and the Ordinance (1981:671) on the Financing of Future Charges for Spent Nuclear Fuel etc.

In PLAN 2001 (SKB, 2001), SKB assumed in its reference scenario that the reactor would be operated for 40 years and that decommissioning did not have to start until 2016 at the earliest when the repository for decommissioning waste would also be ready. On the other hand, in its calculations, SKI used the same scenario that was used the previous year, namely, that a repository for decommissioning waste would be taken into operation in 2010.

In the subsequent PLAN 2002 (SKB, 2002), SKB used the same assumption as in PLAN 2001. SKI chose to change one of the calculation assumptions so that a repository for decommissioning waste could be taken into operation in 2015 (SKI, 2002). This resulted in the decommissioning costs being calculated on the assumption that decommissioning would start in 2015 for all of the reactors. However, in the case of Barsebäck, the decommissioning date was set at 2017 in order for the calculation to agree with the agreement signed between the Swedish state, Vattenfall and the owners. The adaptation of the date for the start of decommissioning which was made in PLAN 2002 meant that the cost estimate in accordance with the Financing Act was harmonized with RD&D Programme 2001.

In PLAN 2003 (SKB, 2003), the start of decommissioning in 2015 was specified for Case B with the exception of Barsebäck where decommissioning was assumed to be started in 2017. In the supplement to the basis for calculating the fee for Case B, which was submitted to SKI on October 9, 2003, SKB had moved ahead the date for the startup of a repository for decommissioning waste to 2020 and, thereby, the decommissioning costs were calculated on the basis of decommissioning starting in 2020 (SKI, 2003).

SKI states that a basic principle for the Financing Act is to create a robust and sustainable financing system that does not run the risk of transferring the costs to future generations. Therefore, it is necessary that the measures planned in RD&D Programme 2004 should actually be implemented.

The calculation of the basis for the fee has so far been based on the assumption that it would be possible to close down each reactor after 25 years of operation and for the accumulation of a complete set of funds to have begun at that time so that money is available to manage spent nuclear fuel and nuclear waste as well as to decommission the nuclear power plants. SKI's most recent proposal and calculations are based on this assumption and on the timetable presented in RD&D Programme 2004. In SKI's view, it is less suitable in the calculation work to use a planning assumption which is based on the assumption that the decommissioning of nuclear power plants will start before a repository has been completed (SKI, 2004). Therefore, SKI considers that SKB's assumption concerning the startup of a repository for decommissioning waste in RD&D Programme 2004 is suitable, which means that the earliest date for decommissioning would be 2020, if no interim storage facility for decommissioning waste is added.

SKB's Report

In Chapter 24 of RD&D Programme 2004, under the heading "Decommissioning", SKB provides an account of how the management of radioactive waste from the decommissioning of Swedish nuclear power plants and SKB's own planned work in the area are to be carried out.

SKB states that previous experience from the decommissioning of nuclear facilities in Sweden is limited to the R1 research facility at KTH. A multi-year project involving the decontamination of the ACL (Active Central Laboratory) at Studsvik has been underway for several years. SKB has followed this work.

SKB presents the decommissioning logistics based on the startup date of the reactors. SKB estimates that Swedish nuclear power plants will be taken out of service over a 13-year period on average.

SKB also presents certain international experience from the decommissioning of nuclear power plants which includes a normative discussion concerning when a nuclear facility can be decommissioned. SKB states that international developments show a tendency towards early dismantling and demolishing compared with a delayed dismantling and demolishing after closure. However, SKB states that variations occur among different countries. SKB provides a number of reasons which are in favour of early dismantling. For example, there may be a need to use the site for alternative purposes, early dismantling means that the nuclear competence at the facility can be used or that dismantling can be conducted for demonstration purposes.

SKB describes the effects of active system and component decontamination. SKB describes the dismantling process with management of active components before conventional dismantling of the buildings can be carried out. SKB estimates the average time for active dismantling at about 6 year per reactor unit.

SKB describes the technical development that has taken place and that is documented in studies from facilities in Sweden and abroad. Both SKB and the power companies are planning to carry out decommissioning studies. SKB states that adequate technology is available for decommissioning and waste management. SKB considers the critical work to be optimizing and adapting existing technology so that good premises are created for decommissioning Swedish nuclear power plants. Using the selected technology as a basis, SKB estimates the time required, the costs and the waste quantities associated with decommissioning.

Planning and licensing of the disposal of radioactive waste from decommissioning require an overall planning process conducted at a national level. SKB points out that there are benefits to co-ordinating this work, with respect to access to special equipment for decommissioning. A basic principle is that no unit is to be decommissioned as long as operations are underway at an adjacent unit. SKB considers that dismantling cannot be started until some time after 2015 and probably not until some time into the 2020's. SKB points out that it is the licensees who have the main responsibility for planning and implementing the physical decommissioning. The responsibility also includes determining a strategy for a selected date and technology for the decommissioning work. The treatment of the radioactive waste is to be planned and conducted in co-operation with SKB.

SKB is responsible for the management of the waste that is generated. The repository for decommissioning waste must be constructed and a transport system that is adapted

to the transportation system needs to be implemented. In the case of the SFL waste, interim storage needs to be provided until the repository is ready.

Comments by the Reviewing Bodies

The National Board of Housing, Building and Planning notes that, through the closure of Barsebäck's second reactor in 2005, the question of decommissioning the nuclear power plant will immediately become relevant. The Board considers that there is a risk that the storage of long-lived low and intermediate-level waste, which largely comes from the decommissioning of nuclear power plants, will be a bottleneck in the disposal chain. Therefore, in the view of the Board, SKB should report on how long-lived low and intermediate-level radioactive waste is to be managed if it is generated at an earlier stage than planned. A zero alternative should also be reported in the description of consequences, namely, what would happen if no action is taken.

The Network for Co-operation among Nuclear Municipalities (KSO) observes that the Government's decision to close down Barsebäck 2 in 2005 has meant that the question of the nuclear municipalities' attitude to the imminent decommissioning of facilities and the municipalities' request for future land use has become even more topical. KSO reminds SKB that the municipalities have a planning monopoly. This means that the municipalities must have decisive influence with respect to future land use in the entire municipality, even with respect to those areas where nuclear power plants are located. In view of the early phase-out which will now be implemented at Barsebäck 1 and 2, and which Kävlinge Municipality in different ways has recommended against implementing both for environmental reasons and for reasons relating to the destruction of capital, KSO demands that SKB, in its RD&D programme, should immediately investigate the possibility of a more rapid decommissioning and restoration of the site than that reported in RD&D Programme 2004.

The Local Safety Committee at the Nuclear Facilities at Forsmark completely agrees with KSO's statement concerning rapidly freeing up space where closed down nuclear power plants are standing. This means that both facility owners and SKB must choose the early phase out of facilities or the construction of interim storage facilities.

Issues that the Swedish Environmental Protection Agency finds particularly important to further investigate in connection with the decommissioning of facilities include the planning of environmental work and thorough monitoring for any impact on human health and the ecosystem.

Oskarshamn Municipality points out that the Municipality, like other municipalities with nuclear power plants, would like a broader dialogue on the subject of decommissioning plans, the timetable for decommissioning and on how decommissioning waste is to be managed.

Umeå University wonders whether events (closure of Barsebäck 1, planned closure of Barsebäck 2) should perhaps warrant a reassessment of the situation so that the planning of reactor decommissioning should be scheduled for an earlier time than originally planned. The University also points out that if sound plans for nuclear power plant decommissioning exist and if this can be demonstrated through the timely professional

and safe decommissioning of Barsebäck, this would certainly speak in favour of the sense of responsibility of the nuclear power sector and serve its interests.

Based on the plans reported in RD&D Programme 2004, Umeå University finds that the closed down reactors at Barsebäck are to be placed in mothballs for a very long time. The University wonders whether it is not warranted to now raise the level of ambition with respect to decommissioning since we may shortly have an entire nuclear power plant that ceases its electricity production. The University also considers that it may also be justified to ensure that the allocation of responsibilities is not unclear between SKB and the nuclear power plant owners.

Östhammar Municipality agrees with what KSO has stated in its joint statement for the municipalities concerning the municipalities' influence over future land use in the entire municipality. The Municipality also agrees that there is a need to rapidly free up space that is occupied by closed down nuclear power plants.

This means that both plant owners and SKB should plan for constructing facilities at an earlier time than planned or constructing interim storage facilities to manage decommissioning waste.

Experience shows that it takes a long time to realize this type of plan. In the view of the Municipality, it should be possible, already at this stage, for SKB to present a plan for the entire nuclear waste programme.

The Swedish Radiation Protection Authority (SSI) considers that SSI should prepare an improved account of strategies and timetables for decommissioning and management of decommissioning waste, in view of the decision to close down Barsebäck 2 etc.

Furthermore, SSI considers that the licensees for the nuclear power plants should provide a clearer description of how they intend to carry out decommissioning. SSI also considers that the allocation of responsibilities between the nuclear power companies and SKB must be clarified.

As a result of the decision to close down Barsebäck's second reactor, the premises for planning decommissioning work are considered to have changed. Therefore, SSI considers that the basic premise should be early decommissioning of the Barsebäck reactors. This is based on the assumption that a repository for short-lived low and intermediate-level waste exists in order to avoid interim storage. In the light of this, SSI considers that the design of a repository for long-lived low and intermediate-level waste should be prioritized in the research programme and that this should be stated in the forthcoming RD&D Programme 2007.

SKI's Evaluation

RD&D Programme 2004 reflects the situation from RD&D Programme 2001 up to September 2004. After RD&D Programme 2004 was submitted, the Swedish Government decided that Barsebäck's second reactor should be permanently closed down. Furthermore, Studsvik Nuclear AB decided to close down the R2 and R2-0 reactors in June 2005. SKI considers that the issue of the decommissioning of nuclear facilities has clearly now been made highly relevant by these two events. SKI points out

that in its report SKB talks about early decommissioning after the final closure of a facility. SKI has noted that several reviewing bodies also consider that decommissioning issues need to be activated and clarified and that issues relating to early and delayed decommissioning must be evaluated.

SKI agrees with most of the review comments presented by the reviewing bodies which, to summarize, entail that SKB is recommended to prepare a clearer and more consistent report of its strategy selection and timetables for dismantling and handling of decommissioning waste. In addition, the possibility for a more rapid decommissioning, and thereby an earlier restoration of sites than described by SKB, should be identified. Certain reviewing bodies would like to see an in-depth dialogue conducted on decommissioning plans, timetables for decommissioning and the management of decommissioning waste. In SKI's opinion, it is essential for parties concerned to conduct an active dialogue and for this dialogue to be carried out at a deeper level over the next few years so that facility closure and decommissioning issues are clarified in the nuclear waste project.

SKI notes that, on the topic of the construction of a repository for decommissioning waste, SKB states that the repository is needed before the decommissioning of the first nuclear power plant can be carried out. At present, this is expected to be done by 2020 at the earliest. The plan is to deposit short-lived waste in SFR. SKI would like to point out that the question of a renewal of the operating licence for SFR to receive short-lived decommissioning waste should be investigated already during the next few years. Such a measure could result in the direct disposal of decommissioning waste from reactors in SFR. SKI considers that short-lived decommissioning waste from the Barsebäck reactor can probably be covered by already approved type descriptions for waste intended for SFR.

In SKI's view, in the light of the line of reasoning presented above, work on decommissioning issues needs to be intensified during the next few years with the aim of presenting a clearer plan in RD&D Programme 2007. In SKI's opinion, SKB and the reactor owners should already at this stage start planning the work on reviewing the possibilities of scheduling for an earlier time for some of the processes leading to a more rapid dismantling and management of waste.

In SKI's opinion, the allocation of responsibilities among SKB and its owners should be clarified so that the distinction between decommissioning technology and decommissioning costs becomes clearer. Even though these two parts of the process are mutually interdependent they require different competencies and entail different methodologies.

SKI would like to point out that, from an international perspective, extensive experience exists of the decommissioning of nuclear facilities. The technology and logistics for the management of decommissioning waste need to be defined and detailed for Swedish conditions before it is possible for the transition to be made to a pure decommissioning process. SKI reminds SKB that a comprehensive EIS must be prepared and approved before decommissioning can start. In order to adapt the planning to the changed conditions resulting from the decisions made concerning the permanent closure of nuclear power plants in Sweden, SKI considers that preparations for decommissioning

plans must be started quite promptly since it is a complex, time-consuming and multifaceted process which has so far not been implemented in Sweden on a full scale. SKI considers that development work is necessary so that the preparedness for nuclear power plant decommissioning is of the same level of quality as the development work for disposal.

SKI would like to clarify the fact that there are two sides to nuclear power plant decommissioning: the technical and the financial side. The financial side is an unconditional prerequisite for the implementation of decommissioning and for the safe management of decommissioning waste. In the case of direct decommissioning, it is possible that the financial risks will be smaller since the events will occur in the near future involving known methods and technology, risks and legislation. SKI therefore considers that an early decommissioning is preferable.

In SKI's opinion, in the light of the conditions discussed above, it is valuable for SKB to implement the measures planned in RD&D Programme 2004 so that more reliable and robust calculations of the future decommissioning costs can be performed and a more detailed decommissioning plan can be created and presented in RD&D Programme 2007.

Finally, SKI would like to emphasize that sufficient funds must be available in the Nuclear Waste Fund to allow for decommissioning in accordance with the current Financing Act. Funds have accumulated based on an earning period of 25 years plus any additional years that a reactor is in operation. Even if the industry currently bases its calculations on an operating time of at least 40 years, the funds accumulated in the Nuclear Waste Fund enable direct decommissioning of nuclear power plants to be carried out after the end of the earning period of each plant is reached. This is the case except for the Barsebäck reactors which have a somewhat different timetable due to the early permanent closure of Barsebäck's first reactor.

10.3 SKI's Overall Evaluation – Decommissioning

SKI's overall evaluation is that if SKB is to be able to deliver a good result with its cost estimates, the desired direction of work presented in RD&D Programme 2004 for the next six years must be realized. If the planned activities are carried out, more reliable cost estimates can be prepared for the decommissioning of the nuclear reactors and SKB's facilities. It is particularly important, from the financial standpoint, that an overall decommissioning study should be carried out during the period, so that detailed estimates of decommissioning costs are available for each nuclear power plant no later than by 2010.

In particular, SKI considers that the following measures must be implemented over the next six years:

- SKB and the individual nuclear power plant licensees should specify the allocation of responsibility among themselves with respect to the choice of methods for decommissioning, waste management and for cost estimates.

- SKB needs to intensify the work on decommissioning issues and to present the results in RD&D Programme 2007. This work should be conducted taking into account the decommissioning plans that the reactor owners are obliged to prepare, for example, with respect to the analysis of facility status, radioactive inventory and competence in decommissioning issues.

- SKB and the reactor owners should also start work on investigating whether certain parts of the decommissioning work can be scheduled for an earlier date.

- SKB should investigate how soon a licensing process for the disposal of decommissioning waste can start, if possible, within the next few years.

In SKI's opinion, a review of decommissioning logistics based on an assumption that the operation of nuclear power plants will be extended from 40 years to 60 years cannot be prioritized since the premises for such a plan are not included in RD&D Programme 2004 or in PLAN 2004. In fact, such a measure could actually prove to be counterproductive since it could lead to the delay of scheduled work in practice which, in turn, could lead to a delay in the startup of the repository for decommissioning waste by an additional couple of decades.

By investigating a changeover from 40 to 60 years of reactor operation, a situation can be created where the mental preparations required for the successful planning of decommissioning are neglected for such a long time that existing knowledge is lost. It is difficult to see how decommissioning can be delayed without having to construct an interim storage facility for decommissioning waste. In SKI's opinion, the construction of an interim storage facility for decommissioning waste should be avoided, since it will result in the need for additional handling of nuclear waste and could lead to the entire nuclear waste project becoming more expensive than planned. The construction of an interim storage facility would probably mean that additional funds would have to be accumulated in the Nuclear Waste Fund since such a measure is not included in the RD&D programme or in the cost estimate in the PLAN report.

11 Low and Intermediate-Level Waste

In this chapter, SKI comments on Chapter 25 of RD&D Programme 2004.

Introduction

In addition to spent nuclear fuel, low and intermediate-level waste must also be managed.

Short-lived low and intermediate-level waste is generated by the operation and maintenance of nuclear power plants and by industry, research and hospitals. This waste is deposited in the repository for radioactive operational and maintenance waste, SFR 1. Short-lived low and intermediate waste is also generated by nuclear power plant decommissioning. The plan is to deposit this waste in an extension of SFR 1.

Long-lived low and intermediate-level waste mainly consists of two types:

- core components, some of the reactor internals and waste from maintenance and decommissioning of nuclear power plants
- long-lived waste from industry, research and hospitals.

Long-lived waste from the operation of nuclear power plants is placed in interim storage at Clab or at the nuclear power plants. The waste from the decommissioning of nuclear power plants will first be placed in interim storage at a site that has not yet been determined and then deposited in a repository for other long-lived waste, SFL 3-5.

SKB has not yet decided whether SFL 3-5 is to be located next to SFL 2, SFR 1 or at a completely different site. According to SKB's timetables, this issue will not be decided until about 2025-2030.

SKB has studied two layout alternatives for the SFL 3-5 repository with either bentonite or gravel as backfill. The primary barrier to radionuclide transport is concrete containments.

SKB's Report

SKB plans to deposit short-lived decommissioning waste in an extension of SFR, some time in the mid-2020's. A new preliminary safety report will be prepared before the next RD&D report. Long-lived decommissioning waste will be deposited in SFL 3-5 in around 2045.

In order to reduce the uncertainties surrounding important substances in the radionuclide inventory of the waste, SKB has focused its research on a number of areas. This has resulted in the development of an improved detection method for nickel-59 in the steel material. A project has started to measure carbon-14 in ion-exchange resins from Swedish reactors. SKB has also started measurements of chlorine-36 in steel material from Swedish reactors.

SKB describes the processes which were found to be of importance for the long-term properties of the barriers and which were identified in research supported by SKB and by international investigations in the area. The following new areas have been added since the RD&D programme:

- concrete degradation in saline water
- the influence of organic additives in cement on radionuclide sorption
- sorption properties of fresh and aged concrete
- the importance of isotope exchange and co-precipitation for retardation of low-sorbing radionuclides.

SKB's programme for low and intermediate-level waste over the next few years (2005-2010) prioritizes the following areas:

- a system for dry interim storage of core components
- preparations for future safety assessments
- handling and storage of waste
- preliminary safety evaluations for disposal of short-lived operational and decommissioning waste in SFR
- study the prospects for a shallow repository for very low-level decommissioning waste
- the diffusion and sorption of radionuclides in high-pH concrete and rock and the impact of organic substances
- models for concrete degradation, including the effects of saline water
- corrosion of metals in a concrete environment
- studies of reactions between leachate from concrete and the surrounding gravel in the repository
- natural analogues of alkaline concrete environments.

SSI's Comments

In SSI's view, SKB in its planning should take into account that it may be unsuitable from the radiation protection standpoint to, for example, "save" space in the Silo for future needs by placing waste that was originally intended for the Silo in a storage facility with reduced protective properties.

SSI considers that long-term waste storage while waiting for a repository to be built should, as far as possible, be avoided and that SKB should therefore review its reasons for delaying the construction of a repository for long-lived waste until most of the nuclear power plants have been decommissioned.

SSI points out that the long-lived low and intermediate-level waste that is currently primarily placed in interim storage at Studsvik, Clab and at the nuclear power plants has, in many cases, been segmented and packed into different types of packaging. Therefore, SSI considers that as long as no credible disposal concept has been developed, there is a considerable risk that the waste will have to be reconditioned prior to disposal, which can result in unnecessary radiation doses in connection with handling. In the light of this, SSI considers that the design of a repository for long-lived low and intermediate-level waste should be prioritized in the research programme and that this should be specified in RD&D Programme 2007.

Comments by Other Reviewing Bodies

The Waste Network and Oss consider that a well thought-out safety assessment of the repository for long-lived low and intermediate-level waste, SFL 3-5 is missing.

The National Board of Housing, Building and Planning points out that, with the decommissioning of the nuclear power plants at Barsebäck, this waste could be a bottleneck in the disposal project. Therefore, the Board considers that SKB should give an account of how long-lived low and intermediate radioactive waste is to be managed if it arises earlier than planned. A zero alternative, namely what would happen if no action were taken, should also be presented in the environmental impact statement.

Oskarshamn Municipality would like to see a broader dialogue on the subject of decommissioning plans, decommissioning timetables and how decommissioning waste is to be managed. The municipality would like to see a clarification of SKB's intentions with respect to a possible co-siting of the SFL 3-5 repository with the repository for spent nuclear fuel, even if SKB has previously stated that the location of the SFL 3-5 repository is independent of the current site selection.

SKI's Evaluation

SKI is positive to the fact that SKB has now also included short-lived waste in its description of the system for the management of low and intermediate-level waste in RD&D Programme 2004.

In SKI's review statement on SKB's RD&D Programme 2001, SKI requested a report on what would be included in the forthcoming safety assessment for long-lived low and intermediate-level waste disposal. No such report has been provided in RD&D Programme 2004. SKI therefore recommends that, in RD&D Programme 2007, SKB should provide a well-structured report which justifies the construction requirements which must be made on the repository from the perspective of long-term safety.

Questions that need to be investigated in greater detail include:

- choice of repository depth
- a possible separation distance between the repository for long-lived low and intermediate-level waste (SFL 3-5) and the repository for spent nuclear fuel (SFL 2)
- backfill material and the hydraulic cage principle
- the repository dimensions
- quantity of cement and choice of cement type.

In addition, SKB should describe the requirements that must be made on a possible candidate site so that it corresponds to the requirements made on the proposed layout of SFL 3-5 (SKI, 2001). In order for SKI to be able to judge the reasonableness of the focus of the forthcoming safety assessment (the plan is to submit a safety evaluation in 2011), SKI considers that SKB should describe the focus in RD&D Programme 2007.

SKI agrees with SSI that a well-founded proposal for the layout of a repository for long-lived low and intermediate-level waste should be presented in RD&D Programme 2007.

SKI also shares SSI's view that the interim storage of waste while waiting for the construction of a repository should, as far as possible, be avoided and that SKB should therefore consider whether the planning and design of a repository for long-lived waste can start at an earlier stage.

SKI agrees with the National Board of Housing, Building and Planning that SKB should describe how the long-lived low and intermediate-level decommissioning waste will be managed if it is generated at an earlier stage than planned and that a zero alternative, namely what would happen if no action is taken, should be presented.

The research work carried out for both short-lived and long-lived waste is reported in RD&D Programme 2004. However, SKI lacks an account of a research strategy in the area. The link between results from completed safety assessments and the additional research that needs to be done belongs to this strategy. RD&D Programme 2004 states only that the work is primarily being conducted to obtain data for the models for analyzing long-term safety. Nothing was said of the need for additional model development. SKI considers that it is important that the priorities that SKB has set in different areas should be reported.

SKB describes the experiments that are being conducted to investigate how leaching products from cement react with rock minerals. The various references for the investigations carried out are published in international journals. SKI considers that it would be valuable for SKB to compile the results so far obtained and report how the results will be used in the forthcoming safety assessments for low and intermediate-level waste as well as whether additional research is needed in the area.

SKB assumes that the concrete construction (this applies to both SFR and SFL 3-5) may contain cracks already from the start and considers that this will not have a negative impact on long-term safety. In SKI's opinion (which was also expressed in SKI's review of RD&D Programme 2001), SKB should carry out an analysis which shows how large and how many cracks can be allowed on different timescales without the protective capabilities of the concrete against radionuclide leaching being considerably impaired. Some form of quantitative requirement should be established and an analysis of requirement compliance for evaluating whether the physical integrity of the concrete can be included in the safety assessment.

In the programme for low and intermediate-level waste, SKB reports the research work that will be needed over the next five years. The report on how the decommissioning waste from the nuclear facilities is to be managed needs to be more detailed in the future. For example, the points (see page 334 of RD&D Programme 2004) are far too brief to describe SKB's strategy on the issue.

12 Social Science Research

In this chapter, SKI reports the comments made primarily by the reviewing bodies on Chapter 22, "Social Science Research" of RD&D Programme 2004.

In connection with the review of RD&D Programme 2001, several reviewing bodies submitted their views on how societal issues, primarily, decision-making processes, environmental impact assessment and psychosocial issues should be studied. Several reviewing bodies wished SKB to supplement its technical report with a social science part describing research on, for example, attitudes, decision-making on complex societal issues and society development in the long term. SKB has taken heed of the request and has included social science research in RD&D Programme 2004.

SKB's Report

SKB sent out an inquiry of interest in participation in research in four generally relevant areas of a social science programme to universities and institutes of technology. Of the research project proposals received, eight were approved, with a distribution of seven universities and institutes of technology, for funding for a period of 1 to 2 years. The research areas, project titles and aim of the projects are as follows:

Socioeconomic Impact

Local development and regional mobilization around technical and large-scale projects (Department of Economic History at Umeå University). The aim is to build up knowledge concerning how the socioeconomic structure of regions is affected by the establishment of a new, large and technically advanced facility.

Long-term socioeconomic effects of major investments in small and medium-sized regions (Department of Social and Economic Geography at Umeå University), where the aim is to analyze the long-term local effects of investments on population and employment.

Decision Processes

Public, experts and deliberation (Man-Technology-Environment Research Centre at Örebro University) where the aim of the project is to contribute knowledge concerning how the different perspectives and judgements of members of the public and experts are combined in consultation and decision processes associated with the establishment of a repository.

Resource or Waste? International decision processes relating to spent nuclear fuel (History of Science and Technology Department, Royal Institute of Technology, KTH). The aim of the project is to identify and analyze decision processes relating to nuclear waste in an international and historical perspective.

Public Opinion and Attitudes

Identity and security in time and space – cultural perspectives on the existential dimensions of the nuclear waste issue (Human Ecology Division at Lund University). In

this project, tacit symbolic and experiential aspects of the debate concerning facilities for the handling and disposal of spent nuclear fuel will be studied in time and space.

Nuclear waste – from energy resource to disposal problem (Theme Technology and Social Change at Linköping University) aims at studying how opinion formation by the media in the nuclear waste issue has changed on the national plane between the 1950s and today.

Attitudes towards a deep repository for spent nuclear fuel (Centre for Risk Research at the Stockholm School of Economics). The project will contribute to a better understanding of risk and policy attitudes which, in turn, is a prerequisite for better and more effective risk communication.

Global Changes

National nuclear fuel policy in a European Union (Department of Law at the School of Economics and Commercial Law at Göteborg University). The aim of the study is to clarify and analyze the legal situation for and authority over nuclear waste management.

Comments by the Reviewing Bodies

The Waste Network and the Opinion Group for Safe Disposal (Oss) note that the experience from previous investigations in the area of social science research clearly show that SKB is using these investigations as biased accounts to raise the level of or secure acceptance for the project in the municipalities concerned. The Waste Network and Oss suspect that this may be the main reason why SKB is now consciously putting much work into the social science aspects at the same time that, in this way, SKB is satisfying the municipalities' most explicit concerns with the project. In the view of the Waste Network and Oss, social science investigations should not fall within the scope of SKB's area of responsibility when this is done at the expense of the quality of the environmental impact assessment. In their view, such aspects should instead be handled by KASAM, for example.

The National Board of Housing, Building and Planning notes that SKB has conducted and will conduct social science research as a basis for the EIS which will be included in the application for a repository for spent nuclear fuel etc. In the view of the Board, it is positive that SKB is taking a broad approach to the handling of this issue and that this will provide a better basis for and information in the dialogue prior to forthcoming decisions.

KSO (the network for co-operation among nuclear municipalities) approves of RD&D Programme 2004's intentions to also allow social science researchers to investigate the consequences to society, in a broad sense of the term, of the establishment of large-scale industries such as nuclear power plants and decommissioning of such plants.

The Swedish NGO Office for Nuclear Waste Review (MKG) considers that SKB's programme for social science research should be reorganized so that the scientific integrity is guaranteed to a greater extent. One possibility is for a foundation that is independent of SKB to handle the funds for social science research or for these funds to be made available to the Swedish Research Council.

The Swedish Environmental Protection Agency considers that, besides additional technical and scientific research studies, the social scientific focus should be reinforced especially with respect to contact with the general public. Risk assessments for accidents, unauthorized access, sabotage, changes in societal systems, incorrect decisions etc. should be carried out.

Oskarshamn Municipality considers that it is positive that SKB has now included a social science section in its RD&D programme. The social science research programme contains relevant areas and has a commendable breadth. For Oskarshamn Municipality, important areas are the EIA, integration of the technological and social science aspects, followup of the municipality's conditions, the link between research and investigation and its impact on the site investigation programme and consultations.

The Society Group at Oskarshamn Municipality considers that the different research areas in the social science programme that have been identified are all relevant. Essential issues are raised and the complexity of the impact on society is made visible. On the whole, SKB's account covers more than what the approved research projects will study. Therefore, it is important for SKB, together with other parties, to continue to expand and deepen its research as planned. One concrete area to be further discussed and to be studied early in the process is global changes in the short and long term. For example, this concerns the existence and development of nuclear power in Sweden since this clearly affects the nuclear waste programme. One of the main views held by Oskarshamn Municipality is that the impact of a repository should be identified on different levels. Knowledge of local, municipal and regional impact is central to discerning variations between these levels. This knowledge is needed in order for results to be tangible and understandable to decision-makers, organizations concerned and, in particular, the interested general public.

The fact that society's view of the nuclear waste programme and the development of society are the largest uncertainty factors according to both SKB and the Municipality provides strong justification for studying these factors in greater detail. The Society Group considers that it is positive that existing projects represent diverse disciplines and scientific approaches. One deficiency is that few seem to be based on the feasibility study experience or site-specific conditions at Oskarshamn or Östhammar. Unresearched areas and central perspectives exist which could reinforce the programme if they were included. One example is the gender-based approach which deals with differences in men and women's perceptions of nuclear waste.

The Group notes that the nuclear waste issue is a large environmental project which is very seldom related to the concept of sustainable development. Therefore, it is important to relate the nuclear waste issue to this concept and the general environmental debate in this area. In this case, it is also a question of examining the concept on the local, municipal and regional scale.

The Society Group also notes that political science perspectives where party-political analysis is performed could be fruitful. The same applies to reviews of the ongoing information dissemination, especially media treatment of the nuclear waste issue. This

is important since SKB, in parallel with the consultations, like other actors in this issue, is conducting an “extensive information activity”.

Furthermore, the Group considers that it would be good if SKB could more clearly describe what it considers to be the boundary for humanistic research. Philosophical, historical and cultural anthropological (ethnological) approaches to disposal and siting would also seem to be relevant. Since Sweden has often been considered to be a role model, social science and humanities researchers from other countries should also been invited to conduct research on the Swedish process.

The aim of social science research is to raise the level of the quality of decision-making and EIS as well as to “provide deeper knowledge and a better body of data as a basis for site and project-related studies and analyses”. In order to achieve this, the Society Group would like an account of how SKB, in concrete terms, envisages that the research findings can influence the programme. This also applies to social science investigation findings. There is considerable overlap between the social science research and the social science investigations and much can be gained from communication among the different projects. The main direction is research which can be turned into practical application. The role played by social science research and investigations in the site investigations and in the EIA and how this role is linked to the decision-making process should therefore be clarified. The process will be more transparent and understandable if SKB specifies which material could become available, when, and for whom the material is intended.

Finally, the Society Group observes that RD&D Programme 2004 is characterized throughout by the high priority given to technological issues and the objective of complying with the timetable. The site investigations that are relevant for society and the EIA are dealt with briefly in an appendix. The social science investigations are not included. On the whole, this gives the impression that the scope for the influence of the social science research and social science investigations over the programme and over the (decision) process as a whole runs the risk of being minimal. Such a development would be unfortunate since the integration of technological and societal aspects is the very key to a good siting process. Therefore the Society Group would also like SKB to present a description which deals with the overall picture and the integration between the different technological and societal processes and the parts of SKB’s programme.

Umeå University notes that since the University has previously called attention to issues relating to processes of change within human society, the University appreciates that social science research has now been included in the project. In this context, one should also be prepared for surprises. Similarly, one should expect that some of the work that is now being planned will be falsified at some point in the future.

Östhammar Municipality notes that, in 2004, SKB started a research programme in the social science sector, which was requested by Östhammar Municipality in its review statement on RD&D Programme 2001. In addition to the research programme and, therefore, separately from the account presented in RD&D Programme 2004, SKB is conducting a number of social science investigations within the framework of the site investigations. Unlike these investigations, it is difficult to perceive how SKB’s programme will tangibly benefit from the findings of the social science research. The

research has recently started and there are only two to four years remaining until SKB intends to submit applications for permission to construct both of the facilities in question. SKB should clearly describe how the research findings will be used by SKB and delivered to the authorities and the municipality within the intended timeframe.

SKI's Evaluation

SKI notes that SKB in RD&D Programme 2004 has incorporated social science research as a new discipline in the research programme. SKI sees advantages in doing so since it should be possible for the interested parties to apply the research findings in ongoing and future consultation processes.

SKI notes that limited resources are being invested in the area of global changes (a project) in the social science research programme. This area should perhaps have deserved somewhat greater attention and a greater scope especially in view of the discussion and activities that are now in progress, in the EU and outside the EU, concerning international repositories.

SKI also notes that the process and procedure for granting funds to researchers could have been better described in the report. Furthermore, the report does not state which criteria were applied to the granting of research funds. At a first glance, it would seem that SKB aimed for a geographical spread of projects where established universities and institutes of technology are located.

SKI, like several reviewing bodies, would like SKB to describe how the findings of the programme will be applied in the EIA and how SKB's other programme areas will benefit from these findings. Therefore, SKI considers that it would have been warranted to provide a preliminary plan of how the findings from the research projects will be dealt with and how the findings will feed into the consultation process and other processes in SKB's programme.

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