SKI Report 2008:48 E

Review Statement and Evaluation of the Swedish Nuclear Fuel and Waste Management Co's (SKB) RD&D Programme 2007

Swedish Nuclear Power Inspectorate (SKI)

June 2008

ISSN 1104-1374
ISRN SKI-R-08/48-SE

Date
12 June 2008

Our reference
SKI 2007/1218

Your date

Your reference

To the Government
Ministry of the Environment
103 33 STOCKHOLM

SKI's Review Statement on the Swedish Nuclear Fuel and Waste Management Co's (SKB) RD&D Programme 2007

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

SKI's Review Statement

The Swedish Nuclear Fuel and Waste Management Co (SKB) has submitted RD&D Programme 2007 to SKI for review section 12 of the Nuclear Activities Act (1984:3).

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

- ***That the reactor licensees, through the Swedish Nuclear Fuel and Waste Management Co (SKB), have fulfilled their obligations in accordance with section 12 of the Nuclear Activities Act (1984:3)***

- ***That disposal in accordance with the KBS-3 method still seems to be the most appropriate planning assumption for disposing of the spent nuclear fuel from the Swedish nuclear power programme***

In this connection, SKI considers that the Government should:

- ***Instruct the reactor licensees to submit supplementary reports concerning SFL, SFR and decommissioning at the latest by 31 March 2009 since SKB has***

not fully taken into account the Government's expectations on reporting of relevant issues in RD&D Programme 2007

- ***Recommend SKB to continue the consultations decided upon by the Government in 1996 and 2001 until SKB submits an application to construct the repository for spent nuclear fuel***

- ***Take note of other evaluations and comments conveyed in this statement***

Supplement

The Repository for Long-lived Low and Intermediate-level Waste - SFL

RD&D Programme 2007 should be supplemented with current plans and programmes for SFL. This supplement should be drawn up in such a way as to provide the authorities with a body of material for evaluation of whether the report on the programme for SFL in RD&D Programme 2010 is of sufficient scope as regards:

- quantitative estimates of the time at which such waste occurs that is intended to be finally disposed of in the SFL repository
- alternatives for the design of the repository, including the design premises and safety functions that will be applied
- the content and focus of future safety assessments of SFL to be able to produce and verify acceptance criteria for waste to be disposed of in the SFL repository
- the content of a research and development programme as support for future safety assessments of SFL.

The Repository for Short-lived Low and Intermediate-level Waste - SFR

RD&D Programme 2007 should be supplemented with clearer reports of plans and programmes for expansion and operation of SFR as well as a preliminary report on the final disposal of operating and decommissioning waste in SFR. This supplement should be drawn up in such a way as to provide the authorities with a body of material for evaluation of whether the report of the programme for SFR in RD&D Programme 2010 is of sufficient scope.

Planning for Decommissioning Nuclear Power Plants

RD&D Programme 2007 should be supplemented with:

- a compilation of the decommissioning plans produced by the nuclear power companies in accordance with SKI's and SSI's regulations
- a report on final disposal of decommissioning waste from Barsebäck which should be supplemented with clarifying supporting documentation, which shows in quantitative terms the possibilities and difficulties of starting deposition of decommissioning waste in the existing SFR at different times
- a report on how Vattenfall AB as licensee for Ågesta heat power reactor intends to comply with its obligations in accordance with section12 of the Nuclear Activities Act.

Supplements must have been received by 31 March 2009 to enable SKB to assimilate comments from the authorities and reviewing bodies before the next RD&D Programme 2010. The review, including the review process ought then to have been completed by 30. September 2009 and it should be possible for the Government to adopt a decision fairly immediately afterwards. This timetable assumes, however, that SKB starts work on the supplement and RD&D Programme 2010 immediately after SKI has submitted its statement on the current RD&D Programme, without necessarily waiting for future government decision.

Consultations

SKB states in RD&D Programme 2007 that it is intended to submit an application for a repository for spent nuclear fuel at the end of 2009. SKI has been informed in the consultations in process that SKB plans to submit an application during the first half of 2010.

In SKI's opinion, it is evident from the report in RD&D Programme 2007 that there are still outstanding issues that need to be further investigated before SKB is able to achieve a completely satisfactory body of material for an application on a repository for spent nuclear fuel.

SKI further considers that it is uncertain whether it is possible for SKB to carry out the additional investigations needed, during the limited time remaining until SKB intends to submit the application.

SKI wishes to emphasise that it is particularly important that SKB can report on results from additional/in-depth investigations in the application in the following areas:

Methodology and Criteria for Final Selection of the Repository Site

- In the choice of site for the repository, SKB should clearly indicate the methodology and criteria which have been applied and which have thus governed the choice of site. This is particularly the case if the supporting documentation for the choice is not wholly comparable
- The rejected site needs to be reported in such a way that the authorities can make their own independent evaluation compared with the selected site.

Long-term Experiments at the Äspö Hard Rock Laboratory

- SKB should state how achieved and expected results from not yet completed full-scale tests at SKB's research laboratories will be reported and adapted to the timetable for the application.
- SKB needs to clarify which additional experiments are needed at the Äspö Hard Rock Laboratory (and at the chosen repository site), the intended purpose of the various experiments as well as to produce a plan for their implementation.

Safety Assessment

- SKB should in an appropriate way relate to the need for research and development initiatives from the critical questions identified by SKI and SSI in the review of the safety assessment SR-Can.
- SKB should use the consultations between the authorities and SKB for a continued dialogue in order to avoid unnecessary lack of clarity concerning methodological issues, interpretations of regulatory requirements and forms of reporting.
- Prior to SR-Site, SKB should rectify weaknesses in the methodology applied to date and increase the level of ambition for quality work in conjunction with safety assessment.

SKB's Plan of Action

- SKB should in RD&D Programme 2010 report a clarified general plan of action which better reports the strategic planning, and which includes more detailed information about the underlying logic and argumentation for the positions taken.
- SKB needs to produce a more developed and detailed report of the content of the future supporting documentation for an application for a repository for spent fuel.
- SKB needs to state in the main document of the application, in the form of a reference, where the content corresponding to a comprehensive system analysis is reported.

SKI proposes that the Government recommend SKB, within the framework of the consultations, to clarify and justify its plans for how to deal with the outstanding questions.

Other Evaluations and Comments

In the review of the RD&D Programme, SKI has furthermore found reason to draw to attention to the following comments.

Safeguards

- SKB should describe in more detail how safeguards will be organised in planned nuclear facilities. This description should cover the specific measures that need to be implemented in the various phases from interim storage in Clab to the sealed repository.

Choice of Method for Construction of the Repository

- SKB should investigate the advantages and disadvantages of alternative methods for construction of the repository. Based on this, SKB shall be able to convincingly justify its choice of method. This applies in particular to preparation of deposition tunnels.

Technology Development in Production Lines

The Rock Line
- SKB should report detailed plans for designing and implementing a large-scale measurement experiment of the excavation-disturbed zone around a blasted tunnel under realistic rock mechanic and hydrogeological conditions.

The Buffer Line
- SKB should produce a more detailed description of the technique to be used during the installation of the buffer to prevent excessively fast saturation of the buffer. SKB should also produce a quality programme for fabrication of the buffer in the same way as was done for the canister.

The Canister Line
- SKB needs to continue to develop design premises so that they can provide better supporting material for choice of materials, design and fabrication checks of the canister.
- SKB should carry out further investigation concerning the possibility that shearing from an earthquake and isostatic load from a glaciation could occur at the same time.
- SKB needs to show how a combination of non-destructive testing methods identifies the fabrication defects that may arise. SKB also needs to continue work on a process to show this with the aid of an independent third-party body.

The Backfill Line
- For backfill, SKB needs to produce a quality programme for fabrication and emplacement in deposition tunnels.
- SKB should demonstrate that they can handle backfill with the range of, in particular, hydrological and geochemical conditions that can be expected to be prevalent at the chosen site for the repository.

The Sealing Line
- SKB needs to investigate whether the methods for plugging of the investigation hole with bentonite need to be updated on the basis of newly acquired knowledge about erosion.

Safety Assessment and Scientific Research

Climate Evolution
- SKB should link together inputs to increase understanding of the hydrological conditions in and around a continental ice sheet and how this continental ice sheet affects the groundwater flow.
- SKB should investigate the consequences of the penetration of groundwater with higher salinity in a repository at both Forsmark and Laxemar in the event of a rise of the Baltic Sea's water level within 1,000 years, caused by melting of continental ice sheets.
- SKB should also report the risk for and consequences of a considerable glacial erosion at the two candidate sites.

Fuel
- SKB should demonstrate fuel dissolution mechanisms by model studies. Furthermore, SKB needs to show that a link has been made between the analyses of fuel dissolution and the development of the repository since, for example, buffer erosion may also affect the prerequisites for fuel dissolution.

The Canister as a Barrier
- SKB needs to continue work with analyses of both insert and copper shell for both glaciation load and shear load and, when appropriate, a combination of these loads.
- SKB needs to further analyse the phenomenon stress corrosion before it is dismissed as a design process in the repository.
- SKB needs to produce updated information of relevance for the question of copper corrosion in anoxic water. The link to the question of hydrogen embrittlement should also be investigated. Both experiments and theoretical calculations should be carried out.

Buffer
- SKB needs to produce a more detailed specification of requirements for the bentonite buffer and propose concrete as a suitable alternative for use in a repository.
- Before submitting the application, SKB should show that knowledge about buffer erosion has achieved a sufficient level of maturity.
- SKB should better justify the temperate criteria for the bentonite buffer and investigate the risk of an extreme dryout of the buffer more thoroughly.

Backfill
- SKB should in the same way as for the buffer report a clearer specification of requirements for backfill with respect to, for instance, chemical and mineralogical composition.
- The risk of a long-term erosion of backfilled tunnels needs to be better reported with the aim of achieving a better theoretical understanding of the controlling erosion mechanisms.
- SKB should also investigate consequences of a gradual reduction of the density of the backfill.
- SKB should also report on how backfill of other repository areas besides deposition tunnels is to be carried out.

Geosphere
- SKB should improve the report on the links between processes in the repository which affect radionuclide transport, buffer erosion and copper corrosion.
- SKB needs to report its comments on whether they consider that the repository as such can constitute a plane of weakness and thus constitute a failure initiation in connection with future earthquakes.
- SKB should, on the basis of a compiled problem description, derive and report a programme for continued work that sheds light on the development of models to assess the effects of an earthquake of magnitude 6 or greater, methods for identification of fractures and deformation zones, further work with discrete network models and development of respect distances and criteria for choice of positions for deposition holes.

Biosphere
- In SR-Site, SKB should remedy weaknesses in the methodology applied to date.
- SKB should clarify how the authorities' comments on SR-Can and on RD&D Programme 2007 will be taken care of in the future biosphere programme.

Partitioning and Transmutation
- SKI has no objection to make to the announced increase in SKB's contributions in the next few years.

Deep Boreholes
- SKB should strengthen the supporting documentation which the authorities need to able to compare deep boreholes with the KBS-3 method prior to the application for construction of the repository for spent nuclear fuel.

Social Science Research
- SKB should further clarify how it has made use of results relating to important issues that have emerged during the programme and the link to the documents and decision-making processes (e.g. EIA) in SKB's research programme.

Regulatory Action

On 28 September 2007, SKB submitted RD&D Programme 2007 to SKI for review.

SKI has conducted the review of SKB's RD&D Programme 2007 in the same way as in SKI's previous review of the RD&D Programme. The programme has been circulated for comment to some sixty reviewing bodies (authorities, universities and environmental organisations et al). Review statements have been received from forty of these.

In its review of RD&D Programme 2007, SKI has taken special consideration to the fact that SKB is planning, within the time period covered by the programme, to submit an application in accordance with the Nuclear Activities Act, to construct, possess and operate a repository for spent nuclear fuel.

Main Points of SKI's Considerations and Conclusions

In SKI's view, the reactor licensees, through the Swedish Nuclear Fuel and Waste Management Co (SKB), have fulfilled their obligations in accordance with section 12 of the Nuclear Activities Act (1984:3).

Overall Evaluation of SKB's Programme

In SKI's opinion, disposal in accordance with the KBS-3 method still appears to be the most appropriate planning assumption for the final management of spent nuclear fuel from the Swedish nuclear power programme.

The content of the programme is appropriate for further development of a method

for final disposal of spent nuclear fuel and nuclear waste in Swedish bedrock except those parts relating to the LILW programme (SFL, SFR and decommissioning).

SKI considers that there is a need to continue the consultations decided upon by the Government in 1996 and 2001 until SKB submits an application to construct the repository for spent nuclear fuel.

The Repository for Long-lived Low and Intermediate-level Waste - SFL

With a vague reference to insufficient resources, SKB has not fully taken into account SKI's, SSI's and the Government's expectations on reporting the plans for SFL in RD&D Programme 2007. Regardless of whether it takes one, two or three decades before the construction of this plant, SKI considers that a credible design of this plant is needed now, which can serve as a basis for criteria for choice of conditioning methods for waste intended for deposition in SFL. Like SSI, SKI therefore considers that SKB needs to supplement RD&D Programme 2007 as regards its plans and programmes for SFL. This supplement should be designed in such a way as to provide the authorities with a body of material for evaluation of whether SKB's report on the programme for SFL in RD&D Programme 2010 is of sufficient extent in the following respects:

- A quantitative estimate of when such waste arises which is intended for final disposal in SFL. This estimate is needed as supporting documentation to justify and evaluate the reasonableness of SKB's timetable for SFL, including identified possibilities for phased expansion and/or the need for intermediate storage of the waste.
- Production of alternatives for the design of the repository, including the design premises and safety functions which will be applied.
- The focus of future safety assessments of SFL, including those intended to be able to produce and verify acceptance criteria for waste intended for disposal in SFL.
- The content of a research and development programme as a support for future safety assessments of SFL.

The Repository for Short-lived Low and Intermediate-level Waste – SFR

SKI and SSI both consider that SKB needs to justify in a clearer way its plans for expansion and operation of SFR. In the first place, this should take place in connection with RD&D Programme 2010. To enable the authorities to obtain assurance in good time in advance that these issues will be dealt with in a good way, SKI and SSI both consider that RD&D Programme 2007 should be supplemented on this point. This supplement should consequently take up how SKB will report on these issues in Programme 2010 including a preliminary account of the management of maintenance and decommissioning waste in SFR. SKB should be able to base this report on the account of management of decommissioning waste recently produced by SKB.

Planning for Decommissioning Nuclear Power Plants

In SKI's view, this part of the Loma programme has still not been given an appropriate structure and a sufficiently detailed content.

It is clearly evident from SKB's report that the nuclear power companies have a remaining responsibility jointly or individually to report on their own plans and strategies for decommissioning the nuclear power plants. SKI like SSI does not consider that SKB's report of the strategies of the nuclear power companies for decommissioning in general terms is sufficient to enable the authorities to evaluate the reasonableness of timetables and action programmes regardless of whether the responsibility is borne by SKB or the nuclear power companies. SKI and SSI therefore consider that SKB should submit a supplement to RD&D Programme 2007 in the form of a compilation of the decommissioning plans produced by the nuclear power companies in accordance with SKI's and SSI's regulations. This supplement should be able to serve as supporting documentation for the evaluation of the Radiation Safety Authority's assessment of how SKB and the nuclear power companies are to make further progress on this question in conjunction with RD&D Programme 2010.

Like SSI, SKI considers that the Government should request that the licensee for Ågesta heat power reactor, Vattenfall AB, report on it intend to fulfil its obligations in accordance with section 12 of the Nuclear Activities Act.

In SKI's view, the justification of the timetable for decommissioning of the Barsebäck nuclear power plant specified by SKB is fairly well-founded. However, certain supporting documentation is still lacking which shows in quantitative terms the possibilities of starting deposition of decommissioning waste in the existing SFR at different times. This applies particularly to an account of when and at what rate different kinds of waste are created during decommissioning. SKI therefore considers that SKB should supplement RD&D Programme on this point. In this case as well, SKB should develop the newly reported document on the decommissioning waste from Barsebäck.

Methodology and Criteria for Final Selection of the Repository Site

SKI wishes to emphasise the importance of SKB, in the selection of the repository site, clearly indicating the methodology and criteria which have been applied and which have thus governed the choice of site. This is particularly the case if the supporting documentation for the choice is not wholly comparable for the sites. SKI also considers that the rejected site needs to be reported in such a way that the authority can make its own independent evaluation compared with the selected site.

To enable the authorities to evaluate the different steps in the siting work leading up to SKB's final site selection, it is necessary that SKB in the licence application can show that it has investigated and taken into account all important factors for the long-term function of the repository as well as reporting on the balances struck

made between different siting factors and other measures to improve the protective capability of the repository.
SKI recommends that this report be followed up in further consultations.

Long-term Experiments at the Aspö Hard Rock Laboratory

In conjunction with the application, SKB needs to report on the outcome of the results obtained in ongoing tests in the Bentonite and Äspo Hard Rock Laboratory concerning bentonite and backfill and, based on this, report a plan for how it is intended to solve the issues that have not been sufficiently answered by the experiments performed. SSI has also made these comments in its referral comment to SKI.

SSI and SKI both consider that SKB also needs to clarify which further experiments are needed, the purpose that the various experiments are intended to achieve as well as producing a plan for their implementation. SKI like SSI proposes that the report be followed up in further consultations.

Safety Assessment

SKI notes that SKB has developed a methodology relating to safety assessment with an appropriate design in relation to SKI's and SSI's regulatory requirements. This conclusion is based on SKI's and SSI's joint review of the safety assessment in SR-Can.

SKI like SSI considers that it is crucial for the future development of the programme that SKB relates in an appropriate way to the need of research and development contributions from the critical issues identified in the review of SR-Can.

It is very important that SKB prior to SR-Site raises the level of ambition for quality work in conjunction with the safety assessment. SKI considers that the consultations between the authorities and SKB could be used for a continued dialogue to avoid unnecessary lack of clarity on methodological issues, interpretations of regulatory requirements and reporting forms.

SKB's Plan of Action

In SKI's opinion, the action plan serves as a good introduction to the other parts of the programme. None the less, SKI considers that the action plan in its present form is at far too general a level to serve its purpose.

SKI considers that the report in RD&D Programme 2010 needs to contain a clearer overall strategic plan of action which provides a better account of SKB's planning, and which contains more detailed information about the underlying logic and argumentation for the positions adopted.

The plan needs in the first place to focus on time and activity plans for construction of new repository facilities, or expansion of existing facilities, which are required

for final management of the nuclear waste arising in connection with decommissioning and dismantling of nuclear power plants.

The plan needs to especially address the process for relicensing and expanding the repository for radioactive operating waste (SFR) and for establishing a repository for long-lived low and intermediate-level nuclear waste (SFL). This plan also needs to include an alternative strategy for storage of spent fuel in case the commissioning of the repository for spent fuel is delayed and available storage space at Clab is fully used.

SKI considers that SKB needs to produce a more developed and detailed report of the
content of future supporting documentation for an application for a repository for spent fuel. It is particularly important to address the links between different phases of the life cycle of the repository: licensing, construction, test running, routine operation with parallel deposition and backfill of repository parts as well as successive expansion, decommissioning/backfill and closure.

The authorities consider that the supporting documentation for an application for a repository does not need to include a freestanding system analysis in the form of a separate document as the authorities and the Government previously requested. However, this assumes that the
main document of the application contains references with information on where the corresponding information can be found in the application documentation, which would have been reported in the comprehensive system analysis document.

SKI wishes particularly to draw to SKB's attention that a procedure which entails that the date for submission of the application will be governed by timetables rather than quality goals may vary well prove counterproductive. SKI proposes that the report can be following up in further consultations.

Safeguards

SKI considers, with reference to the safeguards system when handling fuel in the encapsulation plant, that SKB should report how it is to be ensured that the data for the fuel delivered from Clab is correct before it is prepared for encapsulation. SKB should also indicate when there is a need to know that sufficient information is available on the fuel. It is sufficient that there is a measuring station at the encapsulation plant for final confirmation of the fuel already verified at Clab.

SKI can note that SKB does not describe in detail the extent of how the safeguards system will be organised in planned nuclear facilities. It should be mentioned that these measures, with reference to the safeguards system, include a plant description from a safeguards perspective, accounting for and reporting of nuclear material, a list of fittings, use of camera surveillance and seals, etc. SKB should summarily describe how these measures can be implemented at the different phases from interim storage at Clab via the encapsulation plant to the closed repository.

Choice of Method for Construction of the Repository

SKB should clearly report advantages and disadvantages of the respective method and justify, on this basis, its choice of method for construction of the repository. This applies in particular
to preparation of deposition tunnels. As examples of questions that SKB needs to clarify in its comparison may be mentioned cost, feasibility, flexibility, the need of rock reinforcement and grouting, the extent of excavation-disturbed zones, survey of rock and water inflow, equipment for deposition of buffer and canisters, fabrication and requirements on blocks for backfill, technology for backfill etc.

Technology Development in Production Lines

The Rock Line
SKI regards the limited knowledge about uncertainties relating to the characteristics of excavation-disturbed zones in a drilled and blasted tunnel as one of the weaknesses of the KBS-3 concept from the perspective of long-term safety. SKI therefore supports SKB's plans to design and carry out a large-scale measurement experiment of the excavation-disturbed zone around a blasted tunnel in realistic rock mechanic and hydrogeological conditions.

SKI considers that the choice of reference method for selection of deposition tunnels should take place in conjunction with submission of the application for construction of the repository, which is also SKB's intention. As a basis for this choice, SKB should carry out a comparative study between the alternatives full-face boring and conventional boring and careful blasting in addition to that already done at the Äspö Hard Rock Laboratory.

The Buffer Line
At the Aspö Hard Rock Laboratory, SKB has, on installation of the buffer in the prototype repository, tested how the buffer should be protected from excessively rapid saturation caused by water inflow. SKI considers that SKB should produce a more detailed description of the technique to be used during installation of the buffer to prevent excessively fast saturation of the buffer.

SKI notes that SKB has abandoned isostatic pressing as a reference method for buffer fabrication without giving any reason for this.

SKB does not either report what needs to be included in a programme for quality assurance for the buffer. SKB must therefore produce a quality programme for buffer fabrication in the same way as has been done for canister fabrication.

As regards installation of blocks and rings, SKI considers that SKB has shown that installation of the buffer on a full-scale is in principle possible both in a blasted and full-face bored tunnel through the experiments carried out at the Aspö Hard Rock Laboratory.

The Canister Line
SKI considers that SKB needs to continue to develop the design premises so that they can provide better supporting documentation for choice of materials, design and fabrication checks of the canister. Furthermore, SKB should carry out continued studies of the possibility that shearing from an earthquake and isostatic load from a glaciation could take place at the same time.

SKI also considers that there are still some questions regarding the credibility of SKB's creep models for copper. SKI also wishes to emphasise that it remains for SKB to demonstrate that canister parts can be manufactured at the rate and with the quality that SKB stipulates.

Within development of non-destructive testing, SKB has investigated and assessed a number of different methods. It is important that SKB now decides in more detail which combinations of testing methods are needed to obtain an appropriate quality assurance of canister components.

SKI also wishes to emphasise that SKB needs to show in more detail how a combination of non-destructive testing methods finds the manufacturing defects that may occur. SKB also needs to continue work on a process to assist independent third party bodies to demonstrate this.

The Backfill Line
As regards choice of material for backfill, SKI considers it important that SKB produces a clearer specification of requirements and shows that there is a sufficient quantity of data at least for some conceivable material, to enable an assessment of its characteristics and performance. SKB also needs to produce a quality programme for backfill and emplacement in deposition tunnels.

SKI wishes to emphasise the importance of SKB reporting the timetable for testing and demonstration of backfill on a full-scale at the Aspö Hard Rock Laboratory after pilot tests at the Bentonite Laboratory. SKB should state how tests and expected results will be adapted to the timetable for the application with the appurtenant safety assessment.

SKI and SSI agree that it is very important that SKB demonstrates that it is possible to manage the buffer, backfill and installation of plugs with the range of, in particular, hydrological and geochemical conditions that can be expected at the selected site. It is also important that SKB in its application reports credible reference methods concerning
requirements on methods, choice of methods and material for sealing of the various rock spaces as well as control programmes for these.

The Sealing Line
With reference to newly-obtained knowledge about piping/erosion, buffer erosion and reaction between cement and bentonite, SKI considers that SKB needs to investigate whether the methods for plugging of investigation holes with bentonite need to be updated.

Tectonic movements in conjunction with future glaciations may affect both the sealed bore holes and the repository's tunnels. SKB should therefore report which consequences deterioration in sealing entails for the long-term safety of the repository.

Safety Research and Scientific Research

Climate Evolution
SKI considers that SKB should link measures to understand the hydrological conditions in and around a continental ice sheet and how the continental ice sheet affects the groundwater flow.

In the climate scenario with an increased greenhouse gas effect, SKI considers that the consequences of the continental ice sheets in Greenland and the western Antarctic melting should mean that both Forsmark and Laxemar will be below the surface of the Baltic Sea within 1,000 years. This could lead to penetration of groundwater with higher salinity into the repository.

In SKI's opinion, SKB's calculations of permafrost entail certain uncertainties relating both to models and input data, which are not reported in a clear way. SKI also considers that SKB has not sufficiently discussed the risk of substantial glacial erosion at the two candidate sites. This would entail erosion depth which could considerably affect the calculations of permafrost depth and the possibility of avoiding freezing of the buffer within the period covered by the safety assessment.

Fuel
SKI considers that SKB needs to carry out experiments and studies of fuel with a high burn-up due to plans to gradually increase the average burn-up of fuel at the Swedish nuclear power plants.

In connection with the review of SR-Can, SKI and SSI pointed out that understanding of fuel dissolution mechanisms needs to be better demonstrated by model studies.
Furthermore, it needs to be shown that a link has been made between the analyses of
fuel dissolution and the development of the repository. Buffer erosion may, for instance, also affect the conditions for fuel dissolution.

SKI agrees with SSI that certain additional measures will be required to show that criticicity due to changed geometry and redistribution of radionuclides is not an important process.

The Canister as a Barrier
As regards canister processes, SKI considers that SKB needs to continue the work with analyses of both the insert and the copper shell for both glaciation load and shear load as well as, in appropriate cases, a combination of these loads. These analyses shall provide a body of material both for verifying the strength of the defined design premises as well as providing guidance for fabrication and fabrication checks.

SKI considers that the phenomenon of stress corrosion cannot be disregarded as a design process in the repository. SKB must either show by credible testing that even if a fracture of this kind is initiated, that growth is slow that the integrity of the canister is not jeopardised or report on the consequences of some canisters conceivably bursting through a combination of fractures caused by stress corrosion.

In SKI's opinion, SKB needs to supplement its programme for corrosion by corrosion experiments on copper surfaces directly exposed to groundwater. This need is associated with buffer erosion being an important process in fuel dissolution. The impact on copper corrosion of microbial processes needs to be further studied both for cases with and without bentonite.

SKI considers that SKB needs to produce its own updated information of relevance to the question of copper corrosion in anoxic water. The connection with the issue of hydrogen embrittlement should also be investigated. Both experiments and theoretical calculations should be carried out. SKI further considers that SKB should review the set of corrosion experiments in in-situ environments. These may need to be expanded bearing in mind the fact that new questions about copper corrosion have arisen recently.

Buffer
In SKI's opinion, SKB has in general a good programme for the buffer. However, there is one uncertainty about the buffer materials that may come into consideration and the composition that these materials needs to have. SKI therefore considers that SKB needs to produce a more detailed specification of requirements for the buffer and propose concrete materials as suitable candidates for use in a repository. According to SKI, SKB should better justify the temperature criterion for the bentonite buffer and investigate in more detail the risk of an extreme dryout of the buffer. Implications of a buffer remaining unsaturated for a long period also need to be continued to be studied. SKI is positive to the development of simulation tools for linked processes in the buffer and considers that there should be good opportunities for addressing the above issues.

SKI observes that SKB appears to have a good research programme on buffer erosion. According to SKI, it is very important that knowledge attains a sufficient level of maturity in this area before SKB submits an application to construct the repository.

SKI considers that the time is ripe for planning the additional experiments that need to be performed during the construction phase of a repository. However, SKI can note that the plans in RD&D Programme 2007 are very vague in this area.

As regards chemical processes in the buffer, SKI considers that SKB should pay better attention to cementation process, the link between ion-exchange processes and smectite transformation processes, as well as the risk of a structural decomposition of smectite clay. Chemical processes in the buffer are also

important to calculate the extent of buffer erosion, which at present is the most important uncertainty related to the long-term function of the buffer. It must be possible to set limits for the process concerning buffer erosion and its negative consequences and the role of the buffer in SKB's safety concept needs to be defined in the perspective that it may not be possible to assume that it is wholly stable in the time scale of the safety assessment.

Backfill
SKI observes that considerable measures remain to be done before knowledge of both practical management issues for backfill and analysis of long-term development reaches the same level as for the canister and the buffer. However, SKI considers that SKB in RD&D Programme 2007 has raised the level of ambition for work with the backfill and that there are now concrete plans to fill in the most important gaps in knowledge.

SKI considers that the backfill material that SKB is at present investigating has not been thoroughly reported in the RD&D Programme. As in the case of the buffer, SKI would like to see a clearer specification of requirements for the backfill with respect to, for instance, chemical and mineralogical composition. According to SKI, more concrete plans are needed relating to large-scale demonstration experiments that need to be carried out to investigate the performance of the backfill in as realistic conditions as possible.

SKI considers that SKB has a suitable programme to limit and predict the initial erosion risk that exists during the early resaturation phase. More attention needs to be given, however, to the risk of a long-term erosion of backfilled tunnels. In both cases, SKB should endeavour to obtain a better theoretical understanding of the controlling erosion mechanisms. The consequences of a gradual reduction in the density of the backfill should also be investigated. SKI considers finally that a report is lacking in RD&D Programme 2007 on chemical processes in the backfill as well as information on backfill of other repository areas besides deposition tunnels.

Geosphere
The geosphere chapter in the RD&D Programme is divided into a number of sections where, however, the links required to tie the key issues together (nuclide transport and corrosion) with the relevant processes are not clear in the presentation. SKI considers that it is important to identify the most important needs for further research and development based on the whole system. SKB should plan and report the research and development for transport of radionuclides in an integrated way for important aspects of both the geosphere and the biosphere.
SKI considers that the development of geochemical and hydrological factors which affect copper corrosion in the advection-corrosion case needs to be further investigated if buffer erosion cannot be excluded.

SKB also needs to report its comments on whether they consider that the repository as such can constitute a plane of weakness and thus constitute a failure initiation in connection with future earthquakes.

SSI like SKI considers that SKB, on the basis of an overall problem description, should derive and report on a programme for continued work that sheds light on development of models to evaluate the effects of an earthquake of magnitude 6 or greater, methods for identification of fractures and deformation zones, additional work with discrete network models as well as development of respect distances and criteria for choice of deposition positions.

Biosphere
SSI states that in SR-Can, SKB produced an integrated landscape model that includes several ecosystems in succession of the landscape following isostatic uplift.
The authorities stated in the review of SR-Can that an integrated approach is good. However, there are weaknesses in the methodology that should be rectified prior to SR-Site:

- The metholodogy produces a dilution effect in the dose calculations
- Relevant transport processes have not been included in the model description
- There is insufficient validation of the models against field data
- A safety assessment is lacking

A clear description is also lacking of the further development of dose models, for example, the processes that are to be included in bog and lake models. As regards model validation, the forest model is the only model to be validated, according to SKB. SKB does not either mention how uncertainties in data and models are to be dealt with in connection with dose calculations.

SSI considers that SKB should clarify how the comments of thee authorities on SR-Can and on RD&D Programme 2007 will be dealt with in the continued biosphere programme.

Partitioning and Transmutation (P&T)
SKI wishes to encourage SKB to implement or participate in system studies in the future. In-depth studies should as to date take place in areas where Swedish research has proven capable of making serious contributions. Under these conditions, SKI has no objection to make to the announced increase in SKB's work in the coming years.

Deep Boreholes
On the basis of SSI's comments and argumentation in the statement on this RD&D Programme, SKI supports SSI in its reasoning that SKB should produce more through and better supporting documentation on deep boreholes for a comparison with the KBS-3 method. SKI wishes, however, to emphasise that comments put forward in previous RD&D reviews still apply since SKI considers that deep boreholes cannot at present be regarded as a realistic alternative to the KBS-3 method.
SKI does not, however, agree with SSI that the body of material that the authorities need to be able to compare deep boreholes with the KBS-3 method needs to be

reinforced prior to the application for construction of the repository for spent nuclear fuel.

Social Science Research

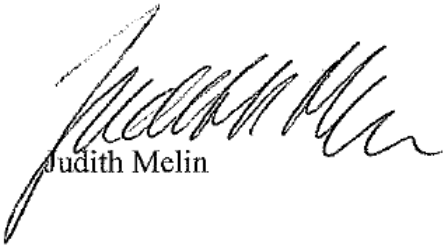
SKI considers that the research carried out by SKB within the research field of social science contributes to a holistic picture of the repository process which is an important part of decision-making when the application for the repository is submitted and is to be dealt with by authorities and other actors.

To benefit from the results from important issues addressed in the programme, it is important that the link between SKB's social science research and other documents and decision-making processes (for example, MKB), which are part of the preparations for SKB's application to construct the repository in 2010, are further clarified.

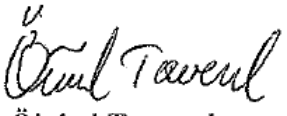
Conduct of this Regulatory Action

Decisions on this matter have been made by SKI's Board. Apart from the undersigned chairperson, the following board members participated in the decision: Michael Hagberg, Carl-Magnus Larsson, Kristin Oretorp, Ann Veiderpass and Kitty Victor as well as SKI employees Elisabeth André Turlind, Leif Karlsson, Ingvar Persson,
Josefin Päiviö Jonsson and Öivind 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 2007. Programme for Research, Development and Demonstration of Methods for Management and Final Disposal of Nuclear Waste. September 2007.

The Swedish Nuclear Power Inspectorate (SKI):

SKI's Review Statement on SKB's RD&D Programme 2007, Review PM. SKI Report 2008:48. June 2008.

Reviewing Bodies Statements on SKB's RD&D Programme 2007. SKI PM 08:05. June 2008.

Reviewing Bodies:

Original statements from 40 reviewing bodies according to the distribution list

Distribution List for Copies of the Review Statement

Reviewing Bodies

Swedish Work Environment Authority
Waste Network Association
National Board of Housing, Building and Planning
Chalmers University of Technology
Swedish Energy Agency
Gustaf Öberg, Lund
Karlstad University
Swedish Chemicals Agency
Swedish Emergency Management Agency
Royal Institute of Technology
Municipality of Kävlinge
Local Safety Committee the Nuclear Facilities at Forsmark
Local Safety Committee at Oskarshamn Nuclear Power Plant
Lund University
Luleå University of Technology
County Administrative Board, County of Kalmar
County Administrative Board, County of Uppsala
The Swedish Society for Nature Conservation and the Swedish NGO Office for Nuclear Waste Review (MKG)
Friends of the Earth Sweden
Miljövänner för kärnkraft *[Friends of the Environment for Nuclear Power]*
Nuclear Waste Secretariat of the Swedish Environmental NGOs (MILKAS)
Swedish Environmental Protection Agency[1]

Waste Network and Opinion Group for Safe Disposal (Oss)
Municipality of Oskarshamn
The Regional Council in Kalmar County
Uppsala Regional Council
National Archives
Swedish Geotechnical Institute
Swedish Radiation Protection Authority
Swedish Board for Accreditation and Conformity Assessment
Sveriges energiföreningars riksorganisation *[National Organisation of Energy Associations]*
Swedish Association of Local Authorities and Regions[1]
The Swedish University of Agricultural Sciences
Geological Survey of Sweden
FOI, Swedish Defence Research Agency
Umeå University[1]
Uppsala University
Westinghouse Electric Sweden AB
Swedish Research Council
Municipality of Östhammar

[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
Riksdagens upplysningstjänst *[Information Service of the Swedish Parliament]*
Ringhals AB
Norwegian Radiation Protection Authority
Prime Minister's Office
Studsvik Nuclear AB
STUK, Radiation and Nuclear Safety Authority, Finland
Swedish Nuclear Fuel & 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 2007

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 which the most important is the Swedish Radiation Protection Authority (SSI).

The review statement for the latest programme, RD&D Programme 2004, was submitted to the Government in June 2005.

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 nuclear 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, the repository for spent nuclear fuel, technology development in the nuclear waste programme, safety assessment, and scientific and social science research, which has been included in SKB's research programme since RD&D Programme 2004 for disposal of nuclear waste. Eight areas of research are reported on under the heading of safety assessment and research: safety assessment, climate evolution, fuel, the canister as barrier, the buffer around the canisters, backfill of the repository (in particular, the deposition tunnels), the geological conditions in the deposition area (the geosphere), land and the environmental impact (the biosphere). Furthermore, SKB reports knowledge and research on alternatives to the planned geological repository at a depth of 400-700 m.

In addition to focusing on the management of spent nuclear fuel, SKB also describes in the concluding chapters of the report the management of long-lived low and intermediate-level waste (the LILW Programme) which is generated as a result of the decommissioning of nuclear facilities etc.

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 2007.

Responsibility for Closed Repository

In its statement on RD&D Programme 2004, the municipality of Oskarshamn requested a statement from the Government as to how it was intended to take care of the matter of responsibility for the repository after closure. The Government subsequently instructed SKI and SSI in the appropriation directions to make proposals as to how the issue of

responsibility can be clarified in current legislation. SKI and SSI have exhaustively reported on current legislation and the responsibility of different actors in a report to the Ministry of the Environment. This report also recommends an amendment to section 14 of the Nuclear Activities Act which emphasises the ultimate responsibility of the state. However, it is not considered appropriate to make a statutory provision for the ultimate responsibility of the state at this stage.

The Municipality of Oskarshamn would like, notwithstanding the conclusion of the report, to see the issue of responsibility regulated now by law and not wait for future closure of the repository. This is a municipal demand based mainly on the needs of those living in the vicinity and landowners.

SKB's Plan of Action

In SKI's opinion, the plan of action serves as a good introduction to the other parts of the programme. SKI none the less considers that the plan of action in its present form is at too general a level to fulfil its objective.

SKI considers that the description in RD&D Programme 2010 needs to include a clarified overall strategic plan of action that better presents SKB's strategic planning, and which contains more detailed information about the underlying logic and argumentation for the positions adopted. The plan needs in the first place to focus on the time and activity plans for construction of new repository facilities, or expansion of existing facilities, which are needed to manage the nuclear waste which arises in connection with decommissioning and dismantling of nuclear power facilities.

The plan needs in particular to address the relicensing process and to expand the repository for radioactive maintenance waste (SFR) and the process for establishing a repository for long-lived low and intermediate-level nuclear waste (SFL). The plan also needs to include an alternative strategy for storage of spent fuel in the event of delay in commissioning the repository for spent fuel and available storage space at Clab being fully used.

SKI considers that SKB needs to produce a better and more developed and detailed report of the content of future supporting documentation for an application for a repository for spent fuel. It is particularly important to address links between different phases of the life cycle of the repository; licensing, construction, test running, routine operation with parallel deposition and backfill of storage facilities as well as successive expansion, decommissioning/backfill and closure. SKI further considers that SKB should produce the clarifying planning documentation within the framework of further consultations between SKB and the authorities.

The authorities consider that the supporting documentation to the application for a repository does not need to include a freestanding system analysis in the form of a separate document. However, this assumes that the main document of the application contains a reference with information as to where in the application document the corresponding information can be found, which would have been reported in the comprehensive system analysis document.

Safeguards

In SKI's opinion, SKB should report, from a safeguards perspective, how they ensure that data for the fuel supplied from Clab is correct before it is prepared for encapsulation. SKB should also indicate when there is a need to know that there is sufficient information on the fuel. It is sufficient that there is a measuring station at the encapsulation plant to finally confirm information on the fuel already verified at Clab.

According to the plans, visual verification shall take place at the encapsulation plant before the steel lid is lifted into position after the canister has been filled with fuel. Nothing is mentioned as to how this verification is to take place or the way in which it is to be documented. This is a critical point in management since it is the occasion when one moves from handling separate fuel elements to the canister being the smallest unit. After encapsulation, the canister must be handled and stored with sufficient knowledge retention, for example, through camera surveillance or a seal.

SKI wishes to emphasise that SKB should be aware that the safeguards aspect needs to be integrated with more parts of SKB's programme and should therefore have been mentioned in more sections of the introductory chapters of the RD&D Programme.

SKI can note that SKB has not described in detail the extent of how safeguards will be organised at planned nuclear facilities. It should be mentioned that the safeguards system includes the description of the facility from a safeguards perspective, accounting and reporting of nuclear material, a register of fittings, use of camera surveillance and a seal etc. SKB should provide a summary description of how such measures can be implemented at the different phases from interim storage in Clab to the closed repository.

The Repository for Spent Nuclear Fuel

Siting Alternatives and Choice of Sites

SKB has in ongoing consultations with SKI and SSI about the site investigation phase indicated that the choice of site for the repository will be announced before the application is submitted to the Radiation Safety Authority. SKI wishes to emphasise the importance of SKB clearly indicating which methodology and which criteria it is intended to apply and which will thereby govern the choice. This applies in particular if the supporting documentation for the choice is not wholly comparable. SKI also considers that the rejected site needs to be presented in such a way that the authority can make its own independent evaluation based on comparisons with the selected site.

To enable the new Radiation Safety Authority to be able to evaluate the different phases of siting work that has led to SKB's final choice of site, SKB must be able to show in the licence application that it has investigated and taken into account all significant factors for the long-term function of the repository and report on the balances struck between different siting factors and other measures to improve the protective capability of the repository. The reporting of the plans and implementation prior to the application can be followed up within the framework of further consultations with SKB.

Feedback from Site Investigation to RD&D work

SKI notes that SKB has come a relatively long way with regard to integration of different geological and geoscientific disciplines. SKI considers, however, regarding use of measurement data from borehole radar, that SKB needs to evaluate the reliability of this data since the plan is to use this technology to investigate the existence of fractures which are not permitted to intersect the deposition hole.

Integrated Evaluation of Choice of Site

SKI observes that SKB in its report in RD&D Programme 2007 does not discuss the plans for detailed investigations during the construction of the repository, which must be regarded as a deficiency. The reason for this is that SKI wishes to have sufficient supporting documentation to evaluate the collection of information in a long-term safety perspective, which is possible during the construction phase.

Starting Points for Construction and Operation

In SKI's opinion, the completely finished choice of technology for application in industrial use does not need to be ready by the time of application during 2010. However, it is necessary that SKB reports the technology development achieved in the application and justifies the technology chosen based on the BAT perspective. Furthermore SKB needs to specify a realistic timetable when fully developed industrial methods for construction of the repository can be presented to the licensing authority.

SKI considers that SKB's assumptions on the time for licensing must be regarded as extremely optimistic. SKI and SSI both estimate that the whole process will take considerably longer than the two years included in SKB's planning horizon.

Working Methodology during Construction and Operation

During construction and operation of the facility, organisation and management systems must be designed taking into consideration the requirements that apply for constructing and operating nuclear facilities. Furthermore, the working method must be adapted to the special conditions that apply for planning and construction of underground facilities. This stringent requirement for adaptation, organisation and management of the project is also emphasised by SKB in the RD&D Programme.

Technology Development in the Nuclear Waste Programme

The Rock Line

SKI shares SKB's view concerning insufficient knowledge about the extent of the excavation-disturbed zone (EDZ) that occur during rock construction and methods of checking and measuring this zone. SKI therefore supports SKB's plans to design and carry out a large-scale measurement experiment of EDZ around a blasted tunnel in realistic rock mechanic and hydrogeological conditions.

SKI considers that SKB's development of methods for investigations and measurements in deposition tunnels and deposition holes is important, since the choice and characterisation of the deposition positions is significant for the initial state of the safety assessment. SKI also considers that it is important that SKB carries out full-scale tests of the methods in order to show that efficient application during the construction phase is possible.

SKI can also observe that SKB to date during the first decade of the 21st century has undertaken important measures, itself or in collaboration with other stakeholders, to increase knowledge about sealing of rock by grouting.

In SKI's opinion, the choice of reference method for excavation of deposition tunnels should be made in connection with submission of the application for construction of the repository, which is also SKB's intention. As a basis for the choice, SKB should carry out a comparative study between the alternatives full-face boring and conventional boring and cautious blasting in addition to that already done at the Aspö Hard Rock Laboratory.

SKI therefore considers that before the application on the repository is submitted to the new Radiation Safety Authority, SKB should clearly report on the advantages and disadvantages of the respective method and justify its choice of method of construction of the repository on that basis. This applies in particular to excavation of deposition tunnels. As examples of issues which SKB needs to shed light on in its comparison may be mentioned cost, feasibility, flexibility, the need for rock reinforcement and grouting, the extent of the excavation-disturbed zone, surveying of rock and water penetration, equipment for deposition of the buffer and canisters, fabrication and requirements on blocks for backfill, technology for backfill etc.

The Buffer Line

At the Aspö Hard Rock Laboratory SKB has on installation of the buffer in the prototype repository tested how the buffer is to be protected from excessively fast saturation in deposition holes with a large water inflow. SKI considers that SKB should produce a more detailed description of the technology to be used during installation of the buffer to prevent excessively fast saturation of the buffer.

As regards full-scale fabrication of blocks for the buffer, SKI notes that experiences are limited to a small number of examples which have been used for experiments at the Aspö Hard Rock Laboratory. SKI therefore considers that further test fabrication may be needed to show that the desired quality can be achieved for the material in question and in circumstances that more resemble batch manufacture. Geometric tolerances and clear acceptance criteria for bentonite blocks should then be produced and applied.

SKI observes that SKB has abandoned isostatic pressing as a reference method for buffer fabrication without giving any reason for this. SKI has previously made comments on SKB's choice of reference method based on the non-availability of an isostatic press for fabrication of full-scale blocks not being available.

SKB has still not reported its ideas about what needs to be included in a programme for quality assurance for the buffer. It is therefore necessary that SKB produces some form of quality programme for buffer fabrication in the same way as was done for canister fabrication. A discussion is also needed on which deviations may occur during fabrication and the importance that deviations may have for long-term safety, for example heterogeneous conditions in the buffer.

Regarding installation of blocks and rings SKI considers that SKB has shown that installation of the buffer on a full scale is in principle possible in both a blasted and a full-face bored tunnel through the experiments carried out at the Aspö Hard Rock Laboratory. However, SKB has not demonstrated deposition of the canister with a shield or remote control for installation of the shield cover over the deposition hole. SKB needs to do this before any deposition can be initiated at an expanded repository at the chosen site.

The Canister Line

In SKI's opinion, SKB needs to continue to develop the design premises so that they can provide better supporting documentation for choice of materials, design and fabrication checks of the canister as well as for the long-term safety. Furthermore, SKB should carry out further studies on the possibility of shearing from an earthquake and isostatic load from glaciation could take place at the same time.

SKI also considers that there are still certain issues regarding the credibility of SKB's creep models of copper. SKI also considers that SKB, when producing its models for copper creep, should take into account the conditions at the repository, i.e. the low temperatures and low loads.

SKI considers that it remains for SKB to show that canister parts can be produced at the rate and with the quality prescribed by SKB. It is urgent, among other things, to develop the methods for fabrication of inserts for fuel from pressured water cooled reactors if SKB is to be able to abide by its timetables. Within the development of non-destructive testing, SKB has examined and assessed a number of different methods. It is important that SKB now decides in more detail the combinations of testing methods needed to obtain appropriate quality assurance.

With regard to non-destructive testing SKI considers that SKB needs to show in more detail how a combination of non-destructive testing methods identifies the fabrication defects that may occur. SKB also needs to continue the work with a process to show this with the aid of an independent third-party body.

The Backfill Line

As regards choice of materials for backfill of deposition tunnels SKI considers it important that SKB shows that there is a sufficient quantity of data for the current alternative, to enable an evaluation of its characteristics and function SKI also considers that SKB should report more clearly how the requirements for the backfill affect the choice of materials and the design of the backfill before the application for the

repository is submitted. SKB also needs to produce a quality programme for fabrication and emplacement in deposition tunnels for the backfill.

SKI considers it important that SKB reports on the timetable for test and demonstration of the backfill on a full scale at the Aspö Hard Rock Laboratory after pilot tests at the Bentonite Laboratory.

SKB should state how tests and expected results are to be adapted to the timetable for the application with appurtenant safety assessment. SKI and SSI agree that it is very important that SKB demonstrates the buffer, backfill and installation of plugs can be managed with the range of, in particular, hydrological and geochemical conditions that can be expected to exist at the chosen site. SKI also considers that SKB in its application should report reference methods for closure of the various rock caverns as well as control programmes for these. This report of the plans and implementation prior to the application can be followed up within the framework of further consultations with SKB.

The Closure Line

With reference to newly-acquired knowledge about piping/erosion, buffer erosion and reaction between cement and bentonite SKI considers that SKB needs to investigate whether the methods for plugging of investigation holes with bentonite need to be updated. SKB should here also investigate the question of whether a respect distance is needed between investigation boreholes and deposition holes.

In the design of the closure of the repository's tunnels and shafts, SKB should take into account the risk of impact through tectonic movements in connection with future glaciations. It also needs to be reported what consequences an incomplete closure would have for the long-term safety of the repository. SKI assumes that this will be reported in SR-Site. SKB also needs to estimate the lifetime for the materials intended to be used for sealing of the different parts of the repository.

Retrieval

According to SKI's regulations and general guidelines, the impact on safety of such measures undertaken to facilitate surveillance or retrieval of disposed nuclear waste from the repository or to make difficult access to the repository shall be analysed and reported to the Nuclear Power Inspectorate.

Alternative Repository Design – KBS-3H

Issues that need to be addressed for the concept of horizontal deposition are the performance of the distance block in the event of uneven watering, which can lead to uneven build-up of swelling pressure in the contact between deposition holes and rock, in particular where rock burst and water inflow can occur.

SKI notes that in addition to differences between KBS-3V and 3H respectively concerning hydrological and chemical aspects, SKB also needs to investigate whether there are differences in mechanical effect in the event of high rock stress. SKI has had

independent consultants study the impact of rock stresses on both concepts in a repository at Forsmark. The least impact on the repository takes place if the deposition tunnels are oriented parallel to the direction of the greatest horizontal rock stress.

The Bentonite and Aspö Hard Rock Laboratory

In connection with the application, SKB needs to report results from the experiment in process at the Bentonite and Aspö Hard Rock Laboratory regarding bentonite and backfill and, on the basis of this report, a plan for how it is intended to deal with the questions that are not sufficiently answered through the experiments carried out. These are also comments made by SSI in its review statement to SKI. SKI and SSI both considers that SKB also needs to clarify which additional experiments are required, the objective of the various experiments and to draw up planning for their implementation. The proposed report can be followed up within the framework of further consultations with SKB.

SKB needs also before the application to report how the different production lines are to be integrated and show their mutual dependence to achieve the initial state when closing the repository.

Safety Assessment

SKI notes that SKB has developed a methodology around safety assessment with an appropriate design in relation to SKI's and SSI's regulatory requirements. This conclusion is based on SKI's and SSI's joint review of the safety assessment SR-Can. It is very important that SKB prior to SR-Site raises the level of ambition for quality work relating to safety assessment. SKI considers that the consultations between the authorities and SKB could be used for further dialogue to avoid unnecessary lack of clarity around methodological issues, interpretations of regulatory requirements and reporting forms.

Scientific research

Climate Evolution

In SKB's climate scenario for glacial climate conditions, numerical simulation shows a continental ice sheet of maximum expected ice thickness of 2,600 m at Laxemar and 3,200 m at Forsmark. SKI considers that the result is reasonable based on observations from Greenland and the Antarctic although it is motivated for SKB to describe the model better and the simplifications on which it is based.

In SKI's opinion, SKB needs to increase understanding of hydrogeological conditions in and around a continental ice sheet by linking together the described measures that may affect the groundwater flow.

In the climate scenario with the greenhouse effect, SKB considers that melting of the Greenland ice sheet will correspond to a global increase of the sea level of around seven metres although isostatic uplift will still continue at both Forsmark and Laxemar. SKI notes that the consequences of the melting of the continental ice sheets in Greenland and

the western Antarctic should mean that both Forsmark and Laxemar will be below the level of the Baltic Sea within 1,000 years. This could lead to penetration of groundwater with higher salinity in the repository.

In SKI's opinion, SKB's calculations of permafrost involve certain uncertainties relating to both models and input data, which are not reported in a clear way. SKI also considers that SKB has not sufficiently discussed the risk of significant glacial erosion at the two candidate areas. This would entail erosion depth that would considerably affect the calculations of the depth of permafrost (250 m at Forsmark and 160 m at Laxemar calculated by SKB) and the possibility of avoiding freezing of the buffer within the period covered by the safety assessment (one million years).

Fuel

In SKI's opinion, SKB needs to carry out experiments and studies of fuel with a high burn-up due to plans to gradually increase average burn-up of fuel at the Swedish nuclear power plants.

In connection with the review of SR-Can, SKI and SSI stated that understanding of fuel dissolution rates needs to better demonstrated by model studies in among other ways. Furthermore, it needs to be shown that a link has been made between the analyses of fuel dissolution and the development of the repository. Buffer erosion may, for example, also affect the prerequisites for fuel dissolution.

SKI agrees with SSI that certain additional measures are required to show that criticity due to changed geometry and redistribution of radionuclides is not an important process.

The Canister as a Barrier

With regard to canister processes, SKI considers that SKB needs to continue working with analyses of both the insert and the copper shell for both glaciation load and shear load as well as in appropriate cases a combination of these loads. These analyses shall provide supporting documentation both for verifying the strength of the defined design bases and for providing guidance for fabrication and fabrication checks.

In SKI's opinion, the phenomenon of stress corrosion can still not be dismissed as a design process at the repository. SKB should either show through credible testing that even if a fracture is initiated that growth is so slow that the integrity of the canister is not jeopardised or possibly report on the consequences of some canisters conceivably cracking through growth of fractures caused by stress corrosion.

Buffer

In SKI's opinion, SKB generally has a good programme for the buffer. There is, however, some uncertainty as to which buffer materials can come into question and the composition these materials need to have. SKI therefore considers that SKB needs to produce a more detailed specification of requirements for the buffer and propose concrete materials as suitable candidates for use in a repository. According to SKI, SKB should better justify the temperature criterion for the bentonite buffer and investigate in more detail the risk of an extreme dryout of the buffer. The consequences of the buffer

remaining unsaturated for a long period need to be studied further. SKI is positive to the development of simulation tools for linked processes in the buffer and considers that there should be good opportunities for addressing the above questions. SKB should prior to the application report as much information as possible from the large-scale demonstration tests at the Aspö Hard Rock Laboratory.

SKI considers that the time is ripe for planning of the additional experiments that need to be done during the construction phase of a repository. SKI can, however, note that planning in RD&D Programme 2007 is very vague in this area.

With respect to chemical processes in the buffer, SKI considers that SKB should pay better attention to cementation processes, the link between ion-exchange processes and alteration of smectite, as well as the risk of a structural decomposition of smectite clay. Chemical processes in the buffer are also important to calculate the extent of buffer erosion, which is at present the most important uncertainty around the long-term performance of the buffer. SKI notes that SKB seems to have a good research programme on buffer erosion. According to SKI, it is very important that knowledge achieves a sufficient level of maturity in this area before SKB submits an application to construct the repository. Limits need to be set for the negative consequences of the process and the role of the buffer in SKB's safety concept needs to be able to be defined in the perspective of it possibly being the case that it cannot be assumed to wholly stable in the timetable of the safety assessment.

Backfill

SKI notes that considerable measures remain before knowledge around both practical management questions for the backfill and analysis of long-term development reaches the same level as for the canister and buffer. SKI considers, however, that SKB in RD&D Programme 2007 has raised the level of ambition with the backfill and that there are now concrete plans for filling the most important gaps in knowledge.

SKI considers that the backfill material which SKB is at present investigating has not been reported properly in RD&D Programme 2007. As in the case of the buffer, SKI would also like to see a clearer specification of requirements for the backfill with respect to, inter alia, chemical and mineralogical composition. According to SKI more concrete plans are needed around large-scale demonstration experiments which need to be carried out to investigate the performance of the backfill in as realistic conditions as possible.

SKI considers that SKB has an appropriate programme for limiting and predicting the initial erosion risk that exists during the early resaturation phase. However, more attention needs to be applied to the risk of long-term erosion of backfilled tunnels. In both cases, SKB should strive for a better theoretical understanding of the controlling erosion mechanisms. The consequences of a gradually reduction of the density of the backfill should also be investigated. SKI considers finally that a report is lacking in RD&D Programme 2007 on chemical processes in the backfill as well as information about backfill of other repository areas besides deposition tunnels.

Geosphere

In the RD&D Programme, the geosphere capital consists of 26 sections and the structure permits a detailed description related to many different processes. SKI considers, however, that the links required to tie together the key issues with the relevant processes are not clear in the presentation. Key issues associated with the geosphere are, for example, radionuclide transport, buffer erosion and copper corrosion. With SKB's choice of arrangement based on processes without a structured link to open key issues, there is a risk that important issues will not be sufficiently clarified.

One issue which is explicitly part of the chapter division is radionuclide transport which is included in four sections. However, SKI considers that it is important to identify the most important needs for further research and development based on the whole system. Accordingly, SKI considers that SKB should plan and report research and development for transport of radionuclides together for important aspects of both the geosphere and the biosphere.

SKI agrees with SKB on the assumption that the risk of spalling during the construction phase is less than for orientation in other directions if the deposition tunnels are oriented parallel to the greatest main stress direction. This is also confirmed in studies carried out on behalf of SKI.

In various contexts, SKI has drawn attention to the lack of studies on structural integrity and deformation of large fractures and fracture zones. This type of study is important in the light of regional and local modelling needed for analysis of stress states, the structural integrity of the rock mass and questions related to linked processes. SKI considers that this issue has not been addressed in a good way in SKB's programme and this needs to be rectified.

SKB also needs report its points of view on whether it considers that the repository as such can constitute a plane of weakness and thus constitute a failure initiation in connection with future earthquakes.

With respect to the creation of new fractures SKI considers that SKB needs to produce better supporting documentation for evaluation of possible impact on the long-term safety of the repository. SKI would like to see a more detailed analysis of the prerequisites for possible formation of new fractures at the candidate sites Forsmark and Laxemar.

Like SSI, SKI considers that SKB, on the basis of an integrated problem description, should derive and report a programme for continued work that sheds light on development of models in order to assess the effects of an earthquake of magnitude 6 or greater, methods for identification of fractures and deformation zones, additional work on discrete network models as well as development of respect distances and criteria for choice of deposition positions.

Biosphere

Since SSI is the expert authority within the biosphere area, SSI's text is reproduced here in extenso.

SSI states that SKB produced an integrated landscape model in SR-Can, which includes several ecosystems in the succession of landscapes arising from isostatic uplift. The authorities stated in the review of SR-Can that an integrated approach is good. However, there are methodological weaknesses that should be rectified prior to SR-Site:

- The methodology produces a dilution effect in the dose calculations.
- Relevant transport processes have not been included in model description.
- The validation of the models in relation to field data is insufficient.
- An uncertainty analysis is lacking.

Furthermore, SSI considers that RD&D Programme 2007 does not answer the issue of whether SKB's programme deals with the weaknesses pointed out by the authorities in connection with the review of SR-Can. A clear description of the further development of dose models is lacking, for example, the processes that are to be included in bog and lake models. As regards model validation, the forest model is the only model that SKB specifies which is to be validated. SKB does not either mention how uncertainties in data and models are to be dealt with in connection with dose calculations.

Since there will not be an additional RD&D report before SKB intends to submit the licence application, SSI considers that SKB should clarify how the authorities' points of view on SR-Can and on RD&D Programme 2007 are to be taken care of in the future biosphere programme.

Partitioning and transmutation

SKI wishes to encourage SKB to continue to implement or participate in systemic studies in the future. In-depth studies should as to date take place in areas where Swedish research has proven capable of making serious contributions. Under these conditions, SKI has no objection to make to the announced increase in SKB's measures in the coming years.

Deep Boreholes

SKI observes as was done in the review of RD&D Programme 2004, and also on the basis of the present level of knowledge, that the only barrier which can be assumed to function for the deep boreholes concept is the rock. It is difficult to assess the characteristics in the short- and long-term at great depth of bentonite or other buffer material in the borehole with regard to protecting the canister against major rock movements. Similarly, the integrity of the canister, even for shorter periods of time, is difficult to evaluate due to the high rock stress and aggressive chemical environment at repository depth.

SKI wishes to draw to attention that a repository concept which from the very beginning only based on rock as the only barrier conflicts with SKI's regulations (SKI FS 2002:1) on safety in final disposal of nuclear materials and nuclear waste.

On the basis of discussions and the argumentation that SSI reported at Kasam's (now The Nuclear Waste Council) seminar on deep boreholes in March 2007 and SSI's comments and argumentation in the statement on this RD&D Programme, SKI can support SSI's argument why SKB should produce better supporting documentation on deep boreholes for a comparison with the KBS-3 method. In SKI's opinion, however, that critical points of view put forward in previous RD&D reviews remain since SKI considers that deep boreholes at present are not a realistic alternative to the KBS-3 method.

SKI agrees, however, with SSI that the supporting documentation which the Swedish Radiation Safety Authority needs to be able to compare deep boreholes with the KBS-3 method needs to be reinforced in the application for construction of the repository for spent nuclear fuel.

Social Science Research

SKI considers that the research engaged in by SKB in the social sciences contributes to a holistic picture of the repository process, which is an important component in decision-making when the application for the repository is submitted and is to be considered by the authorities and other actors. SKI therefore welcomes the focus on continued work based on RD&D Programme 2004 being submitted and reviewed by the parties concerned. The research funded through the programme has included a broad field of social science and has resulted in interesting studies that have taken up new questions with research findings that have produced additional knowledge and insight into earlier questions.

To benefit from the results from the important questions dealt with within the programme, it is important that the link between SKB's social science research and other documents and decision-making processes (for example EIA), which form part of the preparations for SKB's application for construction of the repository in 2010, are further clarified. SKI considers that continuing research in the social sciences is important and that further social science research after 2010 would be desirable.

The LILW Programme and Decommissioning

The Repository for Long-lived Low and Intermediate-level Waste - SFL

With a vague reference to insufficient resources, SKB has not complied fully with SKI's, SSI's and the Government's expectations on a report of the plans for SFL in RD&D Programme 2007. Regardless of whether it takes one, two or three decades before the construction of this plant, SKI considers that a credible design of the plant is needed already now, which can serve as the basis for criteria for choice of treatment methods for waste intended for deposition in SFL. SKI therefore considers that SKB needs to supplement RD&D Programme 2007 with regard to its plans and programme for SFL. This supplement should be designed in such a way as to provide the authorities

with supporting documentation for evaluation of whether SKB's report of the programme for SFL in the programme in 2010 is of sufficient extent in the following respects:

- A quantitative estimate of when such waste arises which is intended to be finally disposed of in SFL. An estimate of this kind is required as supporting documentation to justify and assess the reasonableness of SKB's timetable for SFL, including identified possibilities for phased expansion and/or need of intermediate storage of the waste.
- The production of alternatives for the design of the repository, including the design bases and safety functions which will be applied.
- The focus of future safety analyses of SFL, among other things, with a view to be able to produce and verify acceptance criteria for waste intended to be finally disposed of at SFL.
- The content of a research and development programme as support for future analyses of SFL.

The Repository for Short-lived Low and Intermediate-level Waste – SFR

SKI makes the evaluation that SKB needs to justify more clearly its plans for expansion and operation of SFR. This should take place in the first place in connection with RD&D Programme 2010. In order to enable the authorities to ensure in good time that these questions will be dealt with in a good way, SKI considers, however, that RD&D Programme 2007 should be supplemented on this point. This supplement should consequently cover how SKB will report these questions in Programme 2010 including a preliminary account of management of operation and dismantling waste in SFR. SKB should be able use the report recently produced by SKB as a basis for management of dismantling waste.

Planning for Decommissioning Nuclear Power Plants

In SKI's view, this part of the LILW programme has not yet been given inappropriate structure and a sufficiently detailed content.

It is clearly evident from SKB's report that the nuclear power companies have a remaining responsibility jointly or severally to report their own plans and strategies for decommissioning nuclear power plants. SKI does not consider that SKB's report on the power companies' strategies for decommissioning in general terms is sufficient to enable the authorities to be able to assess the reasonableness in timetables and action programmes regardless of whether responsibility for these is borne by SKB or the nuclear power companies. SKI therefore makes the evaluation that SKB should submit a supplement to RD&D Programme 2007 in the form of a compilation of the decommissioning plans that the nuclear power companies have produced in accordance with SKI's and SSI's regulations. This supplement should be able to serve as supporting documentation for the Radiation Safety Authority's evaluation of how SKB and the nuclear power companies shall make further progress with this question in connection with RD&D Programme 2010.

In SKI's view, the justification of the timetable for decommissioning the Barsebäck nuclear power plant that SKB specifies is quite well founded. However, it is still lacking certain supporting documentation which shows in quantitative terms the possibilities and difficulties of starting deposition of decommissioning waste in the existing SFR at different times. This applies particularly to an account of when and at what rate different kinds of waste are generated during demolition. SKI therefore considers that SKB should supplement RD&D Programme on this point. In this case as well, SKB should be able to use the recently presented document on decommissioning waste from Barsebäck as a basis.

Like SSI, SKI considers that RD&D Programme 2007 should be supplemented with a report on how Vattenfall AB as licensee for Ågesta heat power reactor intends to fulfil its obligations in accordance with section 12 of the Nuclear Activities Act.

1 Introduction

1.1 Background to the Programme

According to Nuclear Activities Act, 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 the planned repository will not be closed until the latter half of this century if everything proceeds according to plan. A series of decisions must be made before this goal is attained. The decision-making process can therefore be describes as a multi-stage process. During these stages, safety and radiation protection will be evaluated and there will be the opportunity for further development work or for selecting improved solutions. SKI's task is to ensure safety compliance throughout all of the stages. SKI now needs to evaluate what needs to have been done by the time of the application and what can wait until a later occasion.

In a decision in December 2005, the Government found that SKB's Programme for Research, Development and Demonstration of Methods for the Management and Disposal of Nuclear Waste, RD&D Programme 2004, fulfilled the requirements made in section 12 of the Nuclear Activities Act (1984:3). 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 now known as the Nuclear Waste Council) stated with respect to SKB's plan of action, responsibility for the closed repository, decommissioning, low- and intermediate-level waste, social science research and alternative methods.

SKB's current programme, which was submitted to SKI on 28 September 2007, is the eighth regular programme in the series which started with RD&D Programme 1986. The previous RD&D Programme 2004 mainly focused on clarifying the fabrication and sealing of canisters as well as other research and technology development. Since SKB plans to submit an application to build the repository for spent nuclear fuel during the first half of 2010, RD&D Programme 2007 is primarily focused on producing sufficient technical data for the application. On the basis of the opinions of the regulatory authorities and the Government regarding the previous RD&D Programme, SKB is also presenting an updated plan of action and a survey report of plans for decommissioning.

1.2 Conduct of this Regulatory Review by SKI

At the end of October 2007, SKI and SKB arranged a meeting for the reviewing bodies at which SKB gave a detailed report of the programme and SKI drew attention to issues that the reviewing bodies could bear in mind when reading the programme. In addition

to this, SKI and SSI reported their most important comments on the previous RD&D Programme on 1 November 2007 and also shed light on issues of interest in the current programme for the municipality of Östhammar.

SKI has carried out the review of SKB's RD&D Programme 2007 in the same way as in SKI's previous reviews of RD&D Programmes. SKI has distributed the programme to fifty reviewing bodies for comment (authorities, municipalities, universities, environmental NGOs etc.). Review statements were received from 40 of these, of which three have 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, canister/canister corrosion and the geosphere. Just under a quarter of the review statements comment on the buffer, climate evolution, retrieval of canisters and the structure, readability and comprehensibility of the report. Six or seven reviewing bodies have also commented on issues relating to selection of methods, site selection, backfill and low and intermediate-level waste. Five reviewing bodies have commented on issues concerning resources to authorities, the decision-making process, funding from the Nuclear Waste Fund and the biosphere while fewer than five review statements discuss fuel, the plan of action, safety assessment, rock construction and responsibility after closure of the repository for spent nuclear fuel.

Two-thirds of the statement from the Swedish Society for Nature Conservation and the Swedish NGO Office for Nuclear Waste Review consists of criticism directed at SKB, the authorities and the Government. Furthermore, these organisations address the Government directly in their summary with a 17-point list of requirements. The remaining third consists of opinions on SKB's RD&D Programme 2007. Where it was considered relevant, SKI has reproduced the organisations' opinions in the last third of the statement.

In April, SKI's board was informed of the content of the review statements 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 on 12 June 2008.

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: "Comments by the Municipalities", "Comments by Other Reviewing Bodies", "General Comments by the Reviewing Bodies", "SSI's Comments" and "SKI's Overall Evaluation".

This review report, SKI's assessment of SKB's RD&D Programme 2007 together with SKI's Review Statement on SKB's report of RD&D Programme 2007 – Programme for Research, Development and Demonstration of Methods for Management and Disposal of Nuclear Waste were submitted to the Government on 25 June 2008 (SKI Report 2008:48). In addition, the statements by the reviewing bodies were submitted in full to the Government as well as a compilation of the review comments referred to in the review report (SKI-PM 2008:05).

2 Overall Opinion of SKB's Programme

In this chapter, SKI presents its comments on the structure and content of this programme. SKI also provides views on certain issues that SKI previously highlighted and which SKB has not included in the programme to the expected extent, for example, the repository for long-lived low and intermediate-level waste. Furthermore, comments are made on issues taken up by SKI, SSI and the Government in the decision on RD&D Programme 2004 which SKB has not taken fully into account. Comments are also made in this chapter on issues relating to the decision-making process and financial resources which have been taken up by some reviewing bodies.

2.1 Introduction

SKB has opted to base the structure of the programme on the requested updated report of the plan of action that includes handling of radioactive waste, the nuclear fuel programme and the Loma Programme. SKB reports on the handling and specification of requirements etc. in the nuclear fuel programme (Chapter 2.4). Parts are then presented that affect the repository for spent nuclear fuel and which include descriptions of site investigations conducted, licensing, construction, commissioning and operation.

In RD&D Programme 2007, SKB has furthermore primarily focused on issues relating to technology development (Chapters 4-10 and 11-18) associated with the repository. This is based on SKB's aim of submitting the application to construct the repository for spent nuclear fuel during 2010. One new feature of this RD&D Programme is that SKB has introduced the concept of production lines (Chapters 11-18) in the report of technology development with specifications of requirements for components included in the KBS-3 concept. To obtain an integrated picture of the requirements and restrictions that constitute design premises for the repository, SKB has produced a methodology for systematic handling of requirements and other design premises. This information is documented in a special database (page 48). The programme with production lines is then linked with the programmes for safety assessment and research on the long-term processes that take place in the repository. The programme concludes with a presentation of social science research and the Loma Programme with decommissioning of nuclear facilities. Each chapter has an extensive reference list.

To make it easier for readers and reviewers, SKB starts off each chapter from Chapters 21-33 of the report 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 the previous RD&D Programmes. Finally, knowledge gained since the last RD&D Programme and the programme for planned research are presented. The other chapters in the report, Chapters 1-20 and Chapters 34-40, have a partly differing structure.

2.2 Structure and Content of the Report

Comments by the Reviewing Bodies

Chalmers University of Technology considers that the research programme (RD&D Programme 2007) distributed for review is very extensive and the description of the activity very detailed. In general terms, SKB has for a long time had a well-considered and evaluated plan for the repository, which is also reflected in RD&D Programme 2007 that covers many relevant areas.

Karlstad University considers that RD&D Programme 2007 is full of information and undoubtedly also of good intentions. However, in many respects, the report is depressingly
insufficient as a basis for decision-making on key issues.

The County Administrative Board of the County of Kalmar notes that SKB, with RD&D Programme 2007, has presented an ambitious research, development and demonstration programme of high quality. The programme covers the period 2008-2013 with a greater level of detail for the first three years. The programme is well-structured and easy to read and the remaining issues are clearly presented. The specially produced summary has additionally facilitated the review and understanding of the extensive RD&D Programme.

The Nuclear Waste Secretariat of the Environmental NGOs, Milkas (Hultén) welcomes the less certain tone of RD&D Report 2007. A report that openly presents problems, "difficult nuts to crack" inspires more confidence. Attempts at contextualisation are likewise welcome, even though they occur too infrequently.

The Swedish University of Agricultural Sciences (SLU) considers that the report is extensive and provides a good view of what has been done and what remains to be done in disposal of nuclear waste. However, in SLU's opinion, the text is rather difficult to understand for the non-initiated. This is reinforced by the use of a large number of technical terms that recur throughout the text but which are never satisfactorily defined.

The Municipality of Oskarshamn considers that SKB has presented a high quality research, development and demonstration programme in RD&D Programme 2007. In particular, according to the Misterhult Group, Part III "Technology Development in the Nuclear Waste Programme" is described in an exemplary way with a pedagogic presentation of what SKB considers to be known and less well-known technology and what SKB needs to develop as regards technological methods for construction, operating and closure of the repository. In Part IV "Safety Assessment and Scientific Research", which is ultimately to lead, through dose calculations, to an evaluation of the impact on people and the environment, there are marked uncertainties around certain processes and course of events, which justifies questions. This applies to the biosphere programme, in particular, which, despite the uncertainties, has been creditably developed.

The Swedish Defence Research Agency considers that the report which describes RD&D Programme 2007 is an impressive review of 500 pages (plus a large number of

references and research reports) of plans, technology development, safety assessment and research. However, the agency notes what is not taken into account at all in RD&D Programme 2007 is the consequences of an expansion of Swedish nuclear power and the impact that this might have on the present siting decision for a repository.

The Swedish Radiation Protection Authority considers that the parts of the report relating to the nuclear fuel programme are well-structured and that the programme has generally been produced with a high level of ambition.

Uppsala University considers that the programme is generally both broad and deep. It is written with exemplary clarity.

The Municipality of Östhammar considers that this RD&D Programme has been made more accessible with the summary and plan of action providing a clear picture of the content of the report and on the nuclear fuel programme.

SKI's Evaluation

SKI can observe that the structure of the report does not differ from the structure of the previous R&D report to any great extent with a presentation in sub-areas containing a varying number of chapters. In this RD&D Programme, the whole plan of action is presented as an introductory part of the report while in the former programme, the major part of the plan of action consisted of an appendix. SKI considers the present arrangement to be an improvement. However, SKI notes that the previous plan of action was more detailed than this plan.

SKI also considers that SKB's report should have stated more clearly, in relation to handling of requirements, both the extent and time for fulfilment of the various stated requirements as well as what is needed and by whom. It is not sufficient simply to state what needs to be done before the application is submitted. It is not clear from the report what happens if the requirements in any of the specified sub-systems are not meet within the stated time limits. Before submitting the application, SKB needs to clarify which critical thresholds and stages need to be achieved.

SKI appreciates that the result of the site investigations has been included in the report. However, SKI finds that the look into the future of what remains to be done before the repository can be commissioned, Part II, Chapters 5-10 could just as well have been incorporated in the plan of action.

SKI also appreciates SKB's attempt to report the comments of the regulatory authorities and Kasam (now the Nuclear Waste Council) on the previous RD&D programme. However, it can be noted that SKB has not always reported planned measures in response to the comments made. This could have been done in all chapters by a report in tabular form, corresponding to an expanded version of Table 19-1 on research into long-term safety and Table 19-2 on the initial state of the repository.

SKI is satisfied to see that SKB presents, as requested, a brief retrospective and important steps forward in previous RD&D programmes at the beginning of the report. This means that new readers of the programme do 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 have recently been concluded. However, the chapter still lacks an attempt to present an overall holistic picture of the programme focusing on important remaining questions that need to be answered at different times as the programme progresses.

SKI also considers that SKB could more clearly have presented a more overall strategy and for the goals to be met, in particular for Chapters 19-28. 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 goals of particular research contributions. One example that can be given is that an integrated presentation of, for example, radionuclide transport would have been preferable instead of report in different sections.

SKI considers that details are also lacking for the remaining planned research contributions. Furthermore, there is no account of the order in which individual projects need to be carried out and their mutual dependence and interaction.

In SKI's opinion, the programme is also lacking a discussion of implementation based on the BAT perspective. This has also been pointed out by the Municipality of Östhammar.

The safeguards aspect is another important issue that should have been taken into account and integrated in the programme in a much clearer way than has now been done in two different sections of the report (Chapters 6.7 and 14.6).

SKI can also note that Part VI The LILW Programme and Decommissioning (Chapters 34-40) is difficult to overview with a lot of repetitions within different parts of chapters and is therefore relatively difficult to review. In SKI's view, the chapter on decommissioning in the LILW Programme has still not been given an appropriate structure and a sufficiently detailed content. Furthermore, SFL has not been presented to the extent that SKI, SSI and the Government had expected.

SKI also notes that SKB, in addition to the RD&D process, now also mentions other ongoing parallel activities such as the PLAN process and EIA consultations. However, a brief presentation of the outcome of consultations that have taken place to date could have been given or at least references provided. A discussion could also have been included if the consultations affected other activities in SKB's nuclear fuel programme to any extent.

2.3 Decision-making Process and Environmental Impact Assessment

Comments by the Municipalities

The Municipality of Oskarshamn states that RD&D Programme 2007 is the last programme to be presented by SKB prior to the application in 2009 to construct a geological repository for spent nuclear fuel in Sweden. The programme covers the period 2008-2013 and thus extends beyond the year of application 2009. In its review of

RD&D Programme 2007, the municipality has therefore highlighted the following questions:

- What parts of SKB's programme have to be complete to make possible a well-supported application at the end of 2009?
- Which unanswered questions can be postponed to subsequent reviews by the regulatory authorities and decisions?

The municipality states that it is only by imposing conditions on the operator that society can contribute to safe and environmentally acceptable disposal. It will be of crucial importance for the regulatory review that the issue of conditions is dealt with in an open and transparent way and that conditions are available at a sufficient level of detail when the municipality is to reach its decision in accordance with the Environmental Code (Environmental Code, Chapter 17, section 6). The municipality considers that it is natural to impose conditions, in connection with a veto decision, that have not been satisfied in the process and would now like it to be clarified whether there are formal impediments or restrictions against imposing conditions in connection with the veto decision.

The municipality also wishes to obtain clarification that there are no formal impediments to one and the same environmental court preparing the Government's consideration of permissibility of the system, including INKA in Oskarshamn, even if it is planned to locate the repository at Östhammar.

The process prior to future decisions on test operation, routine operation, control programmes and closure also needs 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 conditions prior to a decision.

The municipality would like an answer to what would happen if disposal is delayed due to an extension of the lifetime of the nuclear power plants and thus an increased need of interim storage.

It is important for municipal planning to have as realistic timetables as possible. The municipality considers it highly improbable that there will not be an appeal against Sweden's largest environmental regulatory review in such a controversial matter as the issue of nuclear waste to the highest instance. The municipality would like to see clarification of the consequence of this scenario.

In order to be able to produce a good basis for decision-making to the municipal council, the relevant parts of the application documents need to make clear which transport solutions are recommended by SKB. The municipality would like to see canister transportation which is not mixed up with other traffic and environmentally friendly and safe transport alternatives for rock mass and input goods. Given Sweden's and SKB's high-pitched environmental ambitions, the municipality expects the best possible transport solutions.

The municipality notes that SKB intends to report on alternative methods in a separate document and on alternative designs for KBS-3 in the EIA. The issue of alternatives has

been dealt with in Condition 12 of Oskarshamn's decision on site investigation of 11 March 2003 where the municipality refers to Government statements from the RD&D reviews. If the alternatives are presented in a separate document instead of the EIA, they are not included in the consultations in accordance with the Environmental Code. The Environmental Court is the instance that will make the final decision on whether SKB's presentation of alternatives fulfils the requirements of the Environmental Code. The municipality emphasises that it s important that the decision-making process continues as planned and that the issue of alternatives does not entail delays.

The Municipality of Oskarshamn also considers that social science research and reports are an important part of the basis for decision-making for the municipalities. The issue of nuclear waste consists of considerably more than technology. Taking into consideration the complexity of the issue, there is every reason to keep the door open for further social science research and reports even after the dates specified in the programme.

Establishment of a repository system will have a very tangible impact on municipal inhabitants in the parish of Misterhult, in particular during the construction phase. This period will entail considerable strains on municipal inhabitants with the establishment of an extensive industrial activity, large rock accumulations, effect on the groundwater, increased traffic and perhaps considerable attention from the outside world. The municipality takes the view that special importance should be attached to questions raised by the inhabitants of the municipality.

The Municipality of Östhammar states that they requested, in a letter to the Government dated 8 May 2006, that the Government raise the issue of the municipal veto after the review reports by the regulatory authorities are available. The Government replied to the municipality that "if it was not clear from the opinion of the Environmental Court whether or not the municipality gave its approval to the activity or not, the Government would requests the municipality for a statement". The municipality would like to point out again that the freedom of decision of the municipalities must be maintained until the end if the local process is to be perceived as meaningful.

At the same time, the municipality wishes to state that it is very important, from the municipal viewpoint that the process continues at the pace permitted by the safety aspects. The commitment of the municipalities requires resources and has tended to deflect other important municipal issues for many years. It is very important that the repository issue is resolved to enable us to focus on the municipal areas of responsibility. The municipality takes the view that a future government decision must be based on the attitude that the most important factor is long-term safety. SKB regularly states that safety can prove to be equally good at two sites and that other criteria will influence the decision.

The municipality also points out that the requirement for use of best possible available technology (BAT) is of key importance in the Environmental Code, both as regards radiological risks as well as other risks for people's health and environment. The municipality considers that the project should be characterised throughout by the Environmental Code's definition of best available technology and that it is important

that a licensing decision is made in such a way as to have the benefit of developments within the area of technology and safety also after the licensing decision has been made.

Other Reviewing Bodies' Comments

The County Administrative Board in the County of Kalmar notes like the Municipality of Oskarshamn (see above) that SKB identified a number of issues that are not considered as being answered prior to the licence application in 2009, which will be subject to further research throughout the future RD&D period, 2008-2013. It is considered that certain questions will remain even after this date. RD&D Programme 2007 is thus the last programme to be reviewed before SKB submits its licence application for the repository system in accordance with both the Nuclear Activities Act and the Environmental Code.

The county administrative board considers that SKB, prior to the licence application, should clarify the issues that SKB considers have to be completely investigated prior to application and which issues can be dealt with subsequently than at the time of licensing and consideration of permissibility of the activity, and why. Proposed conditions for the licences concerning these issues should be produced during 2008.

The county administrative board further states that SKB should, already in the applications for a licence/permissibility, clarify and assess the consequences of further research in the different areas not producing the expected results. SKB should prior to the application identify and shed light on critical issues that remain and, if these are not satisfactorily answered, how these may affect the timetable for the project.

The County Administrative Board in the County of Uppsala notes that RD&D Programme 2007 shows that there are important remaining issues relating to the disposal of spent nuclear fuel, which, in certain cases, in the view of the county administrative board, need to be answered prior to the application in accordance with the Environmental Code. This applies primarily to the design/method and the site that SKB will apply for a licence for, but also the report on alternative sites and designs in the environmental impact assessment.

The county administrative board assumes that attention will be given in the coming work of investigation to risks of chemical-toxic effects on people's health and the environment, including from different materials (for example, grout), which may be brought to the repository.

The Swedish Society for Nature Conservation and the Swedish NGO Office for Nuclear Waste Review (MKG) consider that societal goals and performance requirements must be formulated to be able to evaluate how well the industry's repository proposal fulfils these goals and requirements. In their opinion, for the relevance of the RD&D programme to be evaluated, it is necessary to specify the disposal project's environmental task and objective. Such a specification is an indispensable step in the process of carrying out an EIA which complies with the requirements of the Environmental Code. In the opinion of these organisations, objectives and requirements should be formulated not by the industry but by society (The Government and the Swedish Parliament, the Riksdag).

The Swedish Society for Nature Conservation and the Swedish NGO Office for Nuclear Waste Review (MKG) notes that the Government, the county administrative boards and the authorities have used the concept of alternative methods for a long time for what the industry now wishes to refer to as other methods. Alternative methods is also the legal name in environmental law for what is to be reported in an environmental impact assessment according to the Environmental Code. The name alternative methods was used consistently in the two seminars on nuclear waste law held by the Nuclear Waste Council during 2006.

In the opinion of the organisations, the use of the alternative concept in the RD&D plan is an evident tactic on the part of industry prior to environmental consideration of its disposal method. The industry has previously stated that it does not intend to report alternative methods such as deep bore holes, transmutation and long-term interim storage in the environmental impact assessment in the application but in a separate part of the application.

The Swedish Society for Nature Conservation and MKG note that the authorities and also to some extent the municipalities have also been critical as to how the industry has acted in the issue of presenting alternatives. The organisations stress that the conduct of the industry in attempting to restrict the presentation of alternatives in the environmental impact assessment is unacceptable.

The Waste Network and Opinion Group for Safe Disposal (Oss) states with regard to quality assurance that it is evident, given the experience of the events at Forsmark in 2007, that the safety and management systems referred to by SKB do not provide any guarantees at all for either the quality or safety of a future repository. The organisations therefore consider that before any decision can be made on realisation of the plans presented, that the company and the responsible authorities must be able to convincingly show that such quality assurance can be guaranteed, and present credible and concrete measures, which are fully reliable throughout the whole of time perspective in question.

With respect to licensing, the Waste Network and Opinion Group for Safe Disposal notes that SKB intends to plan, organise and design facilities and activities in the repository system at the same time as licensing is in progress. This breaches the EIA legislation and the Government should give clear directives in its statement to avoid the future licensing process being undermined by irreversible financial and production engineering decisions.

The Swedish Radiation Protection Authority (SSI) understands that SKB needs in its project planning to assume an estimated time required for the different stages of the process. SSI realises that it can be problematic to attempt to establish a probable timetable for licensing. However, SSI wishes to emphasise the importance of SKB basing its planning on a well-grounded and realistic estimate of the time required for licensing. In SSI's view, it is not probable that the review by the regulatory authorities and the subsequent licensing procedure will be finished within two years.

In SSI's view, SKB must expect a considerably longer period of time than two years for the licensing process to take place. Not least bearing in mind that the affected municipality(ies) must have the necessary time to review the application and the evaluations and conclusions from the review work by the regulatory authorities and the Environmental Court.

In SSI's opinion, the issue of reporting alternatives may also need to be raised in the ongoing EIA consultations.

Westinghouse Electrics Sweden AB takes a very positive view that SKI has given a large number of organisations, active in different fields, an opportunity to make a statement on SKB's RD&D Programme 2007.

SKI's Evaluation

SKI wholly agrees with the Municipality of Oskarshamn and the County Administrative Board in the County of Kalmar about the issues that the municipality wishes to highlight in its statement to SKI, i.e. the parts of SKB's programme that must have been completed to make possible a well-supported application in 2010 and which issues can be postponed to subsequent agency reviews and decisions.

In this report, SKI will clearly present its viewpoints on these issues. However, it is evident that, before submitting the application, SKB needs to report on the questions raised both by the Municipality of Oskarshamn and the County Administrative Board in the County of Kalmar as well partly by the County Administrative Board in the County of Uppsala.

With respect to the environmental impact assessment for SKB's application in accordance with the Nuclear Activities Act (1984:3) to construct, own and operate a repository for spent nuclear fuel, SKI wishes to clarify that alternative methods shall be reported by SKB in the EIA to be submitted in connection with the repository application. This has been notified to SKB in two letters dated December 2006 and February 2008 respectively. SKI points out in these letters that the authority wishes to work for the environmental impact assessment having the focus and scope needed for licensing in accordance with the Nuclear Activities Act and the Environmental Code. A memorandum was enclosed with the letter to SKB in 2008 (SKI dnr. 2007/1155) further clarifying SKI's viewpoints on the matter of the content of SKB's environmental impact assessment.

2.4 The RD&D Process

Comments by the Reviewing Bodies

The Swedish Radiation Protection Authority (SSI) notes in its statement that the RD&D process has not always functioned appropriately. SSI gives examples of issues which SKB and the licensees of the nuclear power plants have dealt with in an unsatisfactory way, despite repeated reminders from the authorities and despite government decisions. This is per se a cause for concern. Since the current RD&D Report is the last one before

SKB intends to select a site and submit the licence application, it is important that the feedback from the review by the regulatory authorities is improved. Otherwise, there is a risk of there being a need of supplements to the supporting documentation with considerable, and unnecessary, delays in the work.

SKI's Evaluation

SKI is wholly in agreement with SSI that SKB has not completely taken into account all the issues raised by the authorities in the recurrent RD&D programmes and given feedback to the authorities' requirements. SKI also considers that, given the length of time, three years, between SKB's RD&D programmes, that it has been necessary to communicate with SKB more frequently. For this reason, important fora for communication with SKB have been made available since RD&D Programme 2001. Examples of this are workshops, seminars, consultation meetings and expert meetings associated with these. The workshops and seminars arranged have concerned fuel, canisters, bentonite and backfill. Consultations which have been confirmed by two government decisions and which will probably continue until the application has been submitted from SKB have concerned system and safety assessment and site investigations.

At the workshops and seminars concerning fuel and engineered barriers, SKB has been invited to present the latest research findings to SKI and its invited experts. Furthermore, SKB and its experts have answered list of questions from experts and SKI. The results of the seven workshops arranged on engineered barriers have been published in SKI reports and also presented in international fora (Toverud and Strömberg, 2007).

To monitor SKB's site investigations, SKI has also established an international group of experts which has advised SKI since the site investigations started in 2002.
An international advisory group to SKI has recently been established in the field of engineered barriers.

2.5 Responsibility for a Closed Repository

Comments by the Reviewing Bodies

In its review statement on RD&D Programme 2004, the municipality of Oskarshamn requested a statement from the Government as to how it intends to deal with the issue of responsibility for the repository after closure. The Government then directed SKI and SSI through the appropriation directions to make proposals as to how the responsibility issue can be clarified in the appropriate legislation. SKI and SSI have presented a detailed account in a report (SKI Rapport 2007:01, SSI Rapport 2007:01) to the Ministry of the Environment on legislation and the responsibility of the various actors. This report contains a proposal for an amendment of the Nuclear Activities Act which is in line with the municipality's site investigation condition 13. However, it is proposed that this amendment should not yet be included in legislation.

The Municipality of Oskarshamn wishes to see the responsibility issue regulated by law now and not to wait for future closure. This is a municipal demand based primarily on the needs of municipal inhabitants and landowners.

SKI's Evaluation

The SKI/SSI report includes a proposed amendment to section 14 of the Nuclear Activities Act which underlines the ultimate responsibility of the state. However, it is not considered appropriate to regulate the state's ultimate responsibility for the repository at this stage. In the opinion of the authorities, it should be sufficient at present to note that the state, by ratifying the 1997 Convention on the Safety of Spent Fuel and Nuclear Waste has undertaken ultimate responsibility for the repository.

2.6 Resources to Actors in the Nuclear Waste Process

Comments by the Reviewing Bodies

The Swedish Society for Nature Conservation and the Swedish NGO Office for Nuclear Waste Review (MKG) point out the importance of resources being available to enable the Swedish Radiation Safety Authority (a new authority on 1 July 2008 created by the merger of SKI and SSI) to produce, independently of the industry, supporting documentation which is sufficient for the purpose of review. This possibility is contained in the Financing Act (section 4(4)) which entails that the requisite funds can be drawn from the Nuclear Waste Fund without being a charge on the national budget.

The Municipality of Oskarshamn notes that SKB wishes to submit the licensing application for the repository at the end of 2009 (recently changed by SKB to the first half of 2010). The municipality's ability to prepare well prior to a decision by the municipal council depends on continued support from the Nuclear Waste Fund. The municipality therefore assumes that this support will be available during the review by the municipality. The municipality therefore intends to participate in the process as a competent party until permission to start operation is given and will therefore make demands for further support from the Nuclear Waste Fund after the government decision.

The Municipality of Oskarshamn also considers that the municipality presented as an alternative site should have resources for active participation in the reviewing process until the Government has made a final decision on a licence for a repository. It is therefore very important that the Government approves financial support for the municipality concerned until the government decision has been made.

The National Organisation of Energy Associations (SERO) considers through participating in the nuclear waste project that considerable body of knowledge is built up by the participating organisations. SERO believes that continued work in some form after the completion of the project at the end of 2008 would be of value for all participating parties.

The Municipality of Östhammar notes that SKB wishes to submit the application for a licence for the repository at the end of 2009 (recently changed by SKB to the first half of 2010). The municipality's ability to prepare well prior to a veto decision by the municipal council is wholly dependent on support from the Nuclear Waste Fund. The municipality therefore assumes that this support will be available for the municipality's review of SKB's application. The issue will probably continue to be relevant for a long time after the Government has made its decision. It can be expected that there will be appeals and referrals and statements to different instances. The municipality may need time to devote to the matter and will then need to use funds from the Nuclear Waste Fund also after the government decision. In the municipality's opinion, it is important that the municipality is able to monitor the issue until permission to start operation is given.

The Municipality of Östhammar has made comments on a number of occasions, both directly to the Ministry of the Environment and in other contexts, on how important it is that the authorities SKI and SSI have sufficient resources both to review SKB's work and to communicate important issues with the municipality. This is of crucial importance for the municipality's ability to penetrate the supporting documentation and for confidence in the process.

The municipality also expressed concern, in connection with the review procedure prior to the merger of the regulatory authorities that the merger is taking place at a time when resources need to be concentrated on the review of the repository issue. The municipality wishes to state emphatically again that it has not to date seen any indication that the authorities have received the additional resources requested by the municipalities.

The local safety committees at the nuclear power plants in the municipalities of Oskarshamn and Östhammar both point out the great importance of the independent role and access to resources of the regulatory authorities. Sufficient resources must be made available to the authorities to review the entire repository system.

3 Comments on SKB's Plan of Action

In this chapter, SKI presents comments on SKB's presentation of Part II of RD&D Programme 2007 corresponding to Chapter 1-3 in SKB's report.

3.1 Introduction

3.1.1 Background

Statement on RD&D Programme 2001
In its review of RD&D Programme 2001 (SKI, 2002), SKI requested that SKB needed to develop a strategy document, which described how SKB would attain the goal of a safe disposal of spent nuclear fuel and nuclear waste. The most important reason for SKI's request was that SKB's planning at this stage assumed a separate government licence for the encapsulation plant some years before the Government was expected to make a decision on a licence for the repository for spent fuel. Another reason for SKI's request was that the authorities concerned needed clarification of which licensing processes are expected to take place over the next few years and how they interact.

The authorities also presented certain requirements on the contents of such a strategy document:

- a timetable, both an overall, realistic timetable and a timetable for future safety assessment and system analyses reports
- objectives 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.

The Government stated in its decision on RD&D Programme 2001 that the Government "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 safe disposal of nuclear waste would be included in the RD&D Programme 2004".

SKB's Report in RD&D Programme 2004
SKB presented the requested plan of action in the RD&D Programme 2004 (SKB, 2004). SKB subsequently published a modified plan of action in March 2005 which was to serve as the basis for SKI's comment and the Government's decision on RD&D Programme 2004. The modified plan of action entails a procedure with simultaneous government decisions on licence applications for both the encapsulation plant and the repository for spent nuclear fuel.

Regulatory Statement on RD&D Programme 2004
In SKI´s view, the plan of action presented by SKB in RD&D Programme 2004 (SKI, 2005) provides a good and systematic description of SKB's timetables and for how different parts of SKB's programme are dependent on each other. However, the authorities considered that the plan of action could and should be further developed and required SKB to produce a new plan to present to the authorities. The request is justified by the fact that planning and implementation of licensing is a stepwise process lasting many years that requires both general and detailed knowledge of the content of the applications and supporting documents.

Application Plan
To further clarify planning for the nuclear waste programme in the next few years, in September 2006, SKB presented the report "Application plan for the encapsulation plant and the repository for spent nuclear fuel" (SKB, 2006). This plan presents the milestones that occur in the nuclear fuel programme until the repository has been commissioned and the planned reporting to be submitted to the authorities on the different reporting occasions

Application for the Encapsulation Plant and Clab
At the end of 2006, SKB submitted a licence application to construct an encapsulation plant at Clab, and to operate the facility integrated with Clab. SKB plans to submit extensive supplementary material for the application at the end of 2008.

3.1.2 SKI's Review of the Plan of Action

SKB's plan of action covers the three initial chapters of Part I RD&D Programme 2007. Chapter 1 consists of a relatively thorough introduction to SKB's programme. Among other things, SKB presents an account of its assignment and how much progress has been made in implementation of the disposal programme and describes in very general terms already established nuclear facilities in the disposal programme as well as the transport system. SKB further presents the prerequisites for further work in terms of resources both for research, development and demonstration and the development work conducted at the Canister Laboratory, the Äspö Hard Rock Laboratory and the Bentonite Laboratory, and for expertise and financial resources.

Chapter 1 concludes with an overall description of SKB's strategy for carrying out the remaining parts of the disposal programme, a review of planning assumptions and presentation of SKB's main timetable. In addition to the most important milestones presented in the main timetable, SKB states that the following prerequisites must be met to realise the timetable:

- The encapsulation plant must be joined to Clab so the two form an integrated facility.
- The encapsulation plant must be joined to Clab so the two form an integrated facility.
- Development of technology for encapsulation and disposal must continue at the planned pace and with the anticipated progress. Unexpected problems at some critical juncture may lead to delays and revisions.

- SKB must obtain permissibility and licence decisions from the Government within two years of submitting an application under the Nuclear Activities Act for the repository and an application under the Environmental Code for the repository system. Moreover, these decisions must not be appealed against to a higher instance.

Chapter 2 contains a more detailed description of the part of the disposal programme relating to handling and disposal of spent fuel (The Nuclear Fuel Programme).

Chapter 3 contains a more detailed description of the part of the disposal programme that covers low and intermediate-level waste (the LILW Programme).

The structure selected by SKB for the plan of action in RD&D Programme 2007 makes it difficult to make comments in the same way as for other parts of the report. SKI has therefore adopted the following arrangement for comments on the presentations made by SKB in the plan of action.

The introductory chapter SKB's plan of action consists of a general review of the different parts of SKB's activities. SKI considers that this section is informative and contains valuable information as well as being a good introduction to the other parts of the programme. SKI notes that the section, as result of this, contains a lot of information in addition to what is relevant for what SKI expects to find in a plan of action. SKI considers that the information in Chapter 1 is at such a general level that it would probably be more appropriate as a general introduction to the RD&D programmes and SKB's activities, in a similar way to Chapter 1 in RD&D Programme 2004, rather than as part of the plan of action. In SKI's view, this is also confirmed by the formulations in Section 1.4.4 that a possible siting of an encapsulation plant at Forsmark would require that the repository was sited there. SKI considers that a formulation of this kind in a forward-looking plan of action could lead to misunderstanding since SKB has already submitted an application under the Nuclear Activities Act to construct the encapsulation plant at Clab. A siting of the encapsulation plant at Forsmark is thus no longer under consideration.

Furthermore, SKI notes in Chapter 1 that large parts contain corresponding information that recurs in Chapters 2 and 3 and to some extent at other places in the report. Due to this, SKI refrains from providing comments otherwise on the information in Chapter 1.

SKI reports in 3.1.3 overall comments on SKB's plan of action. Comments mainly address what the authorities consider to be the main purpose of the plan of action.

Concrete comments on the parts of the plan of action described in Chapter 2, The Nuclear Fuel Programme, are presented in following sections.

Concrete comments on the parts of the plan of action described in Chapter 3 The LILW Programme, are presented in connection with the reporting of comments on Part VI of SKB's RD&D Programme.

3.1.3 Overall Comments on the Plan of Action

SSI's Comments

In SSI's opinion, SKB's plan of action provides a good overview of SKB's timetables and planned work in the different parts of the nuclear fuel programme and that it should be possible to use the structure of the report in future reports. SSI considers that the present structure of the report provides a clearer link between the different parts of the programme, at least at the level of principles, compared with the previous structure.

Comments by Other Reviewing Bodies

The Municipality of Oskarshamn considers that the plan of action provides a good picture of the nuclear waste issue in Sweden with a retrospect of the ten research programmes with supplements produced by SKB since 1984.

The Municipality of Östhammar points out that the area around Forsmark is of national interest as a repository for spent nuclear fuel and nuclear waste. The municipality points out that the role of the area as being of national interest will cease when a decision is made on siting and/or limited to the area covered by licensing. The municipality considers therefore if SKB plans to select Forsmark as the site for a repository for long-lived low and intermediate-level waste, SFL, that it is important to adjust the area of national interest to take this into consideration as early as possible.

SKI's Evaluation

SKI's overall comments address in the first place the plan of action in its function as report on SKB's strategic planning but also as supporting documentation for the authorities strategic planning prior to the build of resources and competence for review of future licence applications.

The Authorities' Expectations
SKI had expected that the plan of action in RD&D Programme 2007 would have been developed in relation to the plan of action presented by SKB in RD&D Programme 2004. SKI considers that this is not the case and that the account in RD&D Programme 2007 is less appropriate in certain respects compared with RD&D Programme 2004. SKI considers this a matter of concern bearing in mind the important function of the plan of action.

SKI's expectations on the plan of action concern, at a general level, two different perspectives for strategic planning. The first perspective concerns overall strategic planning for the whole disposal programme. The other perspective concerns more detailed planning documentation prior to licensing of future applications.

In SKI's opinion, the plan of action is too general in nature to fulfil any of these purposes. SKI considers that the plan in its present form does not fully serve the purpose sufficiently good supporting documentation, neither in its overall strategic perspective nor as detailed planning documentation for the application to construct a repository for spent fuel which SKB – according to RD&D programme 2007 – intends to submit at the end of 2009.

The Need for a Clarified Strategic Plan of Action
SKI would like SKB to produce a clarified overall strategic plan of action which provides a better account of SKB's strategic planning, and which includes more detailed information about underlying logistics and arguments. The plan needs in particular to focus on timetables and activity plans for construction of new repository facilities, and extension of existing facilities, which are needed to manage the nuclear waste that arises in connection with decommissioning and dismantling nuclear power plants. SKI considers that the justifications for producing a new overall strategic plan of action are confirmed by the changed prerequisites for SKB's activity since the report in RD&D Programme 2004. SKB emphasises in particular the extended operating times for the nuclear power plants and the changed prerequisites in the funding legislation. The clarified overall strategic plan of action needs to particularly address the process for relicensing and expanding the repository for radioactive operational waste (SFR) to be able to receive short-lived low and intermediate-level nuclear waste from the decommissioned reactors at Barsebäck and Studsvik, and to establish a repository for long-lived low and intermediate-level nuclear waste, SFL (see Section 8.7).

Furthermore, the plan needs to be expanded to include the measures that SKB would need to take in the event of the construction and initial commissioning of a repository for spent fuel being delayed and the available storage areas at Clab being fully used.

SKI considers that SKB needs to present an overall clarified strategic plan of action, which covers the whole of SKB's programme, at the latest in connection with the report of RD&D Programme 2010.

SKI's evaluations on a clarified strategic plan of action for the LILW Programme, in particular, regarding the repository for long-lived low and intermediate-level waste, are commented on in Section 8.7.

3.2 The Nuclear Fuel Programme

SKI comments in this section refer to Chapter 2 of SKB's RD&D Programme 2007.

SKB's Report

SKB's report is based on two main categories of overall milestones for continued development within the programme (see Figure below). One category concerns milestones subject to legislation and regulations while the other is governed by SKB's internal decisions. The account covers a future time period of around 15 years. SKB refers to the application plan published in September 2006 (SKB, 2006) for more details about the extent and content of applications under the Nuclear Activities Act and the Environmental Code. Furthermore, SKB states that work with the structure and content of the application as well as production of supporting documentation will continue until the application has been submitted and refers to ongoing consultations according to previous Government decisions on RD&D.

SKB states that the part of the plan of action concerning the nuclear fuel programme only includes an overall description and references to the relevant sections of Part II where an account is given of the plans for construction of the repository. A clearer report of the link between the progress made by the programme in relation to milestones and the need for results from the technology development are also described in Part II. The planned technology development measures are then presented in Part III and the prioritised research areas in Part IV.

The opening section (Chapter 2.1) presents the planning for the Swedish nuclear power programme at an overall level. SKB emphasises that the Swedish nuclear fuel programme will probably be the first project of its kind in the world which is to be licensed, that work has been in progress for several decades through a stepwise development, that the prerequisites have been adjusted and that the timetable has been changed apace with the development of the details of the KBS-3 system.

The main points in SKB's report can be summarised as:

- that SKB considers that applications under the Nuclear Activities Act and the Environmental Code will be submitted at the end of 2009,
- that SKB estimates the period from submission of applications to the final licence being granted to at least two years,
- that SKB estimates the time needed to construct the encapsulation plant, the access routes to the repository depth and central area of the repository to the application for test operation to be approximately seven years,
- that SKB estimates that routine operation can start within two years of the start of test operation.

However, SKB points out that uncertainties are attached to these estimates in a number of respects, for example, the characteristics of the sites, the choice of method for rock excavation and the technology development of the different part systems, as well as decisions by authorities.

SKB also states that a prerequisite for being able to construct and operate the repository is that the technology needed at different stages has been developed and is ready to be taken into industrial use at the rate that the needs arise.

The following section (Chapter 2.2) contains a slightly more detailed orientation on the milestones in accordance with SKB's Figure 2.1 in SKB's RD&D programme (see Figure 1 below).

SKB also provides an account (Chapter 2.3) of work in progress for development of the alternative repository design KBS-3H. The most important milestones for this work are presented as:

- a decision on the start of the next development phase,
- a decision on full-scale testing of the whole KBS-3H-system (at the earliest autumn 2009)
- report on long-term safety, operating safety and EIA (at the earliest 2011/2012),

– a decision on changing to horizontal deposition can be made when sufficient supporting documentation is available for comparison with KBS-3V (2012/2013).

SKB states in this connection that the development of KBS-3H can be discontinued at any time during the period up to 2012 if reasons emerge for this in the development work.

The last section (Chapter 2.4) under the Nuclear Fuel Programme provides an overall report of SKB's work in the field of handling requirements and qualification.

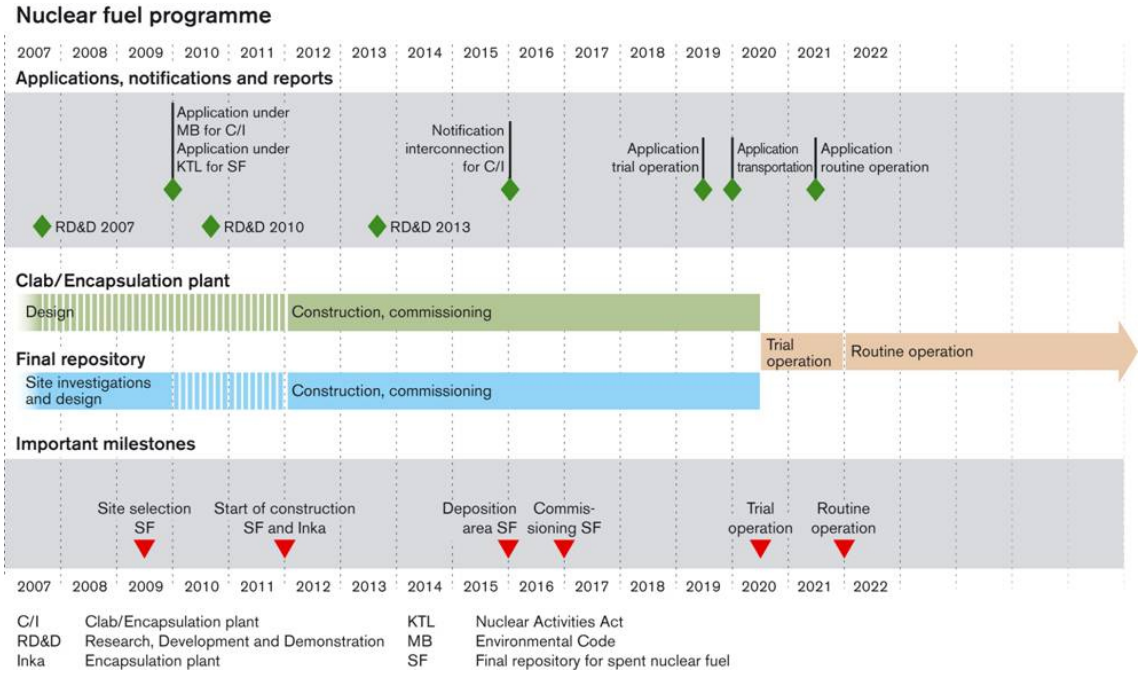


Figure 1. Overall plan and important milestones in SKB's nuclear fuel programme.

SSI's Comments

SSI points out that the future licensing process for a repository for spent nuclear fuel entails that important decisions of principle will have be taken relating to choice of method and site and that it is necessary that the programme is mature to take the next step. SSI considers that research must have made enough progress to provide SKB with sufficient knowledge about the factors that are most crucial for selection of site and method, so that, among other things, SSI's requirements for risk limitation, best available technology (BAT) and radiation protection optimisation can be achieved.

SSI understands that SKB has needed to assume an estimated time expenditure for the different stages of the process in its project planning but points out the importance of SKB basing its planning on a well-supported and realistic estimate of the expenditure of time for the review by the authorities and subsequent licensing. SSI emphasises that the licensing of a repository system is unique and that it is not probable that licensing will be completed within two years and also refers to experiences from the environmental licences for Ringhals AB and OKG AB. SSI also points out that the rules from

Chapter 17, section 6, of the Environmental Code on approval by the municipal council in the municipalities concerned (municipal veto right) did not apply in these cases. SSI considers that SKB must expect licensing to take a considerably longer period than two years.

SSI also points out that it is difficult to say with certainty what other consequences SKB's tight timetable has for the nuclear fuel programme if the plan is not realised. SSI considers that the period "construction and commissioning" – which is planned to take eight to nine years – may prove either to be an overestimate or an underestimate of the actual time taken. SSI points out that if SKB has underestimated the actual expenditure of time that the programme can be substantially delayed in relation to the main timetable. Furthermore, SSI points out that one effect of this may be that the storage capacity at Clab will not be sufficient.

SSI considers that SKB must apply a considerably more realistic timetable for the nuclear fuel programme and clarify the effects that a more extended process may lead to further on, for example, the need for expansion of Clab.

Comments by Other Reviewing Bodies

The Municipality of Oskarshamn draw attention to the following question in its statement: What parts of SKB's programme must be complete to enable a well-supported application at the end of 2009 and which unanswered questions can be postponed to later reviews by the authorities and decisions?

The municipality further states that it considers it natural, in connection with a veto decision, to set conditions which are not satisfied in the process and it wishes to have clarified whether there are formal obstacles or limitations against imposing conditions in connection with the veto decision.

The municipality also states that the process needs to be clarified, prior to decisions on test operation, routine operation, control programmes and closure, and that participating in the process and setting conditions prior to the respective decision is an important prerequisite for the municipality's preparations.

The municipality states that it is important for the municipal planning to have as realistic timetables as possible. The municipality considers it improbable that there will not be an appeal against Sweden's largest environmental regulatory review in such a controversial matter as the issue of nuclear fuel to the highest instance. The municipality would like to see clarification of the consequence of this scenario improbable

The municipality would like to have a decision on what will happen if test operation of the repository for spent fuel is delayed and available storage spaces at Clab have been fully used up

The Municipality of Östhammar states that SKB needs to describe more clearly how additional spent nuclear fuel is to be stored if considerable delays arise in commissioning the repository.

Furthermore, the municipality also requests, as does the Local Safety Committee in the Municipality of Östhammar, when SKB will describe how it intends to handle the issue of a possible changeover from KBS-3H to KBS-3V, since comparative supporting documentation for the different designs will not be available before 2012-2013.

In the opinion of the Waste Network and Opinion Group for Safe Disposal (Oss), SKB should report on the benefits from the point of view of safety which a tighter timetable has compared with a more extended process in order to make it possible to evaluate the importance of the timetable for optimisation of radiation protection and minimisation of long-term risks.

SKI's Evaluation

The Future Licence Application
SKI wishes to point out that the previous review and evaluation of SKB's plans for a repository for spent fuel was based on the perspective that KBS-3 can serve as a planning assumption for SKB's further work, i.e. that SKB considers that it can be shown with a high degree of probability that a repository in accordance with the KBS-3 method can be feasible.

SKI wishes therefore to state that future licensing has an essentially different character compared with previous evaluations, in the sense that SKB does not only have to "make it probable" that the method is feasible. SKB needs to a great extent also to be able to show that the deposition and final disposal of canisters with spent fuel in accordance with the KBS-3 method can in fact be carried out. This means that SKB also needs to have demonstrated to a sufficient extent that safety is feasible in the most critical moments in the long term, and that barriers can be designed with the required quality to fulfil the requirements assumed to apply for the initial state of the repository after closure, and which serve as supporting documentation for analyses of safety in the long term.

SKI also wishes to emphasise that licensing of a repository for spent fuel has not taken place anywhere in the world and there is no relevant experience from similar processes. It is therefore particularly important that the supporting documentation produced by SKB is sufficiently extensive and sufficiently detailed to enable the authorities to comment. SKI therefore considers that SKB needs to develop and present new planning documentation for the authorities to comment on, before SKB submits an application for a repository for spent fuel.

As regards the content and extent of applications under the Nuclear Activities Act and the Environmental Code for the repository for spent nuclear fuel, SKB refers to the report "Application plan for encapsulation plant and repository for spent nuclear fuel" (SKB, 2006). SKI considers that the purpose of the report which SKB refers to was mainly to present how applications for the encapsulation plant and the repository for spent fuel are linked to one another, and that the information compiled in the report is partly no longer relevant.

Some more concrete viewpoints linked to the plan of action are presented below.

Detailed investigations
The figure below from RD&D Programme 2004 (Figure 2) clearly shows that detailed investigations will take place during the construction stage. In the corresponding report in RD&D Programme 2007 (cf Figure 1 above), corresponding information on detailed investigations is lacking. SKI experiences that the concept of detailed investigations has been generally toned down in RD&D Programme 2007.

SKI is submitting additional points of view on management of detailed investigations in Section 4.3.

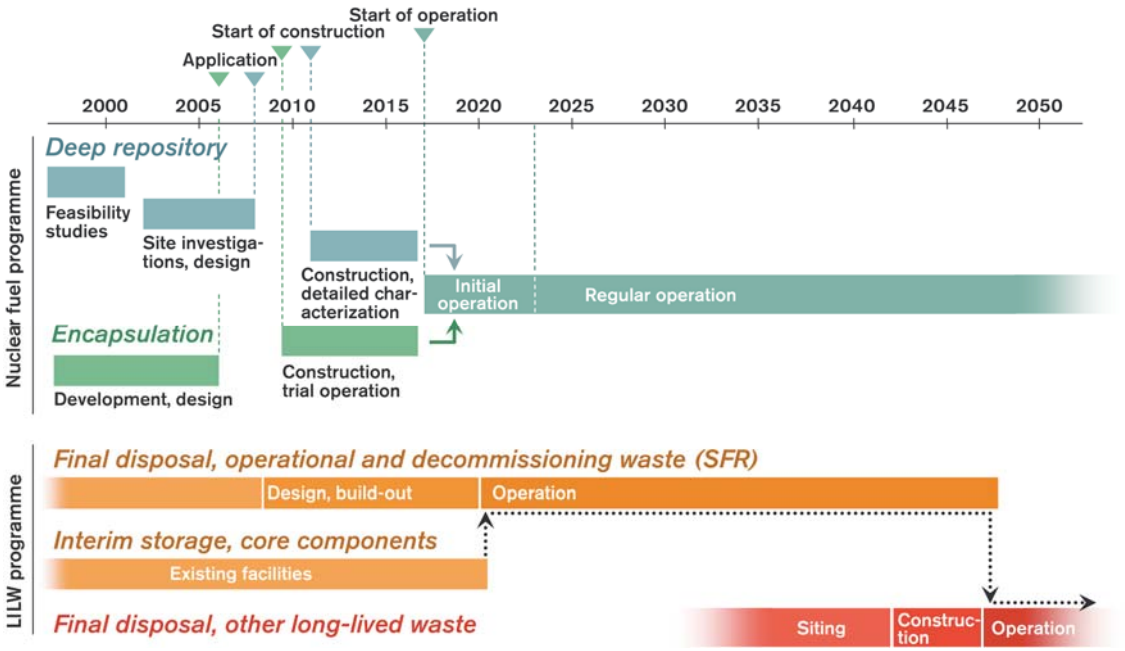


Figure 2. Presentation of overall planning in RD&D Programme 2004

The Application for the Encapsulation Plant (and Clab)
Figure 3 below has been taken from RD&D Programme 2004 and presents in schematic form plans for the extent and content of the application for the encapsulation plant, and how the application is to be linked to the application for the repository.

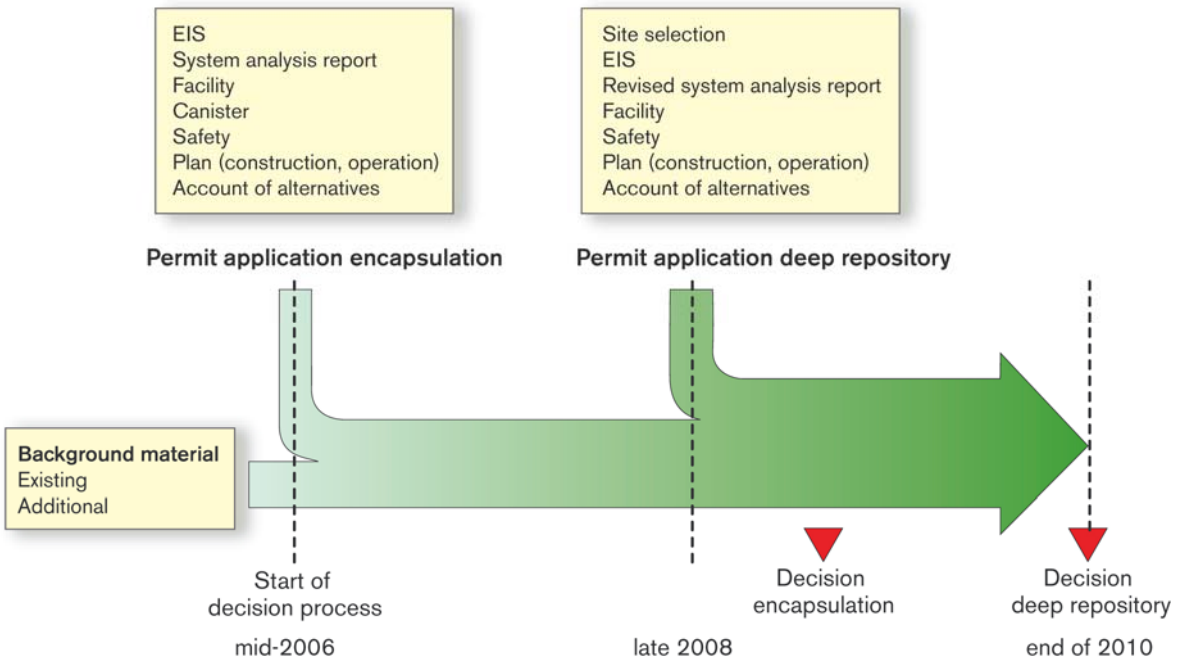


Figure 3. Arrangement for the application for the encapsulation plant in RD&D Programme 2004

As shown above, SKB planned at the time of submission of RD&D Programme 2004 that the application for the encapsulation plant should include the following:

- An environmental impact assessment (EIA) for the encapsulation plant.
- A report on alternative methods for managing spent fuel.
- An analysis of the long-term safety of encapsulated fuel in a deep repository.
- A comprehensive system analysis for encapsulation, transportation and deep disposal.

The following is noted in a comparison with the application for the encapsulation plant and Clab that SKB submitted in November 2006:

- The EIA submitted with the application is preliminary and only covers the encapsulation plant. It will be replaced by an EIA that covers the whole KBS-3 system when SKB submits applications under the Nuclear Activities Act and the Environmental Code for the repository for spent fuel.
- No report on alternative methods was included in the application.
- The analysis of the long-term safety of the encapsulated fuel in a deep repository (SR-Can) which was submitted in autumn 2006 was not included as part of the application form the encapsulation plant and Clab.
- The application did not include any comprehensive system analysis for encapsulation, transportation and deep disposal.

System Analysis Report
In the ongoing consultations on system analysis and safety assessment provided for by the Government, SKB has stated that it considers that the reporting needs which were previously planned to be taken care of in the system analysis report have changed in various respects. SKB has reasoned that the information that would have been contained in the system analysis report is contained in other parts of the application documentation. As a result, SKB considers that it is not necessary to compile a separate document with information that is already available elsewhere in the application documentation. In SKB's opinion, there is therefore no need for a comprehensive system analysis report as part of the application documentation for a future application on a repository for spent fuel.

The authorities agree with SKB's reasoning and consider that the application documentation does not need to include a freestanding system analysis report as a separate document. However, this assumes that SKB presents instructions for readers stating where the corresponding information can be found in the application documentation, which would have been reported in a comprehensive system analysis document.

Freedom of Action and Possible Change from KBS-3V to KBS -3H
SKI wishes to state that an application to construct a repository for spent fuel needs to contain sufficiently detailed specifications for the authorities and other concerned parties to be able to fully comprehend the facility design and freedom of action that they have to take a position on. SKI considers that a prerequisite for granting a licence for the activity applied for is that there is a clear link between the supporting documentation in the application and the actual intended design. In this context, SKI wishes to specially emphasise that long-term safety will probably play a crucial role in licensing and that the safety assessment therefore needs to represent the design and breadth of variation for the facility that SKB intends to build.

SKI wishes to emphasise that any changeover from KBS-3V to KBS-3H according to SKB's current planning therefore places great demands on the scope and content of the application documentation. A procedure that entails a changeover from one design to another requires that sufficiently detailed supporting documentation is available at the time of licensing (e.g. analysis of long-term safety) for the alternative designs which the application is intended to cover. This is necessary to enable the authority to make its own independent evaluation at the time of licensing of the degrees of freedom that are permissible prior to any granting of consent for the activity.

Reference Design
SKB describes in Chapter 6.2, among other things, how the concept of reference design is used in the design of the KBS-3 system and that a reference design is valid from a set point in time until decided otherwise.

Due to the formulations on reference design in Chapter 6.2, SKI wishes to state that the concept of "reference design" may have different meanings depending on the context. SKI wishes, in particular, to point out to SKB that a licence to construct a nuclear facility will be based on the reference design presented in the application, and in the preliminary safety report (PSAR) which has to be approved prior to the actual construction of the facility starts. The reference design in PSAR will accordingly

formally define the reference design for the facility. The reference design approved in PSAR will subsequently serve as the basis for a traceable management of further development in connection with continued detailed planning and design of the facility. It is therefore important that the licence application, as well as the licence conditions for an approved application, is clear about possible deviations from the reference design.

Realism in Timetables
As previously reported, SKB itself has emphasised that the Swedish nuclear fuel programme will probably be the first project of its kind in the world to be licensed. In SKI's opinion, high demands therefore have to be made on the entire procedure based on a well thought-out and well developed strategy for implementation of the project. In particular, SKI considers that the preparatory work prior to submission of the application is important. SKI wishes in this context to emphasise that it is important that sufficient time has been available for preparations to enable SKB to develop application documentation that complies with the authorities' expectations. SKI considers that a procedure that entails that timetables govern the date of submission of the application rather than quality targets may prove counterproductive. If the supporting documentation for the application is not sufficiently developed and solid with respect to its extent, degree of detail and quality, it will probably lead to a difficult and time-consuming procedure involving extensive requirements for supplementary documentation. To conclude, SKI considers that SKB should adapt its timetables to optimise the licensing process in its entirety.

Linking of Clab and the Encapsulation Plant
SKB describes a special milestone concerning the linking of Clab and the encapsulation plant.

In SKI's opinion, a special milestone for linking of the encapsulation plant does not serve any real function. SKI considers that a continuous work of change will take place on Clab to prepare successive connection, performance testing and commissioning of the joint systems of the integrated facility. SKI considers therefore that it will not be possible to distinguish any particular time for the notification of the linking of the parts of the facility.

Periodic Safety Review of Clab (and the Encapsulation Plant)
SKI notes that SKB's timetable needs to be complemented with milestones which represent periodic safety review of Clab (and the encapsulation plant), since these are reports governed by legislation and regulations.

The Need of a Clarified Planning Basis
SKI would like SKB to produce a better and more developed and detailed report of the content of future supporting documentation for a licence application for a repository for spent fuel. Details are needed, in particular with regard to the link between research findings, technology development, long-term experiments and acceptance criteria for barriers as well as such research and technology development that SKB intends to perform after submitting the application. It is particularly important to address links between different stages of the life cycle of the repository; licensing, construction, test operation, routine operation with parallel deposition and backfill of repository parts as well as successive expansion, decommissioning/backfill and closure.

SKI wishes to point out the following aspects as being particularly important for SKB's further work on production of clarified planning documentation:

- Presentation of a principle level of factors and/or events that have an impact on safety after closure (long-term safety) and reasoning on the status that different aspects of the report needs to have achieved at different stages of the licensing, design and operation phases.
- Presentation of a principle level of strategy and management for a possible change of deposition method from KBS-3V to -3H. This presentation needs to include a consequence analysis that takes into consideration relevant aspects of both long-term safety and the impact on design and operation of the repository.
- Presentation of a principle level of strategy and implementation of simultaneous deposition of copper canisters with spent fuel and continuous, stepwise, expansion of the repository.

SKI further considers that SKB in the clarifying planning documentation, should address the reasonableness of assumptions with respect to:

- the time set between submission of the application and an expected decision from the Government to permit the activity,
- the extent of time for construction of the subterranean facility until SKB plans to apply for test operation,
- flexibility and breadth in operations.

SKI proposes that SKB should produce the clarified planning documentation within the framework of the proposed consultation.

3.3 The LILW Programme

SKI comments in this section refer to Chapter 3 of SKB's RD&D Programme 2007.

SKB's Report

Analogous to the report for the nuclear fuel programme, SKB's report is based on two overall milestones for the continued development of the programme. One category refers to milestones governed by legislation and regulations, the other category is governed by SKB's internal decisions.

The initial section (Chapter 3.1) presents an overall level of planning for the three central facilities in the LILW Programme for future decommissioning of plants.

The Repository for Radioactive Operational Waste (SFR)
SKB is planning to extend SFR in two stages. The first extension, which SKB is planning to commission in 2020, is intended to create disposal space for decommissioning waste from the reactors Barsebäck 1 and Barsebäck 2, the Studsvik R2 reactor and from the possible decommissioning of the Ågesta reactor. The date for the second stage, which covers decommissioning waste from other nuclear reactors, has not been set.

The Rock Cavern for Waste (BFA)
The rock cavern, which is located on the Simpevarp peninsula in Oskarshamn, is owned and operated by OKG. The cavern is already in use for dry intermediate storage of long-lived waste from OKG which cannot be disposed of in SFR. BFA may also be used for intermediate storage of long-lived waste from other nuclear power plants provided that the safety report is updated and approved. Transportation of core components to BFA assumes that a licence is granted for use of a new transport cask (ATB-IT). It is expected to be able to start intermediate storage of core components from other nuclear power plants at the earliest at the end of 2011.

The Repository for Long-lived Low and Intermediate-Level Waste (SFL)
The last facility that will be built is the repository for long-lived low- and intermediate-level waste. No site has yet been selected for the repository and no detailed planning has yet been produced. SKB states that a more detailed account will be given on the plans for site selection, repository depth, dimensions and design of the facility in RD&D Programme 2010.

The following sections (Chapter 3.2 – 3.5) contain a slightly more detailed orientation on the milestones for the respective facility and for decommissioning in accordance with SKB's Figure 3.1 in SKB's RD&D Programme, as below:

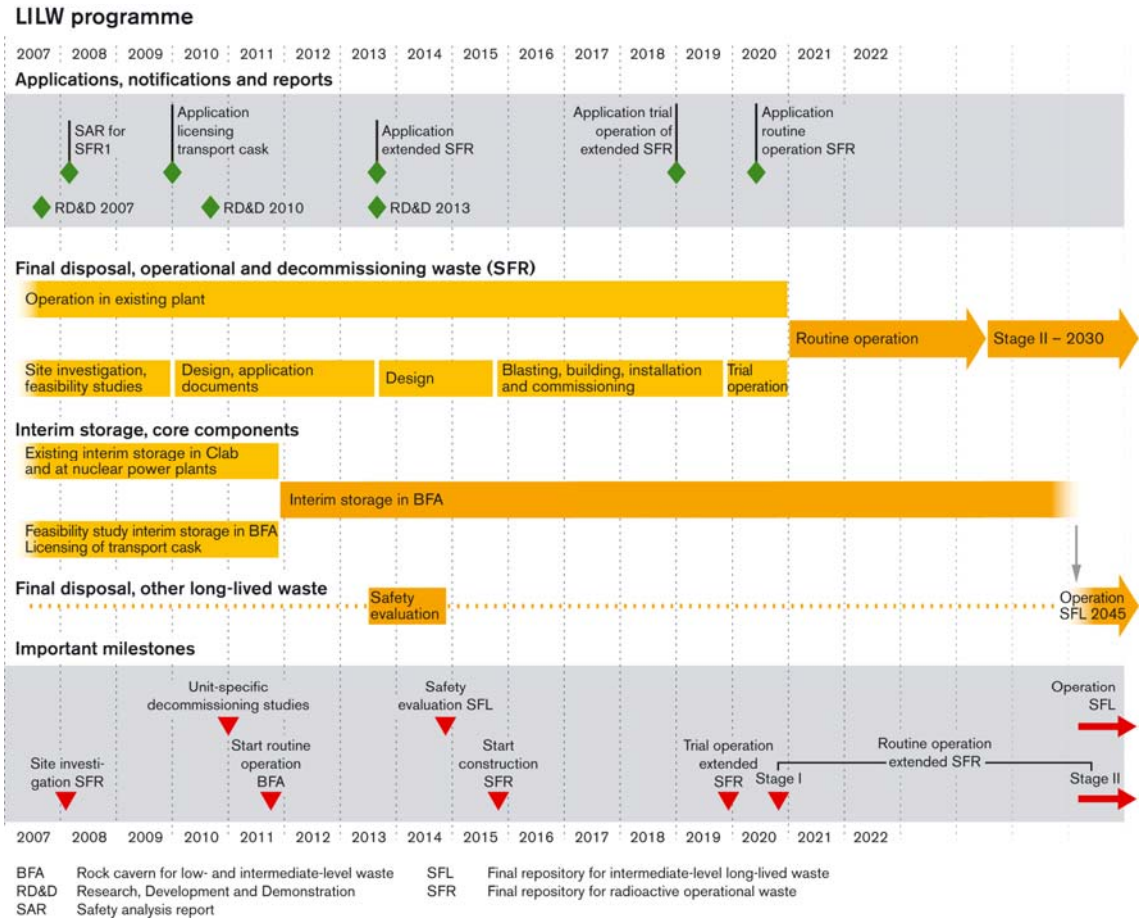


Figure 4. Overall Plan and Important Milestones in SKB's LILW Programme

Comments by the Reviewing Bodies

The comments by the reviewing bodies on the part of the plan of action concerning the LILW Programme are presented in connection with the presentation of comments on Part VI of SKB's RD&D Programme.

SKI's Evaluation

SKI considers that the plan should be complemented with milestones representing the periodic safety review of SFR, since these reports are governed by legislation and regulations.

SKI's comments otherwise on this part of the plan of action referring to the LILW Programme are presented in connection with the comments on Part VI of SKB's RD&D programme.

3.4 SKI's Overall Evaluation of the Plan of Action

Overall Comments

SKI considers that SKB's plan of action in RD&D Programme 2007 is a good and systematic description at a general level of SKB's timetables and on the mutual dependence of different parts of SKB's programme. SKI considers that the plan of action is in this way a good introduction to the other parts of the programme.

None the less, in SKI's opinion, the plan of action in its present form is far too general to serve its purpose. SKI considers that the plan in its present form does not fully serve its purpose of providing sufficiently good supporting documentation, neither in an overall strategic perspective nor as detailed planning documentation for the application to construct a repository for spent fuel which SKB – according to RD&D Programme 2007 – intends to submit at the end of 2009.

Clarified Overall Strategic Plan of Action

SKI considers that the report in the programme 2010 needs to include a clarified overall strategic plan of action which better presents SKB's strategic planning, and which contains more detailed information on the underlying logic and reasoning for the positions taken.

In the first place, the plan needs to focus on both timetables and activity plans for construction of new repositories, or expansion of existing facilities, which are needed for disposal of the nuclear waste that arises in connection with decommissioning nuclear facilities.

The plan needs to particularly address the process for relicensing and extension of the repository for radioactive operational waste (SFR) and to establish a repository for long-lived low and intermediate-level nuclear waste (SFL). The plan also needs to include an alternative strategy for storage of spent fuel in the event of the

commissioning of the repository for spent fuel being delayed and available storage space at Clab being exhausted.

Renewed Planning Documentation prior to the Application for a Repository for Spent Fuel

SKI wishes to state that future licensing has a very different character compared with previous evaluations in the sense that SKB does not only to need to "show that it is probable" that the method is feasible. SKB also needs to a great extent to be able to show that deposition and disposal of canisters of spent fuel can actually be carried out in accordance with the KBS-3 method.

SKI also wishes to emphasise that licensing of a repository for spent fuel has not yet taken place anywhere in the world and no experience is available of similar procedures. It is therefore particularly important that the supporting documentation produced by SKB is sufficiently extensive and detailed to enable the authorities to comment on it.

SKI considers that SKB needs to produce a better and more developed and detailed report of the content of future supporting documentation for an application for a repository for spent fuel. It is particularly important to address links between different stages in the life cycle of the repository; licensing, construction, test operation, routine operation with parallel deposition and backfill of storage facilities as well as successive extension, decommissioning/backfill and closure.

SKI wishes to state that the following aspects are particularly important for further work by SKB on production of clarified planning documentation:

- Presentation of factors and/or events that have an impact on safety after closure and reasoning on the status which the report must have reached at different stages.
- Presentation of a strategy for, and implementation of, a possible changeover of deposition method from KBS-3V to -3H, including a consequence analysis
- Presentation of a strategy for and implementation of simultaneous deposition activity and continuous extension of the repository.

SKI further considers that SKB should, in particular, address in the clarified planning documentation:

- The reasonableness of the present timetable with respect to the extent of time for considering the application after submission until a licence is granted
- The reasonableness of the present timetable with respect to the period of time from a licence being granted until SKB applies for test operation.
- The reasonableness in flexibility and breath of variation of planned applications.

SKI further considers that SKB should produce the clarified planning documentation within the framework of the proposed consultations with SKB.

System Analysis Report

The authorities consider that the supporting documentation for an application for a repository does not need to include a freestanding system analysis report in the form of a separate document. However, this assumes that the main document of the application contains instructions to readers with information on where the corresponding information can be found in the supporting documentation, which would have been reported in the comprehensive system analysis report document.

4 Repository for Spent Nuclear Fuel

In this chapter, SKI presents its views on SKB's presentation of Part II of RD&D Programme 2007, corresponding to Chapters 4-10 in SKB's report.

4.1 Siting Options and Site Selection

SKB's Report

After more than five years of extensive work, the site investigations at Forsmark and Oskarshamn have been largely completed. Figure 4-1 in SKB's report provides an overview of completed, ongoing and remaining major activities, and links between them during the remaining time before submitting the application. The site investigations implemented have been classified as initial site investigations (ISI) and complete site investigations (CSI). The results of the ISI are presented, for example in the form of preliminary safety evaluations for the site concerned.

Forsmark
Investigations commenced in 2002 and were largely concluded in the summer of 2007. After ISI, SKB cross-checked the state of knowledge against the suitability factors and criteria that have been established (SKB, 2000). SKB's conclusion was that the site met the requirements, thus justifying a CSI, and a programme for this was established (SKB, 2004). In the main, it has been possible to comply with the strategy, scope and focus of these investigations. Additional, major tasks in the form of rock-stress measurements are more extensive than envisaged initially. Furthermore, an additional core borehole was drilled at a late stage.

Site-descriptive modelling (SDM) has been published in accordance with plan, and the final integrated model, SDM-Site Forsmark, is expected to be completed during the spring of 2008. As regards facility design, design in the D1 stage has resulted in a preliminary layout (Figure 4-3 in the RD&D Report) for a repository facility at a depth of 400 m. In the current D2 planning stage, the design has been modified, thus increasing the repository depth to 450-500 m, for example.

The SR-Can preliminary safety assessment, which is based on ISI results and the corresponding SDM, indicates that a KBS-3 repository at Forsmark will comply with SSI's risk criterion, but that there are considerable uncertainties as regards the hydrogeological interpretation and knowledge at Forsmark. Supplementary investigations have reduced the uncertainty factors considerably.

According to SKB, there are no indications of major earthquakes (M<7) in the Forsmark area since the last glaciation period although interpretation of traces in the Oskarshamn area is more difficult.

Laxemar
ISI and CSI that commenced in early 2004 were completed during the first quarter of 2008 after a supplementary core borehole was drilled in the southern part of the area to investigate an assumed deformation zone.

The process for site-descriptive modelling, facility design and safety assessment has been implemented in the corresponding manner as at Forsmark. It is considered, however, that major changes in the layout will take place at Laxemar. The remaining uncertainties at Laxemar are also considered to be greater than the corresponding uncertainties at Forsmark due to the greater heterogeneity of the bedrock at Laxemar.

Comments by the Reviewing Bodies

The Waste Network points out that if authorities and municipalities approve disposal in the bedrock in the future, it is essential that one or two reference municipalities are selected in which two complete site investigations are carried out.

Karlstad University notes that the selection of the current candidate sites at Forsmark and Laxemar cannot be considered to fulfil the requirements of the environmental legislation as regards safety-related optimisation since none of the sites has been selected in a process in which the bedrock's hydrogeological characteristics have been allowed to determine the choice of site. In addition, two coastal sites are recommended, which in the event of leakage from a repository of the KBS type at a depth of approximately 500 m will result in a higher risk of more rapid transport of radioactive substances upwards to level close to the surface, since the groundwater close to the coastal zone's discharge areas has a high proportion of upward flows. Karlstad University assumes that the supervisory authorities will urge the Government to instruct SKB to supplement the site-selection process as regards groundwater flow patterns. An additional measure of this nature should correspond to the optimisation stipulated in SSI's instructions for geological repositories (SSI FS 2005:5).

The Nuclear Waste Secretariat (MILKAS) (Mörner) stresses that the two municipalities investigated have no natural prerequisites that are better than those at other sites. According to Mörner, other sites can be identified which have considerably better prerequisites. SKB's selection of Östhammar and Oskarshamn is based on socio-economic aspects and considerations, not the geological factors. Attention should be drawn to this in the environmental impact statement. Neither of these two sites could meet the requirements on a repository in accordance with the KBS-3 method if realistic "respect distances" were employed instead of totally unsupported respect distances of 50-100 m.

According to Mörner, Östhammar–Forsmark is traversed by a shear zone which is several kilometres wide. It was previously considered that nuclear power plants should not be located in such zones - and particularly not waste disposal facilities. The area has had a high degree of seismic activity after the most recent glaciation, with five major earthquakes that have been identified, investigated and described. According to Mörner, the most recent earthquake ("the Forsmark Event") occurred 2,900 years ago, causing a tsunami wave that was 20 m high.

The Swedish Society for Nature Conservation and The Swedish NGO Office for Nuclear Waste Review (MKG) ask whether there is enough information from the site investigations and also wonder whether the Laxemar site investigation has been carried out in an optimal manner, that is to say is there sufficient information about rocks and groundwater in the area concerned to the south and west of Laxemar. These

organisations also question the risks involved in using the Forsmark lens as repository in view of instabilities caused by tectonic movements, and whether the tectonic movements in the area have been studied.

The Swedish Society for Nature Conservation and MKG also stress that the siting of a repository for nuclear waste must be determined on the basis of the goal of finding the best combination of site and method in a long-term environmental and health perspective. Acceptance and industrial considerations have been the decisive factors in the selection of test drilling points, not safety. This is not compatible with the objectives stipulated in the legislation. The reasoning about the need to take major regional groundwater flows, the salinity of the groundwater and collective doses as a result of dilution in the sea into account is important from an environmental viewpoint.

The Opinion Group for Safe Disposal (Oss) and the Waste Network emphasise that the Government should insist on further clarification regarding the possible negative impact of rock reinforcements on long-term safety and its importance for site selection.

The Opinion Group for Safe Disposal (Oss) and the Waste Network and Karlstad University note that RD&D Programme 2007 failed to show that the current Forsmark and Laxemar sites have been selected in a scientifically determined site-selection process in which the hydrogeological characteristics of the bedrock have been allowed to influence the choice.

Furthermore, both the Oss and the Waste Network consider that not basing the site selection process on bedrock's site-specific hydrogeological characteristics and the precautionary principle in the selection process is both unscientific and in contravention of the BAT requirement and optimisation of radiation protection. Oss and the Waste Network consequently consider that the Government should require SKB to supplement its reporting of the regional groundwater problem complex to permit assessment of the relevance of this issue for site selection, and the extent to which SKB's taking of position corresponds to SSI's optimisation requirements.

In its examination of SKB's selection of locations for site investigations (in RD&D –K), Oss and the Waste Network point out that SSI indicated that further investigation of certain hydrological and hydrochemical issues was required before SKB makes it final site selection. The Government took these views into account in its decision regarding RD&D –K. SKB has not given priority to such issues in its follow-up, however. SSI was obliged to request supplementary reports in the autumn of 2004. As noted in SSI's review of the most recent SKB report in 2006, SKB has still not finally evaluated the significance of these issues. In practice, this delay has materially restricted SKB's ability to take such results into account and possibly revise its choice of sites for investigation.

Both the Municipality of Östhammar and Uppsala University note that RD&D Programme 2007 contains details of the investigations carried out regarding glacially-induced faults and fractures at Forsmark and Laxemar. They also note that the way SKB envisages future activities in this area is not clear. According to the University, neotectonic and paleoseismologically active research fields, in which it is possible to analyse, understand and date movements, are subject to continuous improvement.

This is particularly important for the interpretation of earthquake and deformation data, and may possibly be relevant for the construction and operation of the repository.

SKI's Evaluation

Forsmark
SKI and SSI have jointly reviewed SKB's preliminary safety evaluation based on ISI for both Forsmark and Laxemar (SKI, 2008). In this review, the authorities observed that the Preliminary Safety Evaluation (PSE) reports indicate that the amount of hydrogeochemical information regarding the repository depth required for future safety assessments is inadequate. The thermal characteristics of the rock must also be clarified prior to safety analysis, for example the impact of heterogeneity. A better analysis of the role played by rock stress at repository depth is required at Forsmark, where high rock stresses have been registered. Certain deficiencies in the documentation of feedback have been identified, and the balance struck between costs, time and quality has not been clearly explained. It should be noted that problems due to lack of data have largely been taken care of by SKB during CSI.

SKB should have elucidated statements that supplementary investigations have resulted in considerable reduction of the uncertainties by giving examples.

As regards the layout (Figure 4-3), SKI notes that the deposition tunnels appear to be intersected with an angle-variation of 0-25 degrees, based on known fracture orientations (and foliation). This may imply instability in the tunnel walls (wedge-shaped blocks) which SKB needs to be able to identify and characterise.

SKI also notes that the detailed geophysical surface measurements do not cover the border area west of the primary layout area and neighbouring regional structures to the south west. Information about this area may be a key factor in understanding the correlation between structures within the lens and the regional NW deformation zone. This is of importance for estimation of the way in which future rock movements may affect the stability of the lens.

Martin (2007) has found that the high rock stresses which were previously suspected have not been confirmed, and it should therefore be possible to locate the repository at a depth of 450-500 m. SKB (Ask et al, 2007) has recently published a report on hydraulic fracture methodology which suggests lower rock stresses compared with previous measurements. There are, however, other indications of the presence of high rock stresses (e.g. "core disking") at Forsmark. Since the possibility of high rock stresses cannot be eliminated, SKI considers that SKB should plan measures for implementation of the programme if it should none the less prove that the rock stresses are higher than currently assumed.

Laxemar
SKI considers that one potential problem in understanding the characteristics of the rock in the Laxemar area is its heterogeneous geology and limited information about the high-priority area to the south and the south west. As a result, SKI has some understanding of the fears expressed by the Swedish Society for Nature Conservation and MKG regarding whether there is sufficient information from the potential

repository area. There is, however, considerable information for a more extensive area surrounding the potential repository at Laxemar, and good general knowledge about the rock characteristics. As a result, it is not obvious which of the two site investigations is the most thorough and comprehensive.

In the layout presented, SKB considers that the orientation of the deposition tunnels is not critical. SKI also considers that even if the rock stresses are lower at Laxemar than at Forsmark, the tunnels should none the less be oriented parallel with the direction of the major horizontal rock stress in order to restrict rock breakout in the tunnel walls.

SSI and SKI have reported their views on the modelling studies completed by SKB in a communication addressed to SKB (SSI dnr. 2007/1562/26, SKI dnr. 2007/598) entitled "Gemensamma bedömningar från granskningen av SKB:s redovisning av storregional grundvattenmodellering för östra Småland" [Joint evaluations from the review of SKB's report on greater regional groundwater modelling for eastern Småland]. According to this communication, SSI and SKI have both independently studied SKB's latest analysis of major regional ground water flows in eastern Småland (Ericsson et al, 2006). SSI's comments are reported in Dverstorp (2007), which includes a summary assessment and two external consultancy reviews (Voss and Wörman, respectively). SKI has presented a consultancy review of SKB's report previously (Geier, 2006).

In their communication, these authorities note that SKB's R-06-64 report provides supplementary information about the hydrology issues raised by SSI and SKI in connection with SKB's selection of sites for site investigations, and subsequently in the consultations on site investigations. SSI's and SKI's reviews of the SKB's R-06-64 report are intended to provide SKB with guidance about the documentation that these authorities consider they need in order to evaluate SKB's planned application for a repository licence. The purpose of this communication is to summarise the conclusions on which SSI and SKI agree as a result of their separate reviews.

These authorities consider that SKB's study has been well prepared and that it illustrates conceivable flows in eastern Småland in a more objective and detailed manner than previous studies. The authorities also consider that the study may provide a satisfactory basis for evaluation of the impact of higher regional groundwater flows on the siting of a repository. They agree, however, that SKB should supplement some aspects of the study, and that these supplementary points should be reported in the application for the repository licence.

In order to permit the new radiation safety authority to evaluate the various stages in the siting process that have led to SKB's final choice of site, SKB must be able to show in connection with the licence application that it has investigated and taken into account all the relevant factors for the long-term operation of the repository, and report the balances struck when comparing different siting factors and other measures to improve the repository's protective capability.

4.2 Feedback from Site Investigations to the RD&D Process

SKB's Report

Looking back on the site investigations that have been carried out, SKB notes that the technology and methodology for geoscientific investigations have functioned as planned in all essential respects, although some updating and fine-tuning of the technology has taken place. The site investigations have also shown the importance of adapting the investigation methodology and technology to comply with site-specific conditions. Quality deficiencies in the measurement of borehole deviations and the orientation of structures using borehole TV (BIPS measurements) have also been discovered.

SKB also considers that the site investigations have led to a marked improvement in quality as regards the collection, processing, control and reporting of data, and transfer to databases, etc.

SKB considers that there has not been any appreciable need to develop new calculation codes for site-descriptive modelling, although some development has occurred as regards the choice of tools and the way they are used. As anticipated, it has been necessary to adapt the geological modelling to site-specific factors to some extent – soil depth for example. The methodology for thermal modelling has been updated, and this also applies to hydrogeological modelling and its integration with hydrogeochemical modelling. In later versions of models, greater emphasis is placed on achieving a harmonious geological, rock-mechanical and hydrogeological picture of the rock's fracture geometry, stress status and hydraulic properties. SKB considers, however, that there has been little or no reason to use coupled model codes.

SKI's Evaluation

SKI considers that SKB has demonstrated a service-minded approach to the supply of data to SKI's consultants. There have been some deficiencies in the data supplied, however, for example data has been adjusted by SKB as a result of certain defects in oriented data (fracture data from boreholes, BIPS), and this has delayed delivery. It also proven that some borehole geophysical data, such as resistivity, was not available for most of the Forsmark drilling points. Resistivity data is important for analysis of the position of structures in boreholes (cluster analysis).

Examples of other deficiencies in SKB's data processing:

- data does not always have the same designation in P reports as in SKB's SICADA database,
- the same data has also been encountered with different activity codes.

SKI notes that SKB has made considerable progress as regards the development of modelling strategies for rock thermal characteristics. This methodology might also be used in other disciplines, such as rock stresses and matrix diffusion.

SKI also notes that SKB has made considerable progress as regards the integration of various geological and geoscientific disciplines. It is, however, surprising that SKB has

made little use of linked model codes, in view of the fact that SKB has played an active part for many years in the international Decovalex project in the development of linked THM models. Furthermore, SKB has not considered that the development of new numerical calculation codes was necessary. This may be partly because SKB has not carried out any alternative modelling of rock and deformation zones that might call for the development of modelling tools.

As regards the use of measurement data from borehole radar SKI considers that SKB needs to evaluate the reliability of this data, since it is planned to utilise this technology to analyse the occurrence of fractures in the repository that do not permit the cutting of deposition holes.

4.3 Overall Evaluation of Site Characterisations

SKB's Report

In SKB's opinion, the investigations carried out provide the documentation required to meet the requirements stipulated before the site investigations at Forsmark and Oskarshamn commenced. SKB also considers that the decisive factors for site selection are that the basic assessments of the suitability of sites are reasonably reliable and that the documentation permits comparison of the sites.

SKB's guiding principle for the selection of sites is that the site to be chosen should permit establishment of operations with a minimum of damage and detriment. It is considered that the analysis results and reports required will be available in a preliminary form in good time prior to submission of the application.

SKI's Evaluation

SKI notes that SKB does not discuss plans for detailed investigations during the construction of the repository in RD&D Programme 2007, and this must be regarded as a deficiency. SKI has also previously pointed to the need for the preparation of a programme for detailed investigations well before the application. This is because SKI wants to have an adequate basis for assessment of what data collection is feasible during the design stage from the long-term safety perspective. The programme for detailed investigations provides a basis for assessment of whether sufficient quantities of data have been collected during the site investigation phase. SKI's international expert group Insite has also pointed to the importance of presentation by SKB of a programme for detailed investigations before site investigations are concluded.

In the course of ongoing consultations with SKI concerning the site investigation phase (previously referred to as site investigation consultations), SKB has implied that the choice of site for the repository will be announced one year before an application is submitted to the authorities, that is to say during 2009. SKI wants to stress the importance of a clear indication by SKB of the methodology and the criteria that will be applied, and which will hence determine the choice. This applies, in particular, if the supporting documentation for the choice is not fully comparable. SKI also considers that a site that has been eliminated needs to be reported in a manner that permits the

new authority to draw its own independent conclusions when comparing with a site that has been selected.

SKI notes that Forsmark is located in the Bergslagen region, which is a metalliferous province. SKI has previously stressed the need for a geophysical simulation to clarify possible differences between the geophysical response of a repository with copper canisters at a selected repository depth compared with an ore body at the corresponding depth. SKI notes that there is still no study of this nature.

4.4 Basis for Construction and Operation

SKB's Report

SKB assumes that there is no need to present a final choice of technology for industrial use in connection with the repository application. The basic requirement should, instead, be that technology solutions must be presented so that it is clear that they comply with the requirements stipulated and the design premises, and indicating that implementation is feasible. SKB also assumes that the actual licensing process will take at least two years.

Comments by the Reviewing Bodies

SSI considers that SKB needs to demonstrate that all stages in the disposal process can be handled in a single sequence (dress rehearsal) prior to commissioning of the repository. Consequently, further development of the final plans for demonstration and verification of the disposal sequence are required, prior to the licence application.

SKI's Evaluation

SKI considers that it will not be necessary to present a final choice of technology for industrial use when the application is submitted in 2010. It is, however, essential that SKB presents the technology progress achieved in connection with the application, and justifies the technology chosen, based on a BAT perspective. In addition, SKB should indicate a realistic timetable for when fully developed industrial methods for construction of the repository can be presented to the licensing authority.

As regards the time point for licensing, SKI considers that SKB's assumptions must be regarded as optimistic. SKI and SSI both estimate that more time will be required for review of SKB's application.

In the case of detailed comments concerning the status of the technology components for the geosphere and engineered barriers (Tables 5-1 to 5-4 in SKB's report), reference is made to the comments (Chapter 5 of this statement) for the respective production line (rock line, buffer line, fuel line, canister line, backfill line, closure line).

4.5 Work Methodology during Construction and Operation

SKB's Report

SKB describes the work methodology it intends to employ during construction and operation of the repository in a total of seven section headings, starting with a description of the various facility parts, both below and on the surface, including the ramp and shafts that link these parts. The reference design presented corresponds to that presented in the D1 design stage in the design work.

SKB presents a few key concepts for its work methodology in Section 6.2. As regards planning, dimensioning and control of rock facilities, the CEN European nominations committee has established the EN-1997-1 standard in Eurocode 7 as recently as August 2007. SKB is currently employing a design methodology largely based on a step-by-step augmentation of the level of detail, and adaptation to site conditions at Forsmark and Laxemar.

In Section 6.3.2, under the heading "Utgångspunkter för arbetsmetodik under uppförande och drift" [Basis for work methodology during construction and operation], SKB states that data from excavation of rock must be rapidly and effectively fed back to planning, and that this calls for efficient cooperation and interaction between rock operations, investigations, modelling, planning and safety assessment.

In Section 6.5, which covers the main processes and key sub-processes, SKB presents the two principal main processes: 1) Construction and operation and 2) Safety assessment and site modelling. SKB states that the main processes, in their turn, have been divided into a number of sub-processes which are reported under the Construction and operation main process heading, but not for Safety assessment and site modelling.

In Section 6.6, which covers quality control, SKB describes how it intends to comply with safety requirements in an annex to the application in accordance with the Nuclear Activities Act for CLAB and the encapsulation plant, as regards organisation, management and control of operations. SKB intends to provide a corresponding presentation of safety requirements in connection with the application for a repository licence.

In Section 6.7 of RD&D Programme 2007, SKB provides a brief account of its participation in the IAEA's international efforts to define the requirements for safeguards for a geological repository and its cooperation with Posiva in Finland, particularly as regards control of the rock caverns currently being blasted in the rock facility for Onkalo. SKB also mentions that an effective safeguard system applies a holistic approach to the entire fuel-management chain, from the fuel factory up to and including the disposal of spent nuclear fuel, in which for example the canister constitutes a reporting unit.

Comments by the Reviewing Bodies

The Swedish Society for Nature Conservation and The Swedish NGO Office for Nuclear Waste Review (MKG) note that the risk of the proliferation of nuclear weapons in the long term is not covered in the RD&D report. So-called "safeguards" to prevent

nuclear materials falling into the wrong hands during operation of the repository are discussed in Section 6.7, but there is no plan to ensure that there is information regarding how the repository is to be protected after closure.

The Municipality of Oskarshamn considers that it is important that the forms for the monitoring/control of possible leakage of radioactive substances from the repository are analysed in good time, prior to the application. This also applies during the deposition phase as well as after closure. Long-term monitoring possibilities should be developed and should be subject to consultation with the local population.

The municipality also considers that documentation for the repository is highly important, both in the long term and the short term. Through the Misterhult Group, the local population has evinced an interest in participating in discussions on documentation/marking in a long-term perspective.

Uppsala University points out that the Swedish and Finnish repositories will constitute new features in the fuel cycle, and issues involving various aspects of safeguards call for further clarification, for example:

- The safeguards system is based on the "accountancy" concept, which means among other things that a certain quantity of nuclear materials entering a facility must be balanced by materials leaving the facility or which, in a *verifiable* manner, is stored in the facility. The repository does not permit this, and the way in which the facility is to be conceptually incorporated into the safeguards system is still an open question which probably calls for investigation.
- "Continuity of knowledge" is referred to as a basis for safeguards implementation in the encapsulation plant and the repository. This approach would appear to be correct, but the technology assumes that the encapsulated material has first been verified, using satisfactory methods. How this is to be achieved is also an open question, and it may therefore be anticipated that initiation of a research and development programme will be required to indicate lines of development for such methods. The IAEA's general criterion that the "best possible" verification technology should be employed at any given point in time should be mentioned in this context. As a result, a research and development programme should also address the question of how to deal with a situation in which "better" technology is gradually introduced when fuel that has already been verified has been placed in the repository.

SKI's Evaluation

SKI notes that, notwithstanding an outline description of the basic principles for the design of rock facilities in accordance with the new CEN standard, it is not possible to see which of the methods recommended which SKB will employ for the various underground caverns. Furthermore, SKB does not indicate how the site engineering report will be adapted to comply with Eurocode 7. None the less, SKI shares SKB's opinion that large parts of the repository can be designed using conventional design and planning methodologies, and taking into account the relevant CEN standards. This applies in particular to the infrastructure and buildings above ground. These standards

are, however, not specifically designed for a nuclear facility and its special requirements concerning both short-term and long-term safety.

During the design process in layout stage D2, SKB has commenced preparation of a site engineering report with a draft outline. However, SKB does not clearly state how it intends to use this description in its methods of work during construction and operation, and how this description differs from the geotechnical descriptions stipulated in Eurocode 7. This point must be clarified in the future application.

The final point under heading 6.3.2 in the RD&D report provides an example of a too general, overall wording which SKB frequently employs in Chapter 6. The example given here concerning working methods should have been followed by an organisational chart in which SKB indicates how rapid and efficient cooperation, interaction and feedback of the various activities can be achieved by applying a proposal for a good project organisation.

As regards Section 6.5, the question may be raised of whether SKB intends to continue to employ the same discipline-specific classification of the site modelling process (geology, rock mechanics, hydrogeology, etc.) which SKB used during the site investigations, or whether it will opt for some other classification and scope. In Figure 6-4, SKB illustrates the main processes and key sub-processes for construction and operation. The interaction between the main processes is indicated by the words: control – information – feedback. This is a further example of excessively generalised indications of the way the interaction process and the organisation are to function between the main processes. In addition, the contents of Figure 6-5 fail to clarify information flows between the main processes.

Section 6.5.2 and the contents of Figure 6-6 explain the key sub-processes for construction of the facility. On the whole, this provides a sufficiently detailed and satisfactory account of the sub-processes during construction and operation of the facility. The section that covers assessment of the facility's and the operation's safety, site-modelling and safety assessment, and also safety evaluation – long-term safety, are all crucial aspects of the working methods SKB has selected for construction and operation. The process SKB has selected provides a guarantee that more extensive analyses of safety will be carried out if the rock structure or characteristics differ from the circumstances that will be presented in the SR-Site safety assessment.

During construction and operation of the facility, the organisation and management system must be designed in the light of the requirements for the construction and operation of nuclear facilities. In addition, methods of working must comply with the special conditions that apply for the design and construction of subterranean facilities. SKB also emphasises these tough requirements for adjustment, organisation and management of the project in its RD&D programme.

Section 6.6 on quality control would have carried more weight if SKB had outlined the way it intends to organise, control and manage operations during the initial stages of design and operation of the repository.

In the course of SKI's review of the extension of Clab, stage 2, an opportunity was provided to apply the authorities' review and instructions in connection with the extension of an underground nuclear facility. After blasting of the rock cavern, SKB also carried out a special project designed to gain experience of underground working and nuclear design work which may be beneficial in the design and construction of the repository. There is no mention of this transfer of know-how in this RD&D programme. Today, SKB probably has good reason to reactivate experience of this know-how transfer from the extension of Clab, stage 2 and take advantage of this in connection with the repository project.

SKI notes that safeguards for the repository are reported in Section 6.7. SKB should be aware that the safeguard aspect needs to be integrated into several areas of SKB's programme, with the examples indicated below.

SKI notes that according to Section 1.2, SKB's assignment also includes ensuring that nuclear materials for which SKB is responsible are not used for the proliferation of nuclear weapons. In other words, SKB is responsible for adequate control of nuclear materials from a non-proliferation viewpoint.

In Section 1.4.1 of the chapter on the strategic choice of method, it should also be stated that geological disposal is a way of ensuring that nuclear materials are less accessible for future applications, such as in the event of the threat with nuclear weapons.

When describing the encapsulation plant and the repository in Section 1.4.4, it should be mentioned that these facilities should be designed so as to ensure that the flow of nuclear material can be controlled from a non-proliferation perspective. In the paragraph on various types of radioactive waste in Section 1.5, SKB mentions that the presence of fissionable materials means that measures are required to prevent the fuel falling into the wrong hands. SKB should have briefly indicated in this context what steps are planned to deal with this, for example physical protections, safeguards, etc.

Under the milestones heading in Section 2.2, there should also be a reference to notifications to the European Commission, followed by the Commission's and the IAEA's monitoring of the construction of the facilities. Approval by the European Commission in accordance with Euratom regulation 302/2005 should also be included under the decision by authorities heading in Section 5.2.2.

In Section 6.7, SKB states that safeguards refer to measures to prevent nuclear materials falling into the wrong hands although SKB does not indicate in detail the scope of the manner in which safeguards will be organised. It should be mentioned that safeguard measures include description of facilities from a safeguard perspective, stockkeeping and reporting of nuclear materials, inventory registers, the use of security cameras and seals, etc. SKB should have outlined the way in which such measures can be implemented in the various stages from the Clab interim storage facility to the closed repository.

SKI notes that STUK, the Finnish Radiation and Nuclear Safety Authority, and Posiva, which corresponds to SKB, have devoted considerable efforts in recent years to safeguards, with a focus on repository aspects. In the period prior to submission of the

application, SKB should increase its efforts to meet the requirements in the safeguards area that will be made at both the national and the international levels.

4.6 Main phases: licensing, construction, commissioning and operation

SKB's Report

Under the main phase licensing, SKB states (Table 7-1) that the reference method for rock excavation in deposition tunnels is to be determined prior to commencement of construction. In Section 8.2.5, under the heading of rock engineering, SKB states that the technology for excavating deposition tunnels and boring deposition holes, including verification of the criteria for these operations, is to be tested and fine-tuned as soon as possible.

Under the operation main phase (Figure 10-2) SKB states that it should be possible to undertake the deposition of canisters and rock works independently, and in parallel in another section of the deposition area. An alternative proposal for working in stages was presented by SKB at a meeting of experts in December 2007. In principle, this means that rock works and deposition are performed in the same main tunnel in which operations on each side of the tunnel are separated by a temporary partition wall.

In Sections 10.2.3 och 10.2.4 under the Transport and receiving inspection and Physical protection headings, respectively, SKB briefly describes the operations covered by transportation and physical protection.

Comments by the Reviewing Bodies

The Swedish Defence Research Agency (FOI) notes that SKB has not reacted to FOI's review comment on RD&D Programme 2004 as regards the need to minimise the risk that plutonium may be lost during the transportation phase. FOI advocates that the encapsulation plant and the repository should be jointly located and linked by a transport tunnel.

SKI's Evaluation

SKI's views concerning the choice of reference method for rock excavation in deposition tunnels are presented in Section 5.1 in this report under the Rock Line heading.

As regards SKB's alternative proposal (meeting of experts in December 2007) that rock engineering and deposition are to be based on the same main tunnel, SKI wonders whether this is feasible in terms of logistics and whether this is possible in the light of future requirements for repository safeguards. SKB should analyse the problems that would occur in the event of simultaneous rock works and deposition (see Figure 10-2).

Under the Operation heading in Section 7.2, SKI mentions that the European Commission and the IAEA should be informed at an early stage of the preparatory

work. Finnish experience in connection with the construction of Onkalo must be taken into account.

Under the Main phase: Operation heading in Chapter 10, according to SKI there should be a rough outline of the form nuclear materials controls might take. For example, what are the appropriate points for verification of canisters received, is there a suitable location for monitoring reception, can the repository be regarded as a "black box", etc ?

In its comments on RD&D Programme 2004, SKI indicated that SKB should adopt a more ambitious approach in the physical protection area, thus supporting FOI's review comments, particularly as regards the need to specify equipment, technology and tactics for monitoring the fuel in a transportation context. SKB has not yet presented any new information in this context. Section 10.2.4 should also have clearly indicated that SKIFS 2005:1 applies for the encapsulation plant and that this will be a category 2 facility, with the requirements that this entails.

Under the Operation and maintenance of technical systems heading in Section 10.2.6, mention should also be made of the installation and maintenance of any monitoring equipment for control of nuclear materials and physical protection.

4.7 SKI's Overall Evaluation of the Repository

Siting options and site selection

As regards the repository depth decision at Forsmark, Martin (2007) has found that the suspected high rock stresses could not be confirmed, and therefore it appears to be possible to locate the repository at a greater depth (450-500 m) than previously stated (400 m). However, there still appear to be some indications of the existence of high rock stresses (e.g."core disking") at Forsmark. As a result, SKI considers that SKB should carry out a risk analysis and plan steps for implementation of the programme if the rock stresses none the less prove to be greater than those currently assumed.

SKI considers that one potential problem in the Laxemar area is now the limited availability of information about the high-priority southern and south western area. As a result, SKI has some understanding of the fears of the Swedish Society for Nature Conservation and The Swedish NGO Office for Nuclear Waste Review (MKG) that there is currently insufficient information from the site investigations at Laxemar. However, there is considerable information and a broadly satisfactory level of knowledge about rock characteristics in a wider area around the potential repository at Laxemar. Hence, it is not obvious which of the two site investigations has been the most thorough.

In the layouts presented, SKB considers that the deposition tunnels at Laxemar can be oriented arbitrarily. Although the rock stresses are lower at Laxemar than at Forsmark, in SKI's opinion SKB should orient the tunnels in parallel with the direction of the major horizontal rock stresses in order to restrict rock breakout in the tunnel walls.

In order to permit the new Radiation Protection Authority to evaluate the various stages in the siting process that led to SKB's final site selection, SKB must be able to show, in the context of the permit application, that it has investigated and taken into account all the relevant factors for the long-term functioning of the repository. SKB also needs to present the considerations that have been taken into account when balancing siting factors and other measures to improve the protective capability of the repository.

Feedback from the site investigations to the RD&D process
SKI notes that SKB has now made relatively significant progress as regards the integration of various geological and geoscientific disciplines. It is, however, surprising that it has not been considered necessary to employ linked model codes and that alternative models for rock and deformation zones have not played a greater part in SKB's programme.

SKI considers that SKB needs to evaluate the reliability of measure data from borehole radar since this technology is to be used to analyse the presence of fractures in the repository that are not permitted to intersect deposition holes.

Overall evaluation of site selection
SKI notes that there is no discussion in SKB's presentation in RD&D Programme 2007 of plans for detailed investigations during construction of the repository facility, although there should have been some discussion of this nature. The reason for this comment is that SKI wants to have an adequate basis for assessment of what information gathering activities are feasible during the design phase from the long-term safety viewpoint.

In the course of its ongoing consultation with SKI on the nuclear fuel project (previously referred to as site investigation consultation), SKB has implied that the choice of site for the repository will be announced approximately one year before the application is submitted to the authorities (i.e. during 2009). SKI considers that SKB clearly needs to state what methodology and what criteria will be employed in selection of the site.

Basic assumptions for construction and operation
SKI considers that fully complete choice of technology for industrial use does not need to be settled when the application is submitted during 2010. It is, however, essential that SKB presents the level of technology development achieved in its application and, based on best available technology (BAT) perspective, explain the technology selected. Furthermore, SKB needs to specify a realistic timetable for when fully developed industrial methods for construction of the repository can be presented to the licensing authority.

As regards the time required for licensing, both SKI and SSI consider that more time will be required for the processing of SKB's application than envisaged in SKB's timetable.

Working methods during construction and operation
During the extension and operation of the facility, organisation structures and management system must take shape, taking into account the requirements that apply for the construction and operation of nuclear facilities. Furthermore, methods of work must be adapted to the special conditions that apply for the design and construction of underground facilities. These stringent requirements for adaptation, organisation and management of the project are also stressed by SKB in the RD&D programme.

Safeguards
SKI notes that safeguards for the repository are reported in Section 6.7. SKB should be aware that the safeguard aspect needs to be integrated into several features of SKB's programme. Reference should have been made to the safeguard aspect in several sections in Chapter 1, and also in Chapters 2 and 5.

In Section 6.7, SKB claims that safeguards cover measures to prevent nuclear materials from falling into the wrong hands, although SKB does not indicate in detail the scope of the manner in which safeguards will be organised. It should be mentioned that safeguard measures include description of facilities from a safeguard perspective, stockkeeping and reporting of nuclear materials, inventory registers, the use of security cameras and seals, etc. SKB should have outlined the way in which such measures can be implemented in the various stages from the Clab interim storage facility to the closed repository.

Main phases: licensing, construction, commissioning and operation
As regards SKB's alternative proposal (meeting of experts in December 2007) that rock works and deposition are to be performed in the same main tunnel, SKI wonders whether this is feasible in terms of logistics and whether this is possible in the light of future requirements for repository safeguards. SKB should analyse the problems that would occur in the event of simultaneous rock engineering and deposition

Under the Main phase: Operation heading, according to SKI there should be a rough outline of the form nuclear materials inspections might take. Questions that SKB needs to consider might be: what are the appropriate points for verification of canisters received, is there a suitable location for monitoring reception at the repository, can the repository be regarded as a "black box", etc.?

5 Technology Developments in the Nuclear Fuel Programme

In this chapter SKI reports its views on SKB's presentation of Part III of RD&D Programme 2007. SKI comments on the corresponding Chapters 12-18 in RD&D Programme 2007 under the sub-headings rock line, buffer line, canister line, backfill line, closure line, retrieval and alternative repository design – KBS-3H.

SKB has introduced the production lines concept in this chapter. This describes the production flow for the various parts of the KBS-3 system. According to SKB, the idea is to facilitate an overview of the increasingly extensive documentation. SKB has decided to employ four colours – grey, green, yellow/orange and red - to depict the various production lines in order to assist assessment of technology development. Grey indicates current known and proven applications, green indicates known and proven technology, which can be applied, yellow/orange shows known and proven technology that can be employed after testing, while red indicates technology that is not familiar or for which there is insufficient experience in the utilisation envisaged.

Comments by the Reviewing Bodies

The Municipality of Oskarshamn notes that SKB presents requirements in the area of technology development needed for the construction of a geological repository in terms of various lines (production lines in SKB's terminology): rock line, buffer line, canister line, backfill line, closure line, retrieval and alternative repository design – KBS-3H. This is a well-structured approach. It is particularly interesting to note that SKB indicates what the company considers to be most important in the short term for each line in Part III of the report, where the red rectangles in the sections that touch the various lines depict the questions which SKB considers must be answered in 2009.

However, the municipality does not have a clear picture of how much research and full-scale experimentation is still to be completed when the licence application is submitted to the Environmental Court and regulatory authorities in 2009. Backfill of deposition and other tunnels has not yet been tested on a full-scale basis. Technology development is focused on the development of methods and equipment for concepts employing naturally-swelling clay. There is limited time available for full-scale experiments for which results can be presented in the future application. The programme for canister requirements includes testing until 2013. The authorities will be reviewing many of these results in connection with the application for trial operation, scheduled for about 2018, while the municipalities only have a single opportunity to influence the decision in a decisive manner. The municipality would like to receive information from the authorities as regards which tests and results are called for if the licence application in 2009 is to be regarded as complete.

The views of the County Administrative Board in the County of Kalmar broadly correspond to those expressed by the Municipality of Oskarshamn as regards the production lines. The County Administrative Board also points out that there are several questions concerning the buffer line that need to be answered. Furthermore, the County Administrative Board considers that the question of the way in which the buffer

materials are to be protected from water in the rock must be solved and tested under realistic conditions before licence applications are submitted.

SSI considers that SKB needs to demonstrate, prior to the licence application, that there are probably no remaining practical issues of a fundamental nature concerning the possibility of constructing and operating a repository system of the KBS-3 type. There are still a number of problems and unclear factors associated with the installation of canisters, the buffer, backfill, and plugs in the repository. In this context, SSI considers that the problem of confirming the installation of the clay barriers may be the most difficult to handle and the most critical aspect of the KBS 3-method. Clay may be eroded from the buffer and backfill during the installation phase, for example, and this may mean that the requirements specified for the barriers cannot be met. It is considered that these problems may be affected to a considerable extent by on-site hydrological factors at the site selected for a repository. Accordingly, SKB needs to demonstrate, prior to the licence application, (not necessarily on a full-scale) that it can manage the buffer, backfill and installation of plugs in the light of the range of primarily hydrological and geochemical factors which may be expected to apply at the site selected.

SSI has no objections to the principal development and verification of methods for deposition at the Äspö Hard Rock Laboratory, providing that the components, methods and routines employed are those that SKB subsequently intends to use for actual operation.

As regards long-term testing, SSI stresses that previous expressions of opinion concerning SKB's RD & D reports have indicated the need for cohesive discussion of the need for long-term tests. SSI has previously questioned SKB's plans for terminating the tests at Äspö when regular operation of the repository commences. SSI considered that SKB needed to explain this decision more clearly and, in addition, investigate the possibility of further long-term tests for a period of operation extending over several decades in the actual repository selected.

SSI also notes that SKB is considering some form of additional Prototype repository, but fails to indicate any details or analysis of needs. The plans for the Äspö Hard Core Laboratory are vague ("...the laboratory is to be in operation for many years to come"), and the question of long-term testing is not addressed.

In view of the remaining questions regarding the buffer and backfill functions, SSI considers that SKB should have presented an analysis of the adequacy of ongoing testing. SSI considers that SKB needs to explain which tests are required, what is the intended purpose of the various tests, and prepare plans for their implementation.

5.1 The Rock Line

In this section, SKI presents its views on Chapter 12 – Rock line in RD&D Programme 2007.

SKB notes that two major issues appear to present a particular challenge in the rock-line development work (marked red in the boxes): grouting at great depth and in-situ determination of the excavation-disturbed zone's hydraulic characteristics.

SKB's Report

SKB mentions that the formation of a more or less excavation-disturbed around tunnels and rock caverns in connection with rock excavation is a well-known phenomenon. It is considered that knowledge is available about how to limit the extent of this zone, but there is insufficient knowledge about how the hydraulic properties are affected if the extent of disturbance changes. SKB considers that the excavation-disturbed zone can be minimised by careful and controlled technology for drilling and blasting. In order to avoid an excavation-disturbed zone on the floor of the deposition tunnel, SKB introduces the alternative of wire-sawing of the bottom of the tunnel, which would also facilitate the emplacement of the pre-compacted bentonite blocks.

When submitting the repository application, SKB shall have a reference method for the drilling and blasting of deposition tunnels. Furthermore, SKB only intends to study technologies for drilling and blasting, and does not intend to study TBM drilling for rock excavation for deposition tunnels in the current D2 design stage.

Comments by the Reviewing Bodies

Luleå University of Technology considers that the proposed RD&D programme should include studies of the interaction between rock and reinforcement systems and the reinforcement elements. The University of Technology considers that this deficiency is remarkable since the loads to which rock reinforcements are subject are generated by rock movements and the rock reinforcement reaction to this. Furthermore, the University considers that rock reinforcements should be designed to cope with dynamic loads.

Milkas (Pettersson) points out that drilled deposition tunnels result in a very limited disturbed zone. SKB has clearly abandoned this superior method. The introduction of chemical substances such as reinforcement steel alloys, concrete, cement and synthetic sealing materials is envisaged. There is no analysis of the implications for safety in the short and long term. There is no information regarding borehole tolerances for the deposition holes or permissible minimum and maximum flows of water. There are no criteria for holes that are not approved and what action is to be taken about a rejected hole.

As regards of Chapter 12.4 in the RD&D Programme – Sealing by grouting the Opinion Group for Safe Disposal and the Waste Network point out that it is still the case that research designed to develop a more long-term grouting material does not form part of the SKB programme, and that this also applies to determination of the long-term properties of the materials envisaged in this connection.

The Swedish Research Council considers that in-depth knowledge concerning grouting materials is highly relevant and that more information is required concerning the long-stability of such materials.

SKI's Evaluation

SKI considers that the research initiatives planned in the grouting area are important (see further comments on Section 5.1.2 in this report). There are no boxes in Figure 12-1 depicting the need for subsequent grouting and rock reinforcement in tunnels, and this also applies to grouting in deposition tunnels at some stage in the unit's operations.

SKI agrees with SKB's view that not enough is known about the extent of the disturbed zone (EDZ), and methods of controlling and measuring it. Consequently, SKI supports SKB's plans to prepare and implement large-scale measurement tests of EDZ around a blasted tunnel under realistic rock engineering and hydrogeological conditions, and also plans for the appointment of a specialist group at SKB for tunnelling and grouting. This complies well with SKI's view concerning what appear to be major problems in the construction of a repository (see also comments in 5.1.3).

5.1.1 Investigation and Characterisation

SKB's Report

Under this heading, SKB presents 11 different areas for investigation and characterisation of rock for which it intends to develop instruments and methods. These areas are: stabilisation of boreholes, laser scanning, geophysical borehole instruments, rock mechanics measurements, measurement of thermal properties of the rock, hydraulic test equipment (single-hole tests), measurement of water flows in ramp and tunnels, measurement of inflows to deposition holes, determination of sorption parameters, determination of pH and redox conditions, and information systems and information technology.

SKB plans to develop hydraulic test equipment, which is quick to set up and functional for measurements in long investigation holes and probe holes.

SKB is planning a project for the development and selection of methodologies and methods for investigations and measurements in deposition tunnels and holes. This project will involve qualitative and quantitative surveying of positions and flows in borehole walls and the determination of transmissivities with the aid of hydraulic tests.

Comments by the Reviewing Bodies

The Chalmers University of Technology (CTH) considers that it is positive that SKB emphasises the difficulties of transforming laboratory Kd values and ion-exchange capacities into in-situ parameters. Furthermore, CTH regards SKB's programme as relevant for a better understanding of this problem.

Uppsala University (UU) points out that there is no clear commitment for seismic monitoring of the repository. Although such long-term monitoring is mentioned in Chapter 8.2.2, there is no further discussion. If it is to achieve the desired effect, monitoring must commence in sufficient time before commencement of construction operations at the repository site selected. Instruments should be placed in boreholes for specific purposes, but possibly also on the surface and inside the facility, in order to observe occurrences in various spatial and magnitude scales. Mention is made of

geophysical borehole measurements in Chapter 12.3, but not seismic measurements. UU also considers that microseismic observations are of considerable importance in identification of the formation of fractures, hydraulic fracturing and stress redistributions.

SKI's Evaluation

SKI considers that the methods proposed for stabilisation of investigation boreholes are relevant. The methods proposed for the surveying of both tunnels and boreholes in the form of laser scanning and geophysical borehole instruments are both fully justified and, in certain cases, essential. In recent years, there has been development of laser instruments for the surveying and characterisation of rock caverns, and these new developments are, in the main, tested for full application now in SKB's underground operations. As regards rock-engineering measurements, the description in the RD&D programme is limited to an explanation of the decision not to pursue further development of methods for measuring rock stresses from the ground surface. In the section on rock-engineering measurements, there is no information concerning methods and instruments for determining the structural strength of the rock mass and deformation zones, and deformation properties.

SKB has performed admirable work on determinations of the rock and the rock mass's thermal characteristics in connection with the site investigations. At a late stage in the site investigations, SKB presented an interesting method for the characterisation of the rock mass and its thermal conductivity based on density and other parameters. SKB is encouraged to continue this promising development process and to consider extending this methodology for applications in disciplines other that geothermal technology – for example linked to rock diffusion characteristics and rock mechanics.

SKI considers that SKB should clarify the way in which requirements for effectiveness of hydraulic tests are related to opportunities to carry out transient measurements that can be employed to evaluate flow dimensions and boundary effects.

SKI considers that SKB's development of investigation and measurements methods in deposition tunnels and deposition holes is good, since the selection and characterisation of deposition positions is relevant for the initial status of the safety assessment. SKI also considers that it is desirable for SKB to carry out full-scale tests of methods to ensure that effective implementation during the design phase is feasible. There is no mention in SKB's report of measurements in deposition pilot holes. SKI considers that SKB should clarify the manner in which these measurements are to be handled.

In the main, SKI agrees with Uppsala University that SKB needs to adopt a cohesive approach to a programme for seismic monitoring of the repository.

5.1.2 Sealing by Grouting

SKB's Report

The rock needs to be sealed by grouting in order to restrict the inflow of water to the repository and the upward pressure of the underlying salt ground water. Inflows at any point and cumulative flows must also be limited since they may cause erosion of the

buffer and backfill. The requirements for the long-term functioning of the repository lead to certain restrictions as regards the grouting material, for example the pH value for leachate from the grout and the additives used. SKB's requirements for leakage into deposition tunnels are specified at 1 l/min.

Suitable grout for a repository facility has been investigated in cooperation between SKB, Posiva and Numo. As a result, SKB has initiated a development process at the Äspö Hard Rock Laboratory that aims to determine whether silica sol with a low pH (<11) is a suitable material for the grouting of fine fractures (<0.1 mm) at the repository depth. The aim is to seal larger fractures with a cement-based grout. Experience of the grouting of major waterbearing zones in the Äspö Hard Rock Laboratory is to be collated.

Comments by the Reviewing Bodies

The Opinion Group for Safe Disposal (Oss) and the Waste Network note that RD&D Programme 2007 indicates that the SKB programme does not yet cover research designed to develop a more durable, long-term grout. SKB claims, without any acceptable justification, that the KBS-3 system does not require any long-term sealing measures. This appears to be that since there does not appear to be any possibility of achieving a durable restriction of water leakage in the rock material, this problem is to be solved in the simplest manner by declaring that it is totally unnecessary.

The Opinion Group for Safe Disposal (Oss) and the Waste Network also note that, in the event of rock reinforcement, SKB plans to use a low-pH concrete which, according to the programme, is at the experimental stage. The final recipe is clearly an open question. Oss and the Waste Network consider that SKB must indicate which research results are cited if it claims that it does not need to specify a lower pH threshold than that stated in order to eliminate the degrading negative effects of the concrete on the bentonite buffer and the backfill.

Oss and the Waste Network consider that another question that requires clarification is the extent to which steel and iron will constitute or be included in reinforcement and sealing elements in view of the corrosion, gas formation and impact on the physical and chemical characteristics of bentonite. These organisations' interpretation is that there will be both sufficient iron and concrete in the repository after closure to create numerous problems concerning degradation of the bentonite buffer and backfill materials while, at the same time contributing to an environment conducive to the development of bacteria flora that may result in rapid corrosion of the copper canisters.

SKI's Evaluation

SKI notes that SKB is now presenting plans, methods and programmes for the continued studies called for by SKI in its review of previous RD&D programmes. SKI notes that SKB intends to restrict leakage into deposition tunnels to 1 l/min, although there is no limit in this context for leakage into deposition holes (specified in SR-Can).

SKI also notes that there is still no low-pH mixture of cement specified. The presence of additives in the cement and the risk of the formation of complex substances should be

clarified. The issue of the way in which long-term safety is affected by the quantity of cement to be used in the repository needs to be further elucidated. SKB should also indicate whether grouting in deposition holes will be carried out if the criterion for inflows into a deposition hole is exceeded.

SKI also notes that so far SKB has taken significant steps during the present century to improve information about rock sealing by grouting, both directly and in cooperation with other stakeholders. This is justified, since sealing by means of grouting presents a special challenge. Projects implemented by SKB have been conducted for a sufficient time and with satisfactory resources to have achieved a breakthrough in knowledge about various grouting materials and their properties in the bedrock. SKB is currently in a better position as regards basic knowledge about grouting in bedrock, but now needs to ensure that this knowledge is transformed into practical methods which can be applied in excavation works. This applies to the whole chain from the various grouts, the actual grouting process and its control to determination of the results of the grouting process and its quality. In this context, further measures by SKB are required, in cooperation with other stakeholders in the grouting of rock materials.

Accordingly, the continued efforts concerning grouting applications proposed in SKB's programme are justified.

One characteristic feature of a grouted rock mass is that grouting of one section of a tunnel usually results in the occurrence of a new leak in an area that was previously dry and watertight. A leakage-shift of this nature may, in some cases, be envisaged in connection with the progressive extension of the repository. Such a shift in or new formation of leakage may affect groundwater flows in the immediate vicinity of deposition holes and deposition tunnels. SKI is unable to draw the conclusion that SKB has considered this problem in the RD&D programme.

5.1.3 Drilling and Blasting of Rock Openings

SKB's Report

SKB recommends the drill-and-blast method for preparation of the central area, transport tunnels, main tunnels and deposition tunnels in the repository area. SKB bases this on experience of the experiments carried out at the Äspö Hard Rock Laboratory (the Zedex and Apse experiments). SKB explains its decision on the basis of the results of the SR-Can safety assessment in which SKB noted that development of the disturbed zone *appears* to have little relevance for radionuclide transport, compared with the presence of natural fractures intersecting a deposition tunnel. The experiments at Äspö indicate that the scale of the damage that occurred does not endanger functionality in the long term. The Apse experiments indicate that blasting of a deposition tunnel should be implemented in two stages in a top heading location, and in a bench with a vertical thickness of at least 0.8m. Excavation disturbance experiments in the Apse tunnel had a maximum fracture formation of 0.2 – 0.3m, while a reduced seismic p-wave rate indicated disturbance 0.4-0.5 m below the tunnel floor and that the macroscopic fractures induced along the contour holes were not continuous over the boundary with the next blasting shot. Hydraulic characteristics on the relevant scale have not been

established in the disturbed zone affected by macroscopic and microscopic fractures, but the sensitivity of their potential impact has been analysed in SR-Can.

In its review of RD&D Programme 2004, SKB states that SKI indicated that freedom of action regarding methods for rock excavation will be unchanged until excavation removal from the deposition areas takes place.

The most important features of SKB's scheduled programme is studies of the characteristics and impact of various blasting substances' causing a disturbed zone, the follow-up of experience of rock excavation at Onkalo in Finland, the study of radial and axial hydraulic conductivity in the disturbed zone by Decovalex and the design and implementation of a large-scale measurement experiment of the excavation disturbed zone around a blasted rock tunnel with a realistic rock stress situation and realistic geohydraulic conditions. SKB is also planning to carry out tests at the Äspö Hard Rock Laboratory for two methods for the controlled removal of the bottom bench in a deposition tunnel – controlled drilling, blasting and wire sawing.

Comments by the Reviewing Bodies

The Luleå University of Technology considers that no attempt has been made to actually find out what are the mechanical characteristics of the disturbed and damaged zone so as to permit this to be taken into account in the design.

SKI's Evaluation

SKI considers that the selection of reference method for excavating deposition tunnels should be determined in connection with submission of the repository application, and this is also SKB's intention. Selection should be based on implementation by SKB of a comparative study between the following alternatives: full-face boring (TBM) and conventional boring and controlled drilling in addition to that already carried out at the Äspö Hard Rock Laboratory (Zedex and Apse experiments). Prior to submission of the repository application to the new Radiation Safety Authority, SKB should indicate the advantages and disadvantages of each method in a report, and, based on the results, explain its choice of method for the excavation of deposition tunnels. Costs, flexibility, rock reinforcement, grouting, mapping, deposition, backfill, etc. are examples of issues that SKB needs to clarify in this comparison.

SKI notes that one of the arguments cited by SKB for not using TBM technology is the lower degree of flexibility. However, SKB has itself previously discussed the possibility of locating deposition tunnels at an arbitrary angle (e.g. 30-45 degrees) in relation to the main tunnel. This permits a solution of the problem with tight curves (90 degrees) which detract from employment of the less-flexible TBM technology. In the case of drilled and blasted tunnels, SKI may also note that SKB advocates wheeled deposition machines, while rails are considered to be the most advantageous in a TBM tunnel. However, SKI is not aware, of any investigation of the possible utilisation of a wheeled deposition machine in a TBM tunnel.

Based on the best available technology (BAT) principle, SKI considers that there are clear arguments for deciding that full-face boring should be employed for the deposition

tunnel. SKB's experiments (Zedex) have indicated that there is only a minimal damage zone in the entire tunnel peripheral area in comparison with drilling and blasting. SKB has also demonstrated at the Äspö Hard Rock Laboratory (The Prototype Repository) that it is possible to implement deposition in a full-face bored tunnel. This is also confirmed by the fact that this method has been employed for drilling the 7.6m diameter tunnel for the Exploratory Study Facility project at the Yucca Mountain facility in Nevada in the United States. TBM was employed for tunnel working in the test laboratory at Grimsel in Switzerland and at the Äspö Hard Rock Laboratory, and has been proposed as the rock-working method for the deposition tunnels in the Nagras repository programme in Switzerland. A specially manufactured TBM for the drilling of deposition tunnels should be considered as an alternative in the perspective of BAT.

As regards SKB's plans for studies of the impact of various blasting materials on the rock, SKI notes that the charge in the innermost part of each borehole is normally so powerful that it will probably be difficult to limit the disturbed zone to avoid the opening up of water transport routes, despite plans to angle the holes to some extent away from the planned tunnel peripheral area.

SKI would also like to reiterate points made in its comments on RD&D Programme 2004, namely that "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, minimal 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 excavation of deposition tunnels and deposition holes and after deposition is initiated."

As indicated in the above quotation, SKB has unfortunately omitted the word *not* in its presentation of SKI's statement in the 2004 review. SKI would also like to reiterate what it proposed in its review of RD&D Programme 2004, namely that SKB must also present rock excavation solely by mechanical methods in the D2 layout proposal. This applies in particular to rock excavation in deposition tunnels.

SKI considers that the alternative technique involving wire sawing of the bench in a deposition tunnel would appear to represent a return to an older outdated technique in comparison with modern TBM technology, which will probably be developed further prior to the commencement of construction of the repository. In addition, wire sawing will result in sharp corners, probably with a high stress concentration and hence an increased risk of rock breakouts. The advantage of wire sawing may be that the flat surface possible facilitates geological mapping and the insertion of pre-compacted backfill blocks.

Irrespective of the method selected for the excavation of deposition tunnels, SKI takes a positive view of SKB's commitment to Decovalex for investigation of the hydraulic conductivity in the zone in the excavation disturbed zone in the tunnels in the repository.

5.1.4 Boring of Deposition Holes

SKB's Report

As a result of implementation of a pilot study, SKB has decided that reverse raise boring should be the reference method for rock excavation of deposition holes. According to SKB, bevelling of the order of 1.1 m depth and 1.6 m width is required to give sufficient space for the radiation-protected canister before emplacement of the "naked" canister in the deposition hole, and to save costs by reducing the tunnel area. According to SKB, two alternative techniques are wire sawing and water jets, although wire sawing has the greater potential.

SKI's Evaluation

SKI considers that testing of the reliability of the proposed drilling methods in areas in which spalling failures are anticipated could be carried out in tunnels with a geometry that increases rock stresses in the floor in galleries corresponding to the gallery profile used in the Apse project at the Äspö Hard Rock Laboratory.

Irrespective of the method employed for rock removal from the chamfer, the upper part of the deposition hole in conjunction with chamfering will result in a complicated geometry and stress situation, with the risk of high stress concentrations and resultant fracture initiation, fracture propagation and spalling failures. New fracture formations may lead to increased groundwater flows in the critical area between the deposition hole and the floor of the tunnel. As a result, SKB needs to indicate the best way of designing and implementing chamfering so as to achieve minimum disturbance of stability and to minimise the risk of increased groundwater flows in the immediate neighbourhood of the canister.

SKI notes that SKB has not described the practical implementation of boring pilot holes in the deposition hole location, and what tests are planned in the hole.

SKI also considers that it should be possible to design the machine for boring deposition holes in such a manner (by angling the machine) that it can also boring the chamfer required in the deposition hole.

5.2 The Buffer Line

In this section, SKI presents its views on Chapter 13 The Buffer line in RD&D Programme 2007.

The buffer line includes the manufacture, handling and installation of the buffer, in the form of rings and blocks of highly-compacted bentonite that surrounds the canister in the deposition holes. The buffer line includes compaction of bentonite blocks and rings, intermediate storage, fitting out of the deposition holes and installation. The colouring of the boxes shows that SKB considers that most of the technology development is already in existence, but that some further development or optimisation is called for.

SKB's Report

The buffer's main functions are to protect the canister and prevent water flows, as well as to retard the transport of radionuclides from a leaky canister to the rock. SKB lists, under eight headings, the requirements for the methods and equipment needed in order for the installed buffer to fulfil its long-term function, and to permit handling and installation. In addition to the chemical properties of the bentonite, which are a given premise in technology development, the dry density and the water ratio are important parameters. Full-scale bentonite blocks and rings (MX-80) have been fabricated and installed in the Retrieval experiment, the Prototype Repository and the Lasgit experiment at the Äspö Hard Rock Laboratory.

SKB has not finally chosen the reference method for the fabrication of blocks and rings.

Comments by the Reviewing Bodies

The Swedish Society for Nature Conservation and the Swedish NGO Office for Nuclear Waste Review (MKG) point out that the way in which the industry is to handle the experience of the realities encountered in the full-scale tests at the Äspö Hard Rock Laboratory is a key question of special interest. A good example of this is the discovery that it is not possible to place bentonite around the copper canister without protecting it from the groundwater during the deposition phase. Both organisations consider that a full-scale demonstration of the way this can be achieved is required, taking into account that in reality the canisters will be giving off strong radiation during the deposition phase. A fully satisfactory safety assessment cannot be undertaken without testing of this nature.

Nuclear Waste Secretariat (Milkas) of the Environmental NGOs, (Pettersson) notes that the type of bentonite selected (MX-80) has been abandoned and that SKB is currently testing a number of other clay materials. Furthermore, Milkas points out that the checking and control of the swelling pressure of the clay and the temperature in the buffer and backfill present difficulties due to variations in water flows from the rock and variations in air gaps and pockets between the rock and the buffer and between the canister and the buffer. Overall, Milkas notes that considerable demonstration, development and research still need to be done in the areas involving clay swelling.

The Opinion Group for Safe Disposal (Oss) and the Waste Network consider that the Government should require SKB to submit a full and clear account of the functional requirements for the bentonite buffer, a clear description of the optimal groundwater conditions for the functioning of the bentonite buffer, and clear links between the bentonite buffer's specifications, the optimisation of functions and the prerequisites at the site selected, and which fabrication method best meets the stipulated requirements.

SKI's Evaluation

SKI considers that SKB should prepare a more detailed description of which technology is to be employed during installation of the buffer, in order to prevent unduly rapid saturation of the buffer. Although SKB has tested the way in which the buffer is to be

protected from unduly rapid saturation due to water inflows at the Äspö Hard Rock Laboratory in connection with the buffer installation at the Prototype Repository, IPR-02-23 (SKB, 2002) only shows a picture of a plastic sheet which was removed before the gap on the rock wall was filled with pellets, without comments on how successful the test was.

Fabrication
SKB considers that the Prototype Repository has demonstrated that the required buffer density (>2000kg/m3) can be achieved (SKB, 2006a). As a result, SKB considers that fabrication and installation of buffer components have been demonstrated. It may, however, be noted that the stated density was not achieved in the case of any of the disc-shaped rings in the uppermost locations. Furthermore, these experiments at the Äspö Hard Rock Laboratory cover relatively few examples. Hence, SKI considers that further test production may be required to show that the requisite quality for the material selected can be achieved under conditions closer to serial production. Geometrical tolerances and clear acceptance criteria should then be developed and applied. If, in addition, SKB chooses another type of clay, greater efforts to demonstrate the fabrication of buffer components will be required.

As regards fabrication, SKI notes that SKB has abandoned isostatic pressing as a reference method, without giving any reasons. SKI has previous expressed its view on SKB's choice of reference method, based on the fact that there is no isostatic press for the fabrication of full-scale blocks in Sweden. SKI is also surprised that SKB has downgraded its priority for the fabrication of blocks using an isostatic press.

Furthermore, SKB does not present its ideas about what a programme for buffer quality assurance should include. It is therefore essential that SKB develops some form of quality programme for buffer fabrication on the same lines as for canister fabrication. A discussion of what deviations that may occur in the fabrication process is called for, and what impact such deviations may have on long-term safety, for example if heterogeneous conditions occur in the buffer.

Installation of blocks and rings
SKI considers that SKB has shown that, in principle, the installation of the buffer on a full-scale basis is feasible, both in blasted and full-face bored tunnels, as a result of the experiments carried out at the Äspö Hard Rock Laboratory. This involves, however, limited testing carried out to some extent under conditions other than those that apply for future operation of a repository. As a result, SKB should focus on the problems of achieving high quality in the more demanding conditions that apply for routine operation, for example with remote-control deposition at the rate called for with a realistic deposition sequence. Furthermore, SKB has not demonstrated deposition of canisters with radiation screening or remote control for the installation of a radiation shielding hatch over the deposition hole.

SKI agrees with the Opinion Group for Safe Disposal (Oss) and the Waste Network that, in connection with submission of the application, SKB should present a full account of the function specifications for the bentonite buffer, etc.

5.3 The Canister Line

In this section, SKI presents its comments on Chapter 14 The Canister Line in RD&D Programme 2007.

The canister line describes how canisters, which the spent nuclear fuel is encapsulated in, are fabricated, sealed, transported and deposited. SKB specifies two areas where technology development is not known (red-coloured boxes). These are non-destructive testing (NDT) of canister components and transloading to deposition machine. In addition to this, SKB specifies ten areas with known and proven technology that can be applied after tests.

The purpose of the canister in the repository is to isolate the spent nuclear fuel from its surroundings over very long periods of time. The reference design for the canister consists of an outer corrosion barrier of copper and a loadbearing insert of nodular iron

5.3.1 Design Premises for Strength – Requirements on the Canister

SKB's Report

The overall requirements on the function of the canister are described in the design premises for the canister (SKB, 2006b). These serve as the basis for the design of different components of the canister. In SKB's RD&D Programme 2007, the design premises for the canister are presented in a special Annex A to the main report. The canister consists of an outer copper shell with an insert of nodular iron. The purpose of the copper shell is to:

- prevent corrosion,
- isolate the nuclear fuel,
- be part of the radiation protection barrier.

The function of the cast iron insert is to:

- constitute the bearing structure in the event of external loads (shear deformation and isostatic loads),
- keep the fuel in the channels separated,
- constitute part of the radiation protection barrier.

Furthermore, the whole canister shall:

- have negligible thermal, chemical and mechanical effects on the other barriers and the fuel,
- be able to be transported, deposited and otherwise handled in a safe manner,
- be based on known or well-tested technology,
- must be able to be fabricated, sealed and inspected at the desired pace with high reliability in production
- must be able to be tested against specified acceptance criteria.

SKB (SKB, 2006b) admits that not all aspects from the safety assessment SR-Can have completely been taken into account. This is the case, for example, for acceptance criteria for various variables.
SKB states that the design premises in the report do not currently provide complete supporting documentation for the choice of material and design of the canister, although work is in progress to produce complete documentation. SKB's planned programme for design premises for strength-related issues includes:

- New calculations that study the impact on the canister of post-glacial earthquakes. The findings depend both on the geological prerequisites and the properties of the buffer.
- Investigation of the interaction between tolerances in the input data and the margin against threshold effects when calculating the collapse load of the insert.
- Investigation of cases of combined loads and their effect on the total level of strains in the insert.
- Analysis of the damage resistance of the insert with respect to permitted defects in different loads. These are to serve as the basis for quality inspections with non-destructive testing NDT. These analyses shall also take up the effect of any strain corrosion fractures in the insert.
- Analysis of defects in the intermediate walls of the insert and with respect to criticity, which is to serve as the basis for quality inspection with non-destructive testing.
- Survey of handling damage and its effects on the handling safety and long-term integrity of the canister. Furthermore, mishaps during the operational phase shall be studied and their impact on the capability of the canister to contain the fuel.

SKI's Evaluation

SKI agrees with SKB that the design premises presented to date are incomplete. The design premises shall normally include information on loads and load combinations both during normal operation and during expected disturbances, which should be specified in the main scenario of the safety assessment as well as less probable scenarios. SKB should specify approximate occurrence frequencies for the different scenarios. In the case of the repository, load cases shall be included which refer to handling of the canister, for example, if the canister is dropped during lifting or transportation. The design premises shall also include acceptance criteria for different variables where different safety margins are defined. The design premises can include both deterministic and probabilistic criteria. Furthermore, certain remaining requirements on the different materials of the canister are lacking as well as certain final geometric tolerances which are important for the manufacture of the canister. Information is also lacking on the maximum permissible defects in different components of the canister, which are important for fabrication inspection. In a number of cases, SKB is planning in continued work to clarify these issues but it is none the less worthwhile to clarify this.

SKI wishes to emphasise that there is still lacking a complete design analysis of the canister containing a design of the canister and a summary of strength analyses performed with reference to current design premises. SKB should include an integrated design analysis of the canister of this kind including safety margins when applying to

construct the repository. As it is, the strength analyses are spread among a number of reports and it has not been clarified which analyses that SKB considers apply and which reports are considered as being outdated.

More swelling pressure load cases appear in the older edition TR-98-08 (Werme, 1998) of design premises than in R-06-02 (SKB, 2006b). SKB needs to tidy up the swelling pressure load cases and analyse the impact on, in particular, the copper shell.

In SKI's opinion, the analyses presented by SKB are not sufficient to reject the possibility that shearing from an earthquake and isostatic load from a glaciation could occur at the same time. SKB should carry out further studies to clarify how these loads can interact.

To sum up, SKI considers that SKB should continue to develop the design premises to enable these to provide better supporting documentation for the choice of materials, design and fabrication inspection of the canister as well as long-term safety. Furthermore, SKB should continue to carry out investigations into the possibility of shearing from an earthquake and isostatic load taking place at the same time.

5.3.2 Design Premises, Issues relating to Materials – Requirements on the Canister

SKB's Report

SKB's planned programme for design premises for issues relating to materials includes:

- Testing of creep properties of copper has been under way for several years. Recently, the investigations have now been concentrated on the properties of the FSW weld, effects of extremely slow loading and creep with a multiaxial stress state. There have been questions concerning the long-term stability of phosphorus. A validated creep model must be constructed since time-dependent courses must be taken into account in events such as post-glacial shearing of the canister. Creep at low temperature, 0ºC should be studied.
- The effect of hydrogen on copper and nodular iron since occasional fuel rods may be damaged and water may have entered the rod. It is of interest to study whether the formation of hydrogen affects the mechanical properties of nodular iron and copper.
- If cold working has any effect on the long-term properties of the canister, it will be determined what degree of cold working can be permitted. Plasticising of the copper shell can occur in connection with handling. This may lead to deformation hardening, accompanied by an increase in ultimate strength and reduced elongation at break, which may entail an effect on creep characteristics.
- Recently the possibility has been discussed that stress corrosion can occur in the copper shell. It is therefore of interest to carry out stress analyses of the copper shell but also to review the existing chemical arguments.

Comments by the Reviewing Bodies

The Royal Institute of Technology (KTH) has pointed out that the mechanical properties of copper may be changed due to hydrogen uptake/hydrogen embrittlement and that SKB should investigate the effects of hydrogen uptake from the inside of the canister as well with regard to the mechanical properties of copper.

Uppsala University considers it is of the greatest importance that a detailed study is made of the effect on hydrogen of copper and nodular iron, and that all effects of mechanical stresses and radiation are analysed. According to the research programme for material issues (page 161), the effect of hydrogen on copper and nodular iron shall be studied in 2008-2009, and stress corrosion shall be studied in 2008-2010. Research in these areas should be coordinated, and it is doubtful whether the stated time periods are sufficient.

SKI's Evaluation

In a number of reports, SKB has reported on the most recent creep tests and presented a creep model for calculation of copper's creep properties during long periods. Tests carried out on material from the weld have also been presented. In SKI's opinion, there are still some questions which need to be resolved with regard to the credibility of these creep models. SKB intends to undertake further investigations into creep problems and the long-term stability of phosphorus in the next few years.

SKI has previously pointed out that the tests that have been conducted are not always representative for the conditions that prevail in the repository. Other types of failure (ductile contra friable) may have prevailed during certain tests. SKI considers that SKB should take into consideration the conditions that exist in the repository, i.e. low temperatures and low loads when constructing a creep model.

SKB intends to investigate the effect of hydrogen in copper and in nodular iron since it is conceivable that hydrogen will exist in the canister due to anaerobic corrosion. SKI considers that SKB's approach of investigating the effect of hydrogen with regard to the mechanical properties of copper and nodular iron and determining the quantities of hydrogen that are permissible in the canister is a step in the right direction. In its referral response, KTH has pointed out that the effect of hydrogen embrittlement also from the outside of the canister should be investigated. Even though the material that has been selected for the copper canister (anoxic copper, OF copper) is generally considered to be immune to hydrogen embrittlement, SKI considers that additional measures are needed before the risk of hydrogen embrittlement can be excluded.

SKB reports on the damage (SKB, 2006c) that may occur on the surface of the sealed canister. According to SKB, handling damage on the sealed canister can be caused by cold working effects. Cold working can lead to deformation hardening accompanied by an increase in ultimate strength and reduced elongation of break. These may have an impact on the creep characteristics of copper. SKB is planning to investigate whether the working effects have any effect on the long-term properties of the canister. SKI considers in this context that the effect of remaining deformation on stress corrosion should also be taken into account.

SKI accordingly considers that it is positive that SKB has now realised the importance of reviewing its reasoning concerning stress corrosion and plans to conduct more experiments as well as carrying out stress analysis of the copper shell and also to review the reasoning on the importance of chemical factors.

To sum up, SKI considers that SKB when constructing its models for copper creep should take into account the conditions that exist in the repository, i.e. low temperatures and low loads.

5.3.3 Fabrication and Non-Destructive Testing of the Insert

SKB's Report

Fabrication of the insert, subsystem insert in the production system for canister fabrication,
consists mainly of two processes: casting of the insert and non-destructive testing. The subsystem also includes supporting processes such as machining of the insert and fabrication of a steel cassette and a steel lid.

Fabrication of the Insert
SKB presents the activities that have taken place since RD&D Programme 2004. Several inserts have been fabricated both in the BWR and PWR versions. Most inserts have been in the BWR version. A number of adjustments have been made in the design of the insert to improve quality, for example, to enable impurities to be cut off. A probabilistic analysis has been performed on the insert to show that it has sufficient strength. Tests have also been carried out to demonstrate that the canister design, in particular the insert, is sufficiently reliable when it comes to overpressure. Pressure tests have been performed on two shortened canisters. In both tests, the load was gradually increased to around 130 MPa. SKB also presents a report on the development programme that is being carried out in collaboration with SKB's suppliers to fabricate inserts. A programme for pre-qualification of the process for fabrication of BWR inserts is under way.

SKB's programme for the coming three-year period includes:

- intensification of the development of PWR inserts,
- fabrication of BWR inserts in serial production and gathering of material for prequalification etc.

SKB will also work, according to the programme, for qualification which includes qualification of the fabrication of inserts.

Non-destructive testing
The primary quality assurance takes place through fabrication processes being controlled in order to obtain the requisite quality. The non-destructive testing is the most important component to verify this. Certain parts, such as steel lids and bolts, are standard products and can be purchased with associated quality certificates. Work is in

process to define the non-destructive testing required on the basis of design premises and strength analyses.

Ultrasound is the main testing technique for testing canister components. Several ultrasonic methods are presented which will be combined to cover the whole testing volume.

In the next few years, SKB will develop methods for the nodular iron insert and prepare qualification of these. SKB also states that, within the programme for non-destructive testing, testing configurations will be set, based on expected discontinuities and preliminary acceptance criteria and certain prerequisites. Modelling runs will also be carried out to gain further understanding. Work will take place during the period of reliability studies as well as preliminary strategies for qualification of testing systems.

SKI's Evaluation

Fabrication of the insert

One of the requirements on the canister is that it should be possible to fabricate, seal and inspect it at the desired rate. SKB presents a report on the number of components (insert, lid, bottom, etc.) which have been manufactured to date.

SKI admits that methods now exist to fabricate canister components and whole canisters. However, these methods need to be further developed, which is also happening. As regards serial production, SKI considers that further measures are needed. The narrow tolerances that apply for canister components and the complete canister mean that it may be difficult to obtain sufficiently good quality in serial production with a resulting high level of rejects. SKB reports on the number of components that have been manufactured but it is not possible to see how many of these components have met all of the quality requirements set by SKB. The development needs that exist for practically all of the manufacturing methods chosen can make it difficult for SKB to meet their reported timetables. SKI also agrees with SKB that it is very important to develop the fabrication methods for the PWR inserts.

Non-destructive testing

In SKI'S opinion, it should be fully possible to purchase standard products with appurtenant quality certificates as long as requirements of the sub-contractor are investigated and reported.

The current work of defining the non-destructive testing needed on the basis of design premises and strength analyses is in line with SKI's view and current practice at nuclear power plants.

SKB has also been engaged in development of the methods of radiography and inductive testing, although it is still unclear which methods will be finally be used/combined. SKI considers that it is essential and important that SKB develops a number of different testing methods which complement one another. It remains for SKB to develop how this complementing is to take place and report on it in its future work.

SKI considers that work on development and qualification of testing methods for the nodular iron insert is as important as it is for the shell and seal weld.

To sum up, SKI considers that it remains for SKB to show that canister components can be fabricated at the rate and quality stipulated by SKB. It is urgent, among other things, to develop fabrication methods for fabrication of PWR inserts if SKB is to be able to comply with its timetables. Within development of non-destructive testing, SKB has investigated and evaluated several different methods. It is important that SKB now shows in more detail which combinations of fabrication methods are needed to obtain appropriate quality assurance.

5.3.4 Fabrication of the Copper Shell

SKB's Report

SKB presents a report on the improvements of copper ingots that have been achieved through an increase in fabrication capacity for ingots.

SKB also reports on the pipes that have been fabricated by extrusion, pierce and draw processing and forging. A number of pipes have been fabricated by these methods. Extrusion has been a functioning method for pipe fabrication. However, changed material structure has been noticed recently in certain areas, which is being investigated. The advantage of pierce and draw processing is that pipes can be fabricated with an integral bottom. The pipes with integral bottoms which have been fabricated to date have had large grains in the bottom. Experiments are in process to develop the process so as to obtain a bottom with an approved grain size. Development of welding has been in process and it has been possible to fabricate pipes with a fine grain structure.

Copper lids and copper bottoms have been fabricated in large numbers. Ultrasonic testing of these has shown that the manufactured lids have an uneven structure. The forge process will be developed to improve the structure. SKB also presents the different methods investigated to adapt the lids to the friction stir welding (FSW) process.

SKB also reports on development work with laser technology which has been produced to measure the straightness and roundness of the copper tube.

During the coming three-year period, developments of methods for fabrication of copper tubes will continue. SKB will work on improving the geometrical accuracy of the extrusion process and studying the local variations in the material structure along extruded pipes. ´The method for forging lids and bottoms will be developed to obtain a more even structure in these components. Furthermore, the reliability of fabrication and testing methods will be investigated.

SKI's Evaluation

SKB has shown that it is possible to fabricate canister components and to fabricate complete canisters that comply with SKB's quality requirements. SKB also presents a report on the development needs that exist for most of the fabrication methods. In SKI's opinion, there is also a need of development in the cases where SKB has chosen a

reference method. SKB also discusses the capacity of these methods in serial fabrication and reports on the number of components fabricated.

SKI's comments on fabrication of the copper shell are the same as those presented by SKI for fabrication of the insert (see 5.3.3). SKI none the less considers that the development programme presented by SKB is appropriate and is a step in the right direction.

5.3.5 Sealing and Non-destructive Testing of the Weld

SKB's Report

Sealing
SKB plans to seal the canister with FSW and inspect the quality of the weld by ultrasonic and X-ray testing (radiography). In the future production, SKB plans to do its own welding, which means that welding procedures and systems must be developed and welding systems must be installed both in the canister factory and the encapsulation plant. SKB plans to use the same welding method in both plants where the system installed in the encapsulation plant is included in a nuclear activity.

SKB presents the bases for the selection of FSW as a reference method for welding. Following the choice FSW as the reference method, the focus of further research, development and demonstration has been on this method.

According to SKB a large number of welding tests have been performed with FSW with good result and high repeatability. The process window is wide, which means that disturbances or parameter changes during welding do not affect the welding quality.

SKB's programme is now mainly focused on developing the FSW process. The programme for development of EBW will be limited.

Non-destructive Testing
SKB describes the methods which have been developed. SKB has mainly used ultra-sound to cover the necessary testing volume. SKB presents a number of tests carried out both on FSW and on electron beam welding (EBW) to evaluate the mechanical and chemical properties of the welds.

SKB has now selected FSW as reference method for welding. A number of experiments have been conducted to develop the welding process and test the testing systems for this type of defect. Preliminary procedures have been produced for FSW welding and a report made on reliability studies conducted to date. In the future, the programme will be focused on quality preparations. The extent, choice of methods, practical experiments and modelling will be the main tasks in the next few years. In the somewhat longer term, the focus will be on producing quality documentation. This work specifies exactly the nature of testing for each area of testing.

SKI's Evaluation

Sealing
In RD&D Programme 2004, SKI requested an investigation into the chemical and mechanical properties of the weld metal. SKB now presents investigations of this kind. In most cases, the FSW weld has similar properties to the parent metal. These investigations have shown that certain defects such as oxide inclusions or joint line curvature can occur. However, SKB considers that oxide particles can be eliminated and that joint line curvature can be overcome. SKI considers that it remains for SKB to show that this is the case by further tests. In its programme, SKB has accounted for the intention of automating the FSW process. In SKI's opinion, this is of great interest to be able to obtain as high repeatability as possible in the future.

Non-destructive Testing
SKI considers that SKB's planned development of non-destructive testing is appropriate with the focus on basing requirements on the systems on design premises and strength analyses. SKB has moreover come a long way in developing tools for testing of the whole volume of the copper shell. SKI has also understood that discussions have also taken place with the qualification body at an early stage to obtain understanding of the focus entailed by a qualification of the testing systems.

To sum up, in SKI's opinion, SKB should show how defects such as joint line curvature and oxide inclusions can be avoided in the FSW weld. Automation of the welding process is also very important. As regards non-destructive testing, SKB needs to show in more detail how a combination of non-destructive testing methods together find the fabrication defects that may occur. SKB also needs to continue working on the process to show this with the aid of an independent third-party body.

5.3.6 Fuel in the Encapsulation Plant

SKB's Report

SKB's application for a licence to build the encapsulation plant and Clab includes an account of the technology development that has taken place during the design process and since RD&D Programme 2004. The requirements and technical solutions that satisfy the requirements are described in the application. The detailed technical solutions may be changed during system and detailed design of the plant, which is the next phase in the design process. SKB will have measurement equipment for gamma measurements in the encapsulation plant for verification of decay heat. When the canister has been filled, visual verification will take place.

SKI's Evaluation

SKB mentions that there are still no formal requirements on measurement of the fuel, which is correct. However, SKB should report on how it ensures that information about the fuel is correct before the fuel is prepared for encapsulation. If the documentation is incomplete or possibly has deficiencies, SKB should produce a plan of action to deal with this. SKB should also indicate when sufficient information is needed about the fuel. It is sufficient that there is a measurement station in the encapsulation plant for final conformation of information about the fuel already verified by SKB. At this point,

it is too late to check the fuel if differences are noticed which have not been remarked upon previously. These inspections should already have been carried out in Clab. Subsequently, approved fuel should be located separately under a satisfactory "Continuity of Knowledge" (C/S).

Visual verification shall, according to plans, take place before the steel lid is placed in position or after the canister is filled with fuel. Nothing is mentioned about how this is to be done or in what way it is to be documented. This is a critical point in handling since one moves from handling individual fuel elements to the canister as the smallest unit.

5.3.7 Transport Cask for Encapsulated Fuel

SKB's Report

SKB plans to transport encapsulated fuel in a similar way to the transportation of non-encapsulated fuel that has been going on since 1985 from the Swedish nuclear power plants to the Clab interim storage facility and waste to SFR. The transport system is described in relative great detail in RD&D Programme 2004 and SKB is now focusing on production of a suitable transport cask.

A specially designed transport cask is needed for canister shipments to the repository, which must comply with the rules in IAEA's transport recommendations. Despite encapsulation, both gamma and neutron radiation levels are so high that a heavy transport cask is required with thick walls of carbon steel or cast iron. SKB has had two competing companies produce pilot studies of conceivable designs. At least, five casks should have been delivered when the repository is commissioned, after which the remaining casks will be delivered successively.

Comments by the Reviewing Bodies

To be able to present a good body of material for decision to the municipal council, the Municipality of Oskarshamn would like see which transport solutions are recommended by SKB. The municipality wants canister transportation not to be mixed up with other traffic and wishes to see environmentally friendly and safe transport alternatives for rock masses and insert goods.

The Misterhult Group in the Municipality of Oskarshamn points out that it is not clear from RD&D Programme 2007 how transportation to the alternative repository at Laxemar shall take place. The group is concerned about the disturbances in the form, for example, of noise, pollution, accidents and reduced access that this transportation may give rise to, mainly during the construction phase when large quantities of rock masses are to be moved.

See section 4.6 with regard to physical protection of encapsulated fuel during transportation.

SKI's Evaluation

SKI is satisfied to note that two pilot studies have been performed on the conceivable design of the canister transport cask. In its statement on RD&D Programme 2004, SKI considered that a timetable should be established for the entire fabrication and certification procedure to avoid a lack of approved transport casks becoming a bottleneck. It is not clear from RD&D Programme 2007 whether such a timetable exists.

SKI shares the view of the Municipality of Oskarshamn that it would be an advantage if canister transportation did not have to take place on the public highway. The issue of heavy canister transportation by special vehicles and shipments will require special attention. It should at least be necessary to close the road for other traffic when canisters are to be transported.

SKI still lacks arguments on the part of SKB about the dimensioning of the transport operation. SKI raises the question of whether it is reasonable to close the road to Laxemar

Laxemar in the extent that may be necessary or whether FOI's proposal for a transport tunnel is more realistic (see Section 4.6). Furthermore, the issue of how intensive ship traffic will be if the repository is sited at Forsmark needs to be answered. The question also needs to be answered of how any land transport between the harbour at Forsmark and the repository will take place.

5.3.8 Handling of the Canister in the Repository

SKB's Report

According to SKB, handling of the canister in the repository refers to the entire handling chain from the time the canister arrives at the terminal building in the repository's guarded area in a licensed canister transport cask (KTB) until the time the canister has been deposited, all inspections have been performed and documented and an empty KTB has been returned to the terminal building.

SKI's Evaluation

In its review of the previous RD&D programme, SKI pointed out that SKB needs to carry out further work on the whole chain of events for the canister at the repository, so that he activity can take place in a safe way from all points of view. SKI also pointed out that SKB should report on how loading and unloading of the canister can take place and what needs to be automated due to radiation, etc. SKI can now observe that no reports in this respect have been produced by SKB to date. However, SKB does refer under the heading "Newfound knowledge" to knowledge of a number of vague concepts which, for example, have been studied, worked up and produced linked to the expressions chain of events for the canister, transportation on the ramp, preliminary layout and design of the next generation of deposition machine.

SKI also notes that SKB, under the heading of underground transport and transloading and deposition, is not either able to present any report as the progress made in its work. However, SKB presents plans for various activities in the next few years and announces

tests at the Äspö Hard Rock Laboratory, partly in collaboration with Posiva, among other things to verify that the selected method and equipment for handling canisters and buffer units will work as planned.

As regards safety issues, SKI wishes to notify SKB that methods should also be specified, when describing the canister line, to be able to verify/document the content of the canisters from a nuclear safeguards point of views. As pointed out by SKB in Section 6.7, Continuity of Knowledge is an important factor in this phase when handling moves from separate fuel bundles to a whole canister. The description lacks information on how marking or another method to identify the canister is to take place.

5.4 The Backfill Line

In this section, SKI presents its comments on Chapter 15 The Backfilling Line in RD&D Programme 2007.

The backfill line includes manufacture, handling and installation of backfill in deposition tunnels and in the top part of the deposition holes and installation of a temporary plug in the mouth of the tunnel opening into the main tunnel.

SKB identifies three areas in its colour coding where technology development is not known (red boxes). These areas are installation of backfill in upper parts of deposition holes, backfilling with blocks in deposition tunnel and backfilling with pellets/granules in the deposition tunnel.

SKB's Report

The requirements on the backfill are that it should limit the upward expansion of the buffer into the deposition hole and prevent the development of hydraulic transport pathways in the deposition tunnels so that water flux at repository level is affected.

SKB has previously studied several concepts to for backfilling deposition tunnels. Further technology development is now focused on developing methods and equipment for the concept with precompacted blocks of natural swelling clay (Friedland clay).

Trials performed to date on both a laboratory and industrial scale indicate that it is possible to manufacture blocks with a high enough density and production rate. It is planned to backfill the tunnels with block with a size 120 x 80 x 50 cm to 80% of the tunnel's cross-section, the remainder being filled by pellets or granules. It is planned to be able to backfill six metres of tunnel per day.

According to SKB, backfill of the chamfer of the deposition hole requires thorough work to design the concept until the licensing applications for the repository under the Nuclear Activities Act and for the repository system under the Environmental Code.

The backfill method will be tested and demonstrated on a full scale at the Äspö Hard Rock Laboratory after pilot tests at the Bentonite Laboratory for blocks, pellets and granules.

The temporary plug in the deposition tunnel has no long-term function in itself but is designed to withstand the water pressure at repository depth and the swelling pressure in the backfill. It shall also be sufficiently dense that any piping in the backfill that forms during installation can self-heal.

Two types of plugs are mentioned by SKB, a reinforced plug and a friction plug. Reinforced plugs have been installed in the Backfill and Plug Test in the Prototype Repository in Äspö Hard Rock Laboratory. SKB has not yet decided which type of plug will serve as the reference concept in the application, but plans to design and install a full-scale plug of the chosen reference concept at Äspö Hard Rock Laboratory.

Comments by the Reviewing Bodies

The Nuclear Waste Secretariat (Milkas) of the Environmental NGOs (Pettersson) states that a lot of development work remains to be done and, in particular, the swelling and pressure of the bentonite would seem to be the greatest problem. Furthermore, Milkas notes that SKB has not stated which swelling pressure is to be obtained at which stage to avoid the canister being pressed upwards into the tunnel in an uncontrolled way. One complication is that there must be sufficient swelling pressure in the tunnel before the buffer starts to swell upwards; it would appear to be impossible to control and steer this. Milkas states that a new full-scale experiment to obtain an answer as to whether vital parts of the method function is essential before the applications are submitted under the Nuclear Activities Act, the Radiation Protection Act and the Environmental Code.

The Municipality of Oskarshamn notes that the backfill of the deposition tunnels and other tunnels has not been tested in a full-scale test. It is not clear to the municipality how much research and full-scale tests remain to be done when the licence application is submitted in 2009. Technology development is focused on developing methods and equipment for the concept with natural swelling clay. There is limited time for a full-scale test where results can be reported in a future application. The municipality asks what SKB's application is to contain with regard to backfill and whether backfill can be regarded as a barrier in the repository.

The Municipality of Oskarshamn's expert Pereira would like to know when the highest permitted inflow of water into the deposition tunnel on installation of the backfill is to be studied, before or after the application. Furthermore, it is asked what SKB plans to do in the rock areas that are too dry.

The Swedish Defence Research Agency (FOI) considers that technology development remains for the backfill line for installation of bentonite blocks in deposition holes and deposition tunnels and for sealing of investigation holes. FOI also considers that SKB, when designing the backfill of the shaft, ramp, etc. should take into account the possibility as far as possible to make it difficult to intentionally excavate these areas.

SKI's Evaluation

As regards the choice of material for backfill, SKI considers that it is important that SKB shows that there is sufficient data for Fridland clay or the clay that SKB selects so that it is possible to evaluate its properties and function.

Fabrication
SKI pointed out in its review of the previous RD&D Programme that SKB should study the issue of what a scaling-up of the alternative with precompacted blocks which are placed in the tunnel would entail. SKI can note that this has been done through SKB, during test fabrication in existing presses, being able to show that it was possible to produce blocks with a sufficiently high density.

The backfill needs to provide sufficient counter pressure to counteract the vertical expansion of the buffer in the deposition holes. SKB has previously stated a compressibility condition (M>10 MPa) for a backfill consisting of bentonite and crushed rock. SKI considers that SKB should more clearly report on how the requirements for compressibility for the backfill affect the choice of material and design of the backfill.

SKI can note that pre-compacted blocks are a fairly unknown method, which can entail problems in full-scale implementation. For a more efficient and fast backfilling of deposition tunnels, SKB should also consider manufacturing of still larger blocks than those yet reported in the RD&D programme. SKB also needs to produce a quality programme for the backfill for manufacturing and emplacement in deposition tunnels.

As regards manufacturing and use of pellets and granules to fill space between blocks in the deposition tunnels (20 % of the space), these could be replaced by sawn blocks adapted to a circular full-face drilled tunnel. This applies both to tunnel sides, floors and roofs in the deposition tunnel. Pellets and granules may still be needed to seal the gap between bentonite and rock in the deposition holes.

Handling and installation of backfill
Installation of whole blocks of backfill in the upper part of the deposition hole should not cause any major problems since it is assumed that this will take place in the same way as installation of other buffer blocks. However, SKB needs, as is also indicated, to study how the sawn chamfer of the deposition hole will be backfilled regardless of the method chosen for chamfering.

In SKI's opinion, SKB should present the timetable for testing and demonstration of the backfill on a full scale at the Äspö Hard Rock Laboratory after pilot tests at the Bentonite Laboratory and adaptation to the timetable for the application with appurtenant safety assessment. As both the Municipality of Oskarshamn and SSI have pointed out, it is very important that SKB demonstrates therefore that it is possible to handle the buffer, backfill and installation of plugs with the range, in particular, of hydrological conditions and geochemical conditions that can be expected at the selected site.

Installation of Temporary Plug
In the two concepts for plugging of deposition tunnels, it is important that SKB makes sure that the plugs do not hinder water transport in the axial transmissive zone which can arise, in particular if it is intended to blast the tunnel. SKB can presumably disregard this problem if the tunnel is full-face drilled. Regardless of the selected preparation method, the plug shall be sufficiently durable that it remains sealed at least

during the entire operating time of the repository. The reference concept for plugging should be presented before the application for licensing of the repository is submitted to the Radiation Safety Authority.

5.5 The Closure Line

In this section, SKI reports its comments on Chapter 16 The Closure Line in RD&D Programme 2007.

SKB states in its colouring that the most extensive needs for measures applies to closure of investigation boreholes (one red plus four yellow boxes) while measures relating to access tunnels require most new technology (two red boxes). Requirements for backfill of deposition tunnels have been established while requirements for plugging of other areas have not been established.

SKB's Report

SKB is at present working with a strategy where backfill requirements will be adapted to the importance of the respective areas for radionuclide transport from leaking canisters. This will be analysed and reported by SKB in the safety assessment SR-Site. Depending on the results of the safety assessment, SKB will then select the closure method and material. There is a basic concept for sealing of boreholes where the holes are sealed with perforated copper pipes filled with highly compacted smectite clay. In addition to these, three different concepts have been studied, namely the container, couronne and pellet concept. Where boreholes pass water-conducting fractures, the holes can be filled with silica concrete that complies with the requirements for stability during the short time that is required to install clay in a borehole. However, the methods need to be tested in boreholes deeper than 500 m.

Together with Posiva, SKB has developed concepts for sealing long and short boreholes with the aid of bentonite-filled perforated pipes. This method has been tested in an approximately 500 m long drill hole located at the shaft position for one of the shafts to the Onkalo facility at Olkiluoto. Since it will be possible to reach the borehole from the ramp that Posiva is now operating at Onkalo, this will mean that it will be possible to check and evaluate the function of the sealing of the borehole. SKB and Posiva intend to continue investigations into sealing methods and will during the coming research period demonstrate sealings of up to 1,000m long boreholes.

Comments by the Reviewing Bodies

The Opinion Group for Safe Disposal and the Waste Network (Oss) consider that clear functional conditions are lacking in RD&D Programme 2007 for closure of the repository. A crucial criticism of the KBS-3 concept is that the repository will always be accessible in the future for intentional intrusion. The conditions for closure must be included for evaluation of the requirements for "*Safeguards*".

The Swedish Defence Research Agency (FOI) states that a detail that has not been completely developed is the intrusion barriers that are finally to be established close to the ground level at the openings that have existed during operation to the ramp, shaft

and boreholes. FOI considers that this is an important part to make it difficult for undesired groups in later generations to gain access to the plutonium in the repository. However, there is an inherent contradiction between preventing undesirable access and keeping open the possibility of retrieval with a view to applying new and more efficient methods.

SKI's Evaluation

SKI agrees with SKB that the closure of the repository is so far ahead in time one can wait for the result of technology development of backfill of deposition tunnels before SKB makes a decision on which need of technology development exists for the definitive closure of the entire repository. However, it is important that SKB in its application reports on the current requirements and methods, choice of methods and materials for closure of the various rock caverns and inspection programmes for these.

Since the surface parts of a repository will be exposed to repeated freezing and melting, there is reason for SKB to study in more detail how different backfill materials react to repeated freezing and melting. In SKI's opinion, SKB makes a correct assessment when it was decided to carry out these investigations in a full-scale field experiment in an Arctic environment.

It is also important that SKB and Posiva plan and carry out closures of, among other things, boreholes that can be studied and inspected for a long time as is the case with the planned Finnish repository Onkalo.

With reference to newfound knowledge about piping/erosion, buffer erosion and reaction between cement and bentonite, SKI considers that SKB needs to investigate whether the methods for plugging of investigation boreholes with bentonite need to be updated. SKB should also here investigate the issue of whether a respect distance is needed between the investigation borehole and the deposition hole.

In the design of the closure of the borehole and the tunnels of the repository and shaft, it is important that SKB reports on the risk for impact through rock deformation caused by tectonic movements with future glaciations and the consequences that insufficient sealing would have for the long-term safety of the repository. SKI assumes that this will be reported in SR-Site. SKB also needs to report on the lifetime in the short term for material used for sealing the different parts of the repository.

5.6 Retrieval

In this section, SKI presents its comments on Chapter 17 Retrieval in RD&D Programme 2007.

SKB's Report

In its retrieval experiment at the Äspö Hard Rock Laboratory, SKB has demonstrated that it is possible to retrieve a deposited canister through a hydrodynamic method. The disadvantage of this method is that it is time-consuming. SKB has formulated a demand

for the repository to be designed in such a way that it is possible to retrieve deposited canisters before sealing.

Comments by the Reviewing Bodies

The Waste Network Association considers that SKB is unclear with respect to retrieval and claims that SKB must state how far forward in time retrieval is considered to be possible in a safe way and how it is to be financed.

Karlstad University stress with regard to reporting of different strategies for choice of model and principles in Section 4.1 (a theme that recurs at several places in RD&D Programme 2007) that it is not compatible with good scientific method not to report the balances struck when presenting contradictory principles. Most eye-catching are the two principles difficulty of access and retrievability, i.e. the nuclear waste shall be deposited in a way that it remains inaccessible so that it is protected against intentional and unintentional intrusion and that it shall be possible to retrieve the waste if one considers that it is justified to do so. How this necessary balance should be struck is neither reported nor justified in the RD&D programmes.

Milkas (Pettersson) states that retrieval is a given requirement before closure. It is necessary to know this technology. If test operation or ordinary operation for 100 years fails, it will be necessary to retrieve the canisters. There is no planning for this probable scenario. How and where are the canisters to be dealt with subsequently? There should be planning for interim storage. However, retrieval shall not be possible after closure, otherwise the statutory requirements for a final definite solution of nuclear waste will not be met.

Milkas (Hultén) notes that retrievability – a solution that enables transfer of the waste after deposition – has been rejected already in the starting points for SKB's work. Alternatives that offer retrievability have clear disadvantages, the accessibility of the waste is in itself a threat. However, unsolved problems provide support for the idea that a solution with retrievability may be preferable.

The Swedish Society for Nature Conservation and Swedish NGO Office for Nuclear Waste Review (MKG) state that it is clear in the RD&D plan that there are goal conflicts with respect to how accessible the repository is to be for coming generations and that industry has no answer. For example, a possibility for retrievability after closure provides advantages (the discovery of a better final disposal method, the use of the energy content) but also disadvantages (risks of terrorism and nuclear proliferation and unintentional intrusion).

The Municipality of Oskarshamn states that there is no formal requirement in Sweden that it shall be possible to retrieve deposited canisters after closure of the repository. Retrieving canisters is a nuclear activity that requires a licence under the Nuclear Activities Act. The repository shall also be designed in such a way that it is necessary to guard it. The municipality would like to know the view of the authorities on retrievability and its possible importance for long-term safety.

The Opinion Group for Safe Disposal and the Waste Network consider that the Government should give clear directives as to what should apply as function

requirements linked to the non-proliferation demands of the Nuclear Activities Act and the need for safeguards. The Government should request clarification of the risks of unintentional and intentional intrusion in a KBS-repository so that it will be possible to evaluate the suitability of the selected method in this respect.

Uppsala University considers that the repository for spent nuclear fuel shall be designed in such way that it does not need to be guarded. It is good that retrieval of spent nuclear fuel is included as one possible alternative and that SKB has formulated its own requirements on the repository being designed in such a way as to make it possible to retrieve canisters before the repository is closed. This requirement also means that it should be possible to retrieve a large number of canisters at a later stage. This requirement is of great importance in principle since it provides freedom to reuse nuclear fuel in connection with additional energy production if future technology development in the sphere of nuclear reactors permits this.

SKI's Evaluation

SKI wishes here to repeat what was said in the previous RD&D Programme 2004 namely that it is stated in SKI's regulations and general guidelines (SKI, 2002) in section 8 that "The effect on safety of such measures undertaken to facilitate monitoring or retrieval of deposited nuclear material from the repository or to make difficult access to the repository shall be analysed and reported to the Nuclear Power Inspectorate". In the general guidelines on section 8 , it is stated that "Measures may also be called for during construction and operation with the foremost purpose of facilitating retrieval of deposited nuclear material and nuclear waste from the repository, either during the period of operation or after closure". For these measures, it is the case that it should be clear from the safety report for the facility according to section 9 that the measures either have a little and negligible effect on the safety of the repository or that the measures entail an improvement in safety, compared with the case if the measures had not been undertaken".

5.7 Alternative Repository Design – KBS-3H

In this section, SKI presents its comments on Chapter 18 Alternative Repository Design in RD&D Programme 2007.

SKB's Report

SKB is cooperating with Posiva to conduct a programme for horizontal deposition of canisters consisting of three areas: design, demonstration at the Äspö Hard Rock Laboratory and studies of the long-term safety of the concept. SKB considers that the concept has a number of uncertainties and problems, such as piping in the buffer material, strict requirements on the water inflow to the deposition drift, heterogeneous water saturation and cracking in the
distance blocks. It is considered that the water inflow can be reduced with the aid of steel plugs and postgrouting with a megapacker. Other buffer material and other materials than steel in the supercontainer will be studied.

At the Äspö Hard Rock Laboratory, the deposition sequence of the supercontainer has been demonstrated as well as the installation of a short drift-end plug with low pH where the test showed that it was difficult to achieve good adhesion between the plug and the rock surface. SKB considers that long-term tests are needed to study the performance of the compartment plug and how other materials in KBS-3H affect the performance of the buffer.

An international expert group made a preliminary safety assessment of the concept in 2004 and concluded that it could be possible to meet the long-term safety requirements. A preliminary safety assessment for KBS-3H based on site data from Olkiluoto in Finland will be presented by Posiva during 2007.

SKB presents two important differences for the concepts of vertical and horizontal deposition respectively. In KBS-3H, the deposition drifts are long and there is a risk that piping and erosion will occur in the buffer and distance blocks before the bentonite blocks have become water-saturated. KBS-3H has moreover a larger number of steel components, which will corrode and form gas. The iron may also affect the physical and chemical properties of the bentonite.

Comments by the Reviewing Bodies

The Municipality of Östhammar notes that a safety assessment for KBS-3H will not be ready by the time of application since SKB will not have material available for a comparison with KBS-3V before 2012-2013. The municipality, as well as the local safety committee at the nuclear facilities at Forsmark, wishes to know how it is planned to deal with this issue.

SKI's Evaluation

Questions that need to be answered relating to this design are the performance of the distance blocks in the event of uneven watering causing the build-up of swelling pressure in contact between deposition holes and rock, in particular where rock breakout and water inflow can occur. One possible problem that may arise is to get the container into place if spalling/rock breakout takes place in the tunnel and the bentonite, due to the damp atmosphere in tunnel, starts to swell before the container has reached its final position in the 300m-long tunnel.

SKI notes that, in addition to the difference reported in the two designs as regards hydrological and chemical aspects, SKB also mentions the need to study mechanical effect through, for example, high rock stresses and the consequences for the respective design.

SKI entirely agrees about the identified need for further study of rock stresses with reference to SKI's consultants Backers & Stephansson (2008). In 2D-modelling of both the KBS-3V and the KBS-3H method applied to a repository at Forsmark, the consultants have found the most favourable alternative to be KBS-3H. This conclusion is based on the effect of stress changes, swelling pressure from the bentonite and temperature increase being considerably less than for a KBS-3V repository if the deposition drift is oriented parallel with the direction of the greatest horizontal rock stress. The most appropriate repository level with the least effect on the deposition holes

would seem to be a depth of around 450m. The choice of type of repository should, however, as for KBS-3V, be based on a balanced evaluation which also includes other factors.

SKI looks forward to examining (and possibly reviewing) the conclusions that emerge in the preliminary safety analysis to be reported by Posiva during the spring of 2008. SKI expects that the majority of the questions concerning the horizontal deposition design will have been clarified on the basis of the long-term safety requirements.

5.8 SKI's Overall Evaluation of Technology Development

The Rock Line
SKI shares SKB's view that some knowledge is lacking about the extent of the excavation disturbed zone (EDZ) and methods to check and measure it. SKI therefore supports SKB's plans to design and carry out a large-scale measurement test of EDZ around a drill-and-blast tunnel with a realistic rock stress situation and realistic geohydraulic conditions and the plans to appoint a specialist group within SKB for tunnelling and grouting. See also the comments under 5.1.3.

SKI considers that SKB's development of methods for investigations and measurements in deposition tunnels and deposition holes are important since the choice and characterisation of the deposition positions are significant for the initial state of the safety assessment. SKI also considers that it is important that SKB carries out full-scale tests of the methods to ensure efficient application during the design phase. SKB's account mentions nothing about measurements in pilot holes for deposition holes. SKI considers that SKB should clarify how measurements in these should be handled.

SKI notes that SKB now reports plans, methods and programmes for further studies which were requested by SKI when reviewing the previous RD&D programme. SKI notes that SKB intends to restrict leakage into the deposition tunnels to 1 l/min although a limit for leakage to deposition holes (which was stated in SR-Can) is lacking here. SKI further notes that a specified composition of low-pH cement is still lacking and that the effect of additives in cement with, for example, a risk of complex formation, should be clarified. The question is also how chemical conditions in the repository are affected by the quantity of added cement. Another question that SKB should clarify is whether the deposition holes will be grouted and how this will be evaluated in the event of the application of flow criteria.

SKI notes that SKB has made considerable contributions in the 21st century itself or in collaboration with other stakeholders to increase knowledge about sealing of rock by grouting. This is justified since sealing with the aid of grouting at great depth is particularly challenging. The projects conducted by SKB have been sufficient long and have been well-resourced to be able to achieve breakthroughs in the knowledge about different grouts and their properties in the rock. SKB is now better equipped as regards basic knowledge on grouting of rock but now needs to ensure that this knowledge is translated into practical action which can be of use in rock works. This applies to the entire chain from different grout materials, grouting itself and inspection to determine the result and quality of grouting. A lot remains to be done for SKB itself and in

collaboration with other stakeholders in grouting of rock. A continued focus on applied grouting as proposed in SKB's programme is therefore justified.

SKI considers that the choice of reference method for excavation of the deposition tunnels should take place in connection with submission of the repository application, which is also SKB's intention. As a basis for this choice, SKB should carry out a comparative study between the alternatives full-face boring (TBM) and conventional boring and controlled blasting in addition to that already carried at the Äspö Hard Rock Laboratory (The Zedex and Apse experiments). Before the application for a repository has been submitted to the Radiation Safety Authority, SKB should present the advantages and disadvantages of the respective method and justify its choice for preparation of the deposition tunnels. Examples of issues that SKB needs to shed light on in its comparison are cost, flexibility, rock reinforcement, grouting, mapping, deposition, backfill, etc.

In SKI's opinion, the alternative wire sawing of the bench in a deposition tunnel seems to be a return to old obsolete technology in comparison with modern TBM technology, which will probably be further developed before the start of construction of the repository. Furthermore, wire sawing will cause sharp corners with probably high stress concentration and thus increase the risk of rock breakout. The advantage of wire sawing may be that the flat surface facilitates geological mapping and emplacement of pre-compacted blocks as backfill.

Regardless of the method for rock excavation of the chamfer, the upper part of the deposition hole together with the chamfering will result in a complicated geometry and stress situation with the risk of high stress concentrations and accompanying fracture initiation, fracture propagation and spalling failures. New fracture formation can lead to increase groundwater flow in the critical area between the deposition hole and the tunnel floor.

SKB therefore needs to show how the chamfer should be designed and cut to produce the least possible disturbance of the stability situation and minimise the risks for increased groundwater flow in the near-field of the canister.

The Buffer Line
In the Äspö Hard Rock Laboratory, SKB has tested in connection with installation of the buffer at the Prototype Repository how the buffer is to be protected against excessively fast saturation caused by water inflow. In SKI's opinion, SKB should produce a more detailed description of the method to be used during installation of the buffer to prevent excessive saturation of the buffer.

As regards buffer manufacture, SKB considers that it has been demonstrated in the Prototype Repository that the desired buffer density (>2000kg/m3) has been achieved. SKB thus considers that it has been shown that it is possible to manufacture and install buffer components of the MX-80 type with uneasily pressing. However, it can be noted that the specified density has not been achieved in some holes in some of the uppermost disk-shaped rings. None the less, only relatively few components were manufactured for the experiments at the Äspö Hard Rock Laboratory. SKI therefore considers that additional test manufacture may be needed to show that the requisite quality can be

obtained in circumstances resembling serial production. Geometric tolerances and clear acceptance criteria should then be produced and applied. If SKB moreover selects another type of clay, the requirement for new-manufactured buffer components will be still more extensive.

As regards manufacture, SKI can note that SKB has abandoned isostatic pressing as a reference method without giving any reason for this. SKI has previously made comments on SKB's selection of reference methods based on an isostatic press for fabrication of full-scale blocks not being available in Sweden. SKI is also surprised that SKB gives less priority to the fabrication of blocks with isostatic presses.

SKB does not either present a report about its ideas as to what needs to be included in a programme for quality assurance of the buffer. It is therefore essential that SKB produces some form of quality programme for buffer manufacture in the same way as has been done for canister fabrication. A discussion is also needed on the deviations that may occur during fabrication and the possible significance of these deviations for long-term safety, for example heterogeneous conditions in the buffer.

As regards installation of blocks and rings, SKI considers that SKB has shown that installation of the buffer on a full-scale is possible in both a blasted and a full-face bored tunnel through the experiments that have been conducted at the Äspö Hard Rock Laboratory. However, these were limited tests carried out under partly differing circumstances than in the future operation of a repository. SKB should therefore give attention to the difficulty of achieving high quality in the more demanding conditions that exist for routine operation, for example, with remote-operated deposition at the speed required by an actual deposition sequence.

SKI agrees with the Opinion Group for Safe Disposal (Oss) and the Waste Network that SKB should present a complete report on performance requirements for the bentonite buffer, etc.

The Canister Line

SKB has described the overall requirements made on the canister in the report on design premises for the canister. In summary, SKI considers that SKB needs to continue to develop design premises to enable them to provide a better basis for choice of materials, design and fabrication inspection of the canister as well as for long-term safety. Furthermore, SKB should carry out further studies on the possibility of shearing from an earthquake and isostatic load from glaciation occurring at the same time.

SKB's planned programme for design premises for selection of materials includes the creep properties of copper; the effect of hydrogen on copper, cold working effects on copper and stress corrosion in the copper shell. In SKI's opinion, some questions remain regarding the credibility of creep models. SKI considers that SKB when producing models for copper creep should take into consideration the circumstances that exist in the repository, i.e. low temperatures and low loads.

SKI further considers that SKB's approach to investigate the effect of hydrogen on the mechanical properties of copper and cast iron and to investigate the quantities of hydrogen that can be permitted in the canister is a step in the right direction. SKI also

considers that it is positive that SKB has now realised the importance of reviewing its arguments on stress corrosion and is planning to carry out more tests and perform stress analysis of the copper shell and also review the arguments from a chemical viewpoint that have been discussed in this area.

Fabrication of the insert, subsystem insert in the production system for canister fabrication, consists mainly of two processes: casting of the insert and non-destructive testing. In summary, SKI considers that it remains for SKB to show that canister parts can be fabricated at the rate and quality stipulated by SKB. It is urgent, among other things, to develop fabrication methods for fabrication of PWR inserts if SKB is to be able to abide by its timetables. SKB has investigated and evaluated a number of methods in the development of non-destructive testing. It is important that SKB now decides in more detail the combination of testing methods needed to obtain an appropriate quality assurance.

With regard to sealing and non-destructive testing, SKI considers to sum up that SKB should show how defects such as joint line curvature and oxide inclusion can be avoided in the FSW weld. Automation of the weld process is also very important. As regards non-destructive testing, SKB needs to show in more detail how a combination of non-destructive testing methods together can find the fabrication defects which may occur. SKB also needs to continue working with a process to show this with the aid of a third-party body.

With regard to fuel in the encapsulation plant, SKB should show how it is made certain that the information on the fuel is correct before it is prepared for encapsulation. Checks should have been carried out already at Clab. Visual verification shall according to plans take place at the encapsulation plant before the steel lid is lifted into place after the canister has been filled with fuel. Nothing has been mentioned about how this is to be done or the way in which it is to be documented. SKI considers this to be a critical point in handling since this is the occasion on which one moves from handling individual fuel elements to the canister being the smallest unit.

As regards transport between the encapsulation plant and the repository, SKI still lacks reasoning on the design of the transport operation. In the event of siting of the repository at Laxemar, SKI wonders if it will be necessary to shut the road to Laxemar. In the event of siting of the repository at Forsmark, SKB needs to provide an account of how transport between the harbour at Forsmark and the repository will take place.

The Backfill Line

As regards the choice of material for the backfill, SKI considers that it is important that SKB shows that there is a sufficient quantity of data for Friedland clay or the clay selected by SKB to enable its properties and performance to be evaluated. SKI also considers that SKB should more clearly report on how the requirements for compressibility for the backfill affect the choice of material and design of the backfill before the application for the repository is submitted. SKB also needs to produce a quality programme for the backfill for fabrication and emplacement in the deposition tunnels.

In SKI's opinion, it is important that SKB presents the timetable for testing and demonstration of the backfill on a full scale in the Äspö Hard Rock Laboratory after pilot tests at the Bentonite Laboratory. SKB should state how tests and expected results will be adapted to the timetable for the application with the appurtenant safety assessment. As both the Municipality of Oskarshamn and SSI have pointed out, it is of the utmost importance that SKB therefore demonstrates that it can handle the buffer, backfill and installation of plugs with the range of hydrological and geochemical conditions that can be expected to occur at the selected site.

The Closure Line
SKI considers that it is important that SKB present credible reference methods in its application with regard to requirements on models and material for sealing of the different rock caverns as well as control programmes for these.

Since the surface parts of the repository will be exposed to repeated freezings and thaws, it is motivated for SKB to study more closely how different backfill material reacts to repeated freezings and thaws. SKI therefore considers that SKB makes a correct assessment when it was decided to carry out these investigations as large-scale field experiments in an Arctic environment.

Taking into account newfound knowledge on piping/erosion, buffer erosion and reaction between cement and bentonite, SKI considers that SKB needs to investigate whether the methods for plugging investigation boreholes need to be updated. SKB should here also investigate the issue of whether a respect distance is needed between the investigation boreholes and deposition holes.

In the design of the closure both of boreholes and the tunnels of the repository, it is important that SKB reports on the risk for impact through rock deformation caused by tectonic movements in connection with future glaciations and what the consequences of insufficient closure will be for the long-term safety of the repository. SKI assumes that this will be reported on in SR-Site. SKB needs also to report on the lifetime in the short term for the materials intended to be used for closure of different parts of the repository.

Retrieval
According to SKI's regulations and general guidelines, the impact on safety of measures undertaken to facilitate surveillance or retrieval of deposited nuclear material or nuclear waste from the repository or to make difficult access to the repository is to be analysed and reported to the Nuclear Power Inspectorate, SKI. It is stated in the general guidelines that measures may also be taken during the construction and operation with the foremost purpose of facilitating retrieval of deposited nuclear material and nuclear waste from the repository, either during the operational period or after closure. In the case of these measures, it should be clear from the safety report for the facility that these measures either have a small and negligible effect on the safety of the repository or that the measures entail an improvement in safety, compared with the case of the measures not having been undertaken.

Alternative Repository Design – KBS-3H
Questions that need to be answered for the concept horizontal deposition are the performance of the distance block in the event of uneven watering causing uneven

build-up of swelling pressure in the contact between the deposition hole and the rock, in particular where rock breakout and water inflow can occur.

SKI notes that, in addition to the reported differences in the two designs 3V and 3H relating to hydrological and chemical aspects, SKB also needs to investigate the situation relating to mechanical effect, for example, through high rock stresses and its consequences in the respective design. SKI has also had consultants investigate the effect of rock stresses on the two designs at a repository facility in Forsmark. The least effect on the repository occurs if the deposition tunnels are oriented parallel to the direction of major horizontal rock stress.

6 Safety Assessment and Scientific Research

6.1 Safety Assessment

This section presents comments on Chapter 20 in RD&D Programme 2007 on the safety assessment.

SKB's Report

SKB presents a ten-step methodology for implementation of safety assessment, which has been developed for the safety assessment SR-Can. In broad outline, the ten steps aim to define the system, to describe external conditions and internal processes which are expected to affect the system, to select safety functions and input data for calculations, to analyse the development of the system, identify and analyse scenarios, as well as finally to report on compliance with requirements and to identify the need for further work. All planned further development of safety assessment methodology is to be used in the coming safety assessment SR-Site. SR-Site shall be used as supporting documentation for SKB's future application to construct a repository for spent nuclear fuel. The development of methodology prior to SR-Site will mainly consist of updates and further development of the tools applied in SR-Can.

Important new developments in SKB's safety assessment methodology include the in-depth use of safety functions based on performance indicators with adherent criteria. The safety functions also serve as the basis for a partly new method for selecting scenarios for the safety assessment. Another area, which is being developed, is quality assurance of data, models, use of experts etc. SKB is working on producing quality plans for safety assessment and control documents.

Comments by the Reviewing Bodies

Karlstad University notes that SKB has, in a very decisive way, developed the present KBS design to a very impressive level of technology in many respects. However, with a more concrete approach in material-related issues for waste canisters, bentonite buffers and backfill of tunnels and shafts, a number of safety problems have come to the fore again. These include information on rapid corrosion of copper under certain conditions, degrading of bentonite buffers (including by illitisation), gas formation in the repository and difficulties in long-term sealing of backfill in tunnels and shafts.

The Local Safety Committee at Oskarshamn nuclear power plant points out, with respect to the future safety assessment, SR-Site, that SKB states that there is sufficient knowledge about the major part of the processes in the repository to meet the needs of the safety assessment. The Safety Committee considers that there cannot be any gaps in knowledge as far as the safety assessment is concerned but all processes must be analysed. The Local Safety Committee considers that the safety assessment constitutes a very important document in SKB's application for a licence for the repository. Like the Municipality of Oskarshamn, the Local Safety Committee considers that SKB and the authorities must agree on a "minimum level" for the research and development that is to have been completed when the application is submitted in 2009.

The Local Safety Committee wishes to particularly emphasise the importance of the safety aspects and thorough analyses of the selection of site for a repository for spent nuclear fuel. In this context, it is also important that analyses and other technical supporting documentation are available to and comprehensible for different groups in society.

The Local Safety Committee at the nuclear power facilities in Forsmark consider that it is of the greatest importance that safety, supported by careful analyses, is the factor that determines the choice of site for the repository for spent nuclear fuel.

The Local Safety Committee supplements the municipality's statement with the comment that SKB should present a clear report on the meaning of SSI's and SKI's regulations in the future Swedish version of SR-Site.

The Swedish Society for Nature Conservation and the Swedish NGO Office for Nuclear Waste Review (MKG) note that closer study of the research plan gives the impression that a large number of issues that are important for the future safety assessment in the application (SR-Site) will not be sufficiently investigated prior to submission of the application. These include the issues taken up in Part III of SKB's Report and which need to be answered to be able to carry out the design, deposition and the backfill and closure of the repository safely. It applies to an even greater extent to the issues dealt with in Part IV relating to long-term safety.

The Swedish Society for Nature Conservation and MKG also point that that a central issue is how much of the research and development work which is to serve as the basis for the long-term safety of the repository can be left until after the application has been submitted.

The Municipality of Oskarshamn points out that the safety assessment SR-Site will constitute the scientific supporting documentation for the decision of the municipalities, the authorities (SSI/SKI) and the Government on a geological repository for spent nuclear fuel. The municipality considers that SKB and the authorities must be in agreement on a "minimum level" of the research and development that is to have been completed by the time of submission of the application in 2009.

The municipality further notes that the canister with its copper shell is the most important engineered barrier in the safety system. Copper corrosion has come into focus after two researchers showed copper corrosion in anoxic conditions. It is important that these research findings are followed up by the authorities so that no questions remain when the licence application is to be examined. The analysis of long-term safety starts from the existing state when the repository has just been closed. This requires in turn knowledge of the state that existed prior to the construction of the repository and how it was subsequently affected.

SSI considers that the ten-step methodology proposed by SKB is a good starting point prior to SR-Site. This conclusion is mainly based on the inter-authority review of SR-Can (SKI, 2008). SSI identifies a number of points where SKB needs to develop the methodology: a) the methods for safety assessment should be justified in a more coherent way b) safety functions and adherent criteria should be better justified, c)

the completeness of the scenarios should be reviewed, for example, taking into consideration excluded FEP, d) uncertainty and sensitivity analyses should be systematically carried out and linked to evaluation of optimisation and best available technology, e) handling of dilution and transportation processes should be improved in the calculations of dose and risk, f) complete routines for quality assurance of all parts of the analysis should be implemented.

SSI considers that SKB needs to make a new report on its programme for method development in safety assessment in the ongoing consultations for the site investigation stage. This is because it has not been possible to use RD&D Programme 2007 to report measures for reasons of time due to the authorities' review of SR-Can.

The Municipality of Östhammar points out the importance of the safety assessment SR-Site being in Swedish when it is to be reviewed by the municipality.

SKI's Evaluation

SKI notes that it is not meaningful here to go into any particular details in SKB's safety assessment methodology because a detailed review has recently been conducted (SKI, 2008), and there is therefore no complete report on these issues in RD&D Programme 2007.

Like SSI, SKI considers that a dialogue should take place within the consultations between SKB and the authorities on different parts of SKB's safety assessment methodology. The aim should be to achieve a common view of the application of methodology prior to SR-Site to enable the review to focus on issues of direct relevance for safety and radiation protection. With the establishment of the new Radiation Safety Authority, there may be reasons to report on clarifications of the application of the current regulations in the consultations. SKI
considers that the improvement proposal (six points) that SSI identified in its review constitute a good starting point for the continued dialogue with SKB. These points also serve as a good summary of the comments of the two authorities on methodological issues in the SR-Can review.

SKI considers that one of the most important components in the methodological development that has taken place is the use of well specified and well supported safety functions to govern the direction and form of the assessment. This is a more useable basis for identifying scenarios than lists of processes, properties and events (FEPs) of greatly varying significance for safety and radiation protection. SKI considers, however, that the FEP methodology still needs to be used as a complement. The scenarios selected mainly based on safety functions should also be checked against available FEP databases.

SKI agrees with the Municipality of Oskarshamn and the Local Safety Committee at Oskarshamn nuclear power plant that a certain minimum level of knowledge and experience must be complied with prior to SR-Site. However, it is difficult in advance to define detailed requirements on the report in particular areas since the significance for safety depends on the context in the complete safety assessment. However, SKI plans through the expert groups Brite, INSITE as well as in different research projects

to follow up a number of gaps in knowledge identified at the review of SR-Can as soon as possible.

SKI can, like Karlstad University, note that previously unknown problems with the buffer have been noticed for the first time in SR-Can. A robust basis is needed here for the controlled handling needed for consequence calculations and some form of report that shows that buffer erosion cannot be significantly reduced by alternative designs of the engineered barriers.

SKI has for some time had some concerns that SKB's quality work in safety assessment has not been sufficiently well defined and that the level of ambition regarding the application of quality programmes and controlling documents is not the same everywhere in SKB's organisation. To remedy this, SKI has carried out certain reviews of SKB's quality work. It has also started a dialogue with SKB about these issues in the consultations. We can now note that development is moving in the right direction. However, it is important that SKB as soon as possible adopts a final quality programme for SR-Site with the necessary controlling documents, etc. SKB also needs to create the best possible prerequisites for application of the quality programme and to follow up its implementation systematically. To the extent that quality deficiencies are noted, they need to be documented and concrete measures should then be taken.

6.1.1 SKI's Overall Evaluation - Safety Assessment

SKI notes that SKB has developed a methodology around safety assessment with an appropriate design in relation to SKI's and SSI's regulatory requirements. This conclusion is based on SKI's and SSI's joint review of the safety assessment SR-Can. It is very important that SKB prior to SR-Site raise the level of ambition for quality work in connection with safety assessment. SKI considers that the proposed consultations between the authorities and SKB could be used for a continued dialogue to avoid unnecessary lack of clarity around methodological issues, interpretations of regulatory requirements and reporting forms.

6.2 Climate Evolution

In this chapter, SKI presents comments on Chapter 21 Climate Change in RD&D Programme 2007.

Climate changes can be expected in the more than hundred-thousand year time perspective in which the safety of the repository is to be analysed. A good understanding and a good description of conceivable future climate changes is therefore essential. To be able to apply this knowledge in a safety assessment, it is also necessary to be able to quantify the effect of these changes on the performance of the repository. Knowledge about what has taken place at an appropriate site during previous climate cycles is an important puzzle bit for understanding future climate changes. It is important to compile this knowledge and use it in the description of the impact of the climate on a repository. In SKI's opinion, climate issues have been integrated into the safety assessment in a good way in the safety assessment submitted to SKI in November 2006 (SR-Can).

In RD&D Programme 2004, SKB presented a comprehensive programme of research in the field of the climate in comparison with previously programmes. Special consideration was given to shoreline displacement, the occurrence of postglacial earthquakes, erosion and hydrological systems of the inland ice sheet and, to a limited extent, permafrost.

SKB's Report

In this RD&D programme, SKB focuses its research measures in the field of the climate on identifying and understanding conditions and processes in three different climate domains, the temperate, permafrost and glacial domain, which are important for the repository and its safety. SKB also mentions the importance of investigating the significance of the duration of climate domains and including conceivable transitions between these.

SKB's approach is based on first designing a main scenario that shows how climate domains follow one another during a glacial cycle of around 100,000 years. Two variants of main scenario have been selected and analysed. The first variant is a reconstruction of how climate-related parameters varied during the most recent glacial cycle Weichsel. In the other variant, a warmer climate dominated initially, caused by an increased greenhouse effect which can entail melting of the Greenland ice sheet. This leads to a global rise in the sea level which may affect both the coastal sites Forsmark and Laxemar.

In addition to the main scenario, SKB chooses a number of alternative site-specific climate evolutions of more extreme climate in terms of amplitude and extent in time. This makes it possible to analyse the performance of the repository in the event of, for example, thicker inland ice or deeper permafrost than in the main scenario.

SKB's climate programme is divided in this RD&D report into the sub-programmes inland ice dynamics and glacial hydrology, isocratic changes and shoreline displacement, permafrost growth and climate and climate variations. However, SKB does not mention anything about glacial erosion. Under the heading of the hydrology of the inland ice sheet, SKB mentions an established contact with Denmark's and Greenland's Geological Surveys where the Greenland ice sheet is intended to be used as an analogy of the Scandinavian ice sheet.

Comments by the Reviewing Bodies

Chalmers University of Technology means that SKB's intention to investigate the effect of climate change on a larger scale than is the case today due to the current climate debate is hardly meaningful. In the previous studies, the climate changes that could be expected within a period of 100,000 years have been dealt with, including a couple of ice ages and intervening increase in temperature. What is happening today with global warming does not constitute any greater difference as regards the global effects although it does entail faster change and large local variations. Regardless of how future changes take place, the general uncertainty of the forecasts and the impact of possible variations are of great interest.

The university notes that rain is not discussed in the chapter on climate evolution, for example. The forecast of an increased amount of rain in Sweden within the coming period and in a more long-term perspective needs to be included according to Chalmers. Uncertainty factors related to how much the sea level will rise should be studied in more detail since both planned repository facilities are in coastal locations. In general, one should be very careful about discussing climate as a predictable cyclical phenomenon.

The environmental organisation Friends of the Earth Sweden notes that if the betonies is eroded away due to a large inflow of groundwater, the risk of corrosion of the canister increases. A scenario of this kind is possible after a glaciations when the land surface is pressed down below the surface of the sea. Strong isocratic uplift can cause earthquakes and the consequence of these may be formation of new fractures in the bedrock.

Milks (Holton) asks the question of the importance and effect on the rock that the repository as such has through its natural properties and balance up to this point being put out of action. Milks considers this question to be important although it is not taken up in RD&D Report 2007 to the expected extent. The report does not give any examples of rock, which has lost its integrity within a short time through passing through a glaciation period, as far as Milkas can see. Has this problem been dealt with elsewhere? Or is reference material perhaps lacking? Or is it because this aspect has simply not been considered as a problem in the research programme? Unless Milkas has missed this reference, it is not mentioned either in SR-Can.

The Swedish Society for Nature Conservation and the Swedish NGO Office for Nuclear Waste Review (MKG) ask the question of how great the effect will be on a repository during glaciations (additional loads from the ice, hydrology, microbiology, isostatic uplift, depression and future climate changes. The organisations point out that there are new findings that consider that the sea level could be raised by as much as 50 metres if the Greenland ice sheet and considerable parts of the ice in Antarctica melt. If this happens during a thousand-year period, how will it affect the repository? How will a possible increase in rain affect groundwater conditions in a repository? Is there a risk that global warming will cause a new ice age relatively quickly?

The Municipality of Oskarshamn's expert Pereira considers that it seems reasonable that the experimental programme associated with the Greenland Ice should be given top priority and a considerable part of SKB's climate evolution resources. Pereira therefore considers that it is not sufficient to write that "SKB is continuing to monitor the possibilities in this area" (page 238, first paragraph, page 246 in SKB TR-07-12).

Pereira also asks the question of how the permafrost affects the upper parts of the repository which are to be backfilled (boreholes from surface, the ramp, etc.). Pereira considers that this part of the programme should be given priority bearing mind the planed assessment of the long-term safety.

The Municipality of Oskarshamn notes that it is evident from the RD&D programme that SKB still has a lot to investigate before the application is submitted in 2009.

The Geological Survey of Sweden considers that the importance of the permafrost for the flow and composition of the groundwater appears to have been assessed on a very conservative basis and the programme for further studies appears reasonable.

Uppsala University notes that SKB in RD&D Programme 2007 places great weight on glacial conditions and their possibilities of inducing large earthquakes. It is natural bearing in mind that major earthquakes, greater than magnitude 8, which are known from the end of the last ice age and it is probable that several glaciations are to be expected during the lifetime of the repository. SKB is currently pursuing research that increases understanding of the processes underlying glacial earthquakes. This commitment should continue, in particular bearing in mind the fact technology development that is taking place in the sphere of modelling of the earth's response to a glaciation just now. The same applies to the possibility of modelling and understanding the earthquake process as well as the hydrological conditions during a glaciation. These progresses together should have major significance for understanding of the processes underlying glacially induced earthquakes.

The Science Council notes that there has been a marked improvement in the state of knowledge since RD&D Programme 2004 although it points out that SKB should more clearly report the quality of the models used in simulations of groundwater flow, microbial activity, gas formation/gas solution, methane ice formation and salt exclusion. The Science Council also considers that it is difficult to anticipate and the pace at which the climate evolves. SKB's strategy of including extreme situations with two reasonable main scenarios is a reasonable method of work.

The Municipality of Östhammar and the Local Safety Committee at the nuclear facilities at Forsmark point out that SKB has not investigated compression of the rock's pores and fractures in connection with a glaciation and how this can affect water flows in the rock and hydrochemical conditions that control corrosion of the copper canisters. The municipality and the Safety Committee therefore ask the question of whether SKB will study compression of fractures and pores in connection with glaciation and also whether there are plans for field studies of bentonite that has undergone glaciations.

SKI's Evaluation

Initially, SKI can note that SKB has made great progress in understanding how climate changes affect a repository, in particular for the forthcoming glaciations.

Inland Ice Dynamics and Glacial Hydrology
SKI notes like SKB that a bottom-frozen ice produces additional hydrostatic pressure at repository depth because of its weight while a bottom-melting ice sheet also provides an addition to groundwater flow through the very ion-poor and oxygen-rich meltwater that forms under the ice. When the water reaches repository depth, it can affect the properties of both the buffer and the backfill (see sections 6.6 – 6.7). In addition to the effect of the glacial meltwater, rock stresses are also affected in the repository area which could entail reactivation of fracture zones in the form of glacial earthquakes, see section 6.8.5.

The inland ice simulation carried out shows a maximum expected ice thickness of 2,600m at Laxemar and 3,200m at Forsmark. SKI's consultant Holmlund (2008)

considers this result to be reasonable based on observations from Greenland and the Antarctic although there is reason for SKB to describe the model better and the simplifications on which it is based.

In the review of SKB's safety assessment SR-Can, SKI's and SSI's expert group SIG ("Site Investigation Group") urged SKB to use experiences from natural analogies such as the Greenland ice sheet. SKI therefore views with satisfaction SKB's plans to use the aforesaid analogy in particular concerning questions how an ice sheet affects groundwater flow and chemistry around a repository. However, SKI lacks a reference to work in process linked to the Greenland ice sheet.

SKI also supports Holmlund's comments that the issue of glacial hydrology needs to be better integrated with the handling of climate-related issues and to be described better. Holmlund also states that differences in assumptions between the calculations for glacial hydrology and the development of inland ice sheets should be clarified. SKI also considers that SKB should deal with the uncertainties that arise given that most process studies have been carried out on relatively small glaciers while most modelling relates to large-scale inland ice sheets, which SKB has also observed.

SKI also considers that SKB should link the measures to increase understanding of the hydrological conditions in and around an ice sheet and how the ice sheet affects the groundwater flow to measures described in SKB's Chapter 26.2.7 Reactivation – Movement along Existing Fractures. Different groups worked with these issues in SR-Can and knowledge from integrated THM models was not made use of in the modelling of the glacial hydrology.

Isostatic Changes and Shoreline Displacement
SKI agrees with SKB that shoreline displacement is the most important climate-related process for a repository in the temperate climate state. SKI also notes that SKB has initiated a project where Global Isostatic Adjustment (Gia) modelling is a key part which is intended to understand and quantify shoreline displacement. Based on simulations, SKB considers that isostatic uplift at Oskarshamn and Forsmark during the next 40,000-50,000 years will be in the range of 20-35 metres, which SKI has no reason to call into question.

In the climate scenario with an increased greenhouse effect, SKB considers that melting of the Greenland ice sheet corresponds to a global increase in the sea level of approximately seven metres but that isostatic uplift will still continue at both Forsmark and Laxemar. The assumption on the level of melting cannot be called into question either. IPCC (2007) assumes that the Greenland ice sheet may melt within 1,000 years and cause the aforesaid rise in the sea level. The isostatic uplift at Forsmark during the same time period will amount to 6 metres and at Laxemar 1 metre. If the ice sheet in the western Antarctic collapses, this will add another 5 metres to the rise in the sea level (IPCC, 2007). The thermal expansion of the world seas may in the longer term mean an additional rise in sea level. SKI notes that the consequences of the above assumptions mean that both Forsmark and Laxemar will be under the surface of the Baltic Sea within 1,000 years. This could possibly lead to penetration of groundwater with higher salinity in the repository.

Permafrost Growth
SKI notes that SKB has adopted the comments made on RD&D Programme 2004 and now reports results from calculations of permafrost depth and its possible effect on the buffer for the siting alternatives Forsmark and Oskarshamn. In the calculations carried out, SKB considers that the permafrost in the main scenario to reach 250 metres at the deepest at Forsmark and 160 metres at Laxemar. SKI considers like SKI's and SSI's expert groups during the SR-Can review (Site Investigation Group) that SKB should evaluate the geochemical and hydrological changes during permafrost in more detail, as well as the uncertainties associated with these. The importance of the permafrost period is underlined by this being expected to be longer than the glacial period during a glacial cycle and to occur during a previous phase of fuel dissolution.

SKI's consultant Holmlund (2008) considers that SKB's calculations of permafrost involve certain uncertainties concerning both models and input data, which are not reported in a clear way. One of the uncertainties is that the air temperature of central Greenland probably cannot be estimated more exactly than ± 10ºC, which would considerably affect the depth of permafrost if it persisted for thousands of years. SKI agrees with Holmlund that SKB should better report and evaluate uncertainties in connection with permafrost calculations to, among things, be better able to evaluate the significance of the large safety margins referred to by SKB.

SKI also agrees with the comments which Holmlund made in the review of SR-Can that SKB did not sufficiently discuss the risk of considerable glacial erosion at both candidate sites. Bearing in mind that the analysis spans a million years, this cannot be excluded a priori. The extent of the erosion depth for the whole period depends on the erosion potential and the period of glacial erosion during each cycle. Holmlund does not exclude erosion rates of around 1 mm/year during erosion periods of 20,000 – 30,000 years. This would entail an erosion depth that could considerably affect the calculations of permafrost and the possibility of avoiding freezing of the buffer towards the end of the period covered by the safety assessment.

SKB should report on the consequences if a freezing of both the buffer and backfill nevertheless takes place. SKI notes that SKB intends to study the effect of the backfill material freezing in deposition tunnels and ramps.

Climate and Climate Variations
SKI notes that the point made in the review of RD&D Programme 2004 that SKB should report more clearly on how it made sure that the selected climate evolutions shed light on the most important climate-related stresses on, in particular, the performance of the engineered barriers, for example, hydrostatic pressure, groundwater chemistry and rock movements have now been addressed.

SKI also supports SKB's plan to carry out two projects with the aim of obtaining a more nuanced picture of what the climate might be like in Scandinavia during specific periods of a glacial cycle for example periods with a cold and very dry climate which favours the growth of permafrost.

6.3 Fuel

In this section, issues are discussed relating to, inter alia, characterisation of spent nuclear fuel as well as its reaction with groundwater. SKI's comments refer to Chapter 22 Fuel in RD&D Programme 2007.

6.3.1 Characterisation of Spent Fuel

SKB's Report

SKB calculates that the total quantity of PWR and BWR fuel that needs to be disposed of in the Swedish programme amounts to 12,000 tonnes. In addition, there is a small amount of MOX fuel from Ågesta and fuel residues from Studsvik.

SKB notes that differences between the inventory for different burnups and fuel types are marginal from a safety assessment perspective. New calculations have been done for the radionuclide inventory in MOX-fuel. SKB may make new calculations for fuel with a high burnup. SKB has also studied non–radioactive fission products.

With respect to the gap inventory, SKB has studied the prerequisites for radiation-induced diffusion increasing the gap inventory. However, calculation shows that this process is only of marginal importance for periods of up to one million years. In the coming period, SKB will investigate how the gap inventory is affected by an increase in average burnup.

Comments by the Reviewing Bodies

SSI considers that SKB should deepen its understanding of how radiation-induced diffusion can change the gap inventory as a function of time. It is further pointed out in SSI's review that studies of the effects of helium production in the fuel should apply to all fuel types not only fuel with a high burn-up and MOX fuel as stated in SKB's programme.

SKI's Evaluation

SKI considers that the plans of the nuclear power plants to increase burn-up mean that more data will be needed for fuel with a high burn-up. The importance of burn-up cannot be determined without adequate supporting documentation. Future safety assessments should represent fuel with a probable distribution of burn-ups and not only the average burn-up of the fuel which is now stored at Clab. There are reasons to suspect that a high burn-up affects, among other things, the fuel structure and physical properties. This may mean an increased contact surface for fuel in contact with groundwater and that the proportion of radionuclides which can be readily available for dissolution is greater than for the fuel studied most to date. It is therefore good that SKB is planning leaching tests with fuel with burn-ups of around 50 MWd/kg U. Even if the proportion of MOX fuel is small in the Swedish programme, supporting documentation is also needed in this case, which can show that this fuel type has been handled in a reasonable way in future safety assessments.

SKI agrees with SSI that certain additional measures may be required to evaluate effects of radiation-induced migration of radionuclides as well as the significance of helium production in the fuel. As pointed out in SKI's and SSI's joint review of SR-Can, a more transparent and detailed justification of these processes is needed. It was also pointed out in this review that SKB needs to review the supporting data and justification of the percentage proportion of different radionuclides which are assumed to be available for fast dissolution in the safety assessment calculations (the "gap inventory").

6.3.2 Dissolution of Spent Fuel in Groundwater

SKB's Report

During the completed RD&D period, SKB has, itself and in international collaboration, conducted experiments to study how fuel dissolution is affected by radiolysis. The significance of this issue is linked to radiolysis creating oxidants which can speed up dissolution. Experiments have been conducted with material with wholly different radiation fields such as spent fuel, alpha-doped uranium dioxide and ordinary uranium dioxide. Alpha-doped uranium dioxide simulates a fuel which is some thousands of years old without the original strong gamma radiation field. One important result is that hydrogen and iron (II) have a capacity to consume oxidants produced through radiolysis such as hydrogen peroxide.

Tests at Studsvik with spent fuel indicate that fuel dissolution reduces sharply over time. This conclusion is based on measurements of the release of non-redox sensitive fission products, which can be used as a measure of the dissolution rate. The concentrations of radio-sensitive nuclides decline with time to values equivalent to the solubility of their reduced oxides. The concentrations of plutonium and neptunium are even lower, which is interpreted as possible co-precipitation of neptunium and plutonium with uranium.

Bearing in mind the plans to increase average burnup of fuel at the Swedish reactors, SKB plans to carry out dissolution experiments with fuel with high burnup in the coming period (higher than 50 MWd/ kg U). Measurements of fuel dissolution under in-situ conditions will also be carried out at the Aspö Hard Rock Laboratory with the Chemlab II probe.

Work to understand fuel dissolution mechanisms in the presence of dissolved reducing substances will also be continued through experiments and modelling studies. Fuel model uncertainty will also be evaluated within the EU Micado project.

Comments by the Reviewing Bodies

SSI considers that SKB has identified the most important issued for fuel dissolution rates in RD&D Programme 2007 but the programme needs to be deepened in certain fields prior to the licence application.

SKI's Evaluation

SKI considers that SKB has in general a good research programme in the field. Like SSI, SKI considers, however, that supplements and a more in-depth approach may be

necessary, in particular if buffer erosion also needs to be included in future safety assessments (buffer erosion may entail a deterioration in the long-term isolating ability of the canister, which increases the importance of the fuel dissolution rate). This applies, for example, to the time-dependence of fuel dissolution and analysis of how controlling mechanisms are changed over a long time. It has, for example, been suggested that radiolysis eventually ceases to play a predominant role for fuel dissolution in time (Stenhouse et al, 2008). In connection with the review of SR-Can (SKI, 2008), SKI and SSI pointed out that understanding of fuel dissolution mechanisms needs to be better demonstrated by model studies. Model studies are needed, for instance, to show the effect of conceptual uncertainties. Furthermore, it needs to be shown that a link has been made between the analyses of fuel dissolution and the development of the repository.

SKI considers that it is good that SKB is planning to carry out in-situ experiments with spent fuel (The Chemlab II probe). There is a general need to demonstrate to a reasonable extent that laboratory experiments and modelling studies do not produce significantly different results compared with experiments in a realistic repository environment. Demonstration experiments of this kind need to be planned so that data is available at important dates for decision-making for the Swedish programme.

6.3.3 Speciation of Radionuclides, Criticality-related Issues, and Issues relating to Colloid Formation

SKB's Report

With respect to chemical processes for individual radionuclides studies of redox kinetics are planned for radionuclides in oxidised form, as well as studies of precipitation of radium with barium. Since the chemical properties of most radionuclides depend on redox conditions, studies of processes are in progress that check redox in a damaged canister.

SKB plans to make new criticality calculations to investigate the importance of casting defects in the canister insert and to obtain supporting documentation for MOX fuel as well.

Comments by the Reviewing Bodies

SSI considers that SKB needs to investigate whether removal of the buffer and canister material can entail an increased risk of criticality due to changed fuel geometry.

SKI's Evaluation

SKI considers that it is good that co-precipitation of Ra-226 with barium sulphate will be studied during the coming RD&D period. A considerable effect of co-precipitation processes for top doses of Ra-266 was indicated, for example, in the SR-Can interim report (SKB, 2004). Since Ra-226 is a dominant nuclide within SR-Can, a major impact on the final result of the safety assessment cannot therefore be excluded. According to SKI, it is therefore important that supporting documentation is produced, which shows the credibility that can be attached to co-precipitation processes in the context of safety assessment.

SKI considers that the supplements in the field of criticality referred to in RD&D Programme 2007 are important. SKI furthermore agrees with SSI that certain additional measures will be required to show that criticality due to changed geometry and redistribution of radionuclides is not an important process. A well-rounded discussion is lacking in SR-Can about this risk. When the studies about this issue previously referred to were carried out, there was no knowledge, for example, that buffer erosion may need to be taken into account.

SKI considers finally that more work is required within the field of colloid formation of radionuclides. Since the case with buffer erosion is still apposite, there is a risk that the buffer cannot filter colloids as has previously been envisaged. It is, for example, known that plutonium and possibly other tetravalent actinides can form colloids through polymerisation or formation of nanoclusters of crystalline plutonium dioxide (Stenhouse et al, 2008).

6.4 The Canister as a Barrier

In this section, SKI presents comments on Chapter 23 The Canister as a Barrier in RD&D Programme 2007.

6.4.1 Initial State

By initial state, SKB means that state of the canister at the time of deposition, which is described in the safety assessment with the aid of a set of variables.

SKB's Report

SKB states that analyses of the insert have been conducted as part of the work to produce acceptance criteria for fabrication of the nodular iron insert. In SKB's opinion, these analyses indicate that the insert is very defect-tolerant. SKB also states that residual stress measurements were performed on a lid weld carried out by friction stir welding, which show that residual stresses are well below the yield strength of the weld metal. SKB intends to update the damage tolerance analysis for the nodular iron insert and to carry out additional determinations of residual stresses in sealing welds carried out by friction stir welding.

SKI's Evaluation

SKI is positive to SKB's intention to continue work on damage tolerance analyses. These analyses need to provide sufficient guidance for the required checks with NDT that the canister will be subjected to. SKI also welcomes additional investigations of residual stresses after welding of the copper lid to the copper cylinder and, in particular, the significance these may have for the occurrence of damage due to stress corrosion or creep.

6.4.2 Canister Processes

Deformation of the Canister
This section presents SKB's activities intended to determine the strength of the canister (both the nodular iron insert and copper shell) exposed to an isostatic load as well as shearing from an earthquake load.

SKB's Report

SKB has carried out a probabilistic analysis of the insert with a statistical distribution of cast iron defects to determine the probability of (local) collapse when the canister is exposed to increased pressure corresponding to a glaciation load. SKB states that at an external pressure of 44 MPa, the probability of failure was insignificant (about 2E-9), even when several conservative assumptions were made. Furthermore, SKB states that the probabilitistic analysis carried out only considers local collapse and that a total collapse of the canister will occur at a much higher pressure. SKB claims that this is confirmed by the large-scale experiments being carried out by two shortened canister segments of full diameter. Analyses performed in connection with these experiments show, according to SKB, that shortened canisters do not offer any advantages from a strength viewpoint.

SKB states that work is under way on deterministic analyses of total collapse of the canister with and without defects and that these results will serve as the basis for acceptance criteria for non-destructive testing of canister inserts.

SKB has also performed analyses of the effect of shearing from an earthquake load. According to SKB, these analyses show that plastic strains of over 1% occur in the copper shell after only 10 cm shear in all cases with sodium and calcium bentonite. The maximum plastic strains in the copper shell and the insert are in all cases studied greater with calcium bentonite than with sodium bentonite. Cemented bentonite gives more serious consequences for the canister due to the increased stiffness of the bentonite. However, SKB points out that the properties of cemented bentonite are not known. Furthermore, SKB states that a start has been made on analysing the effect of creep of copper material in a shear load with use of specific creep models in the computer code ABAQUS. SKB states that it is intended to complement the analysis of canister strength for a shear movement with probabilitistic analyses. Moreover, SKB intends to continue work on introducing creep models and carrying out the experiments needed to verify the models.

SKI's Evaluation

SKI agrees that SKB's analyses show that the shortened canisters studied experimentally do not produce any crucial differences in relation to a full-length canister. However, the two-dimensional stress analyses of a limited part of a canister cross-section produces a more favourable result due to mandatory boundary conditions from the symmetry. SKB should therefore carry out additional analyses of the canister (insert plus copper shell) with a pressure up to canister failure (corresponding to when a hole occurs in the canister) which takes into consideration the full size of the canister and provides information on the sensitivity to variation of both material data and certain geometric key parameters such as excentricity.

SKI welcomes SKB's intention to carry out determinist analyses of total collapse of the canister with and without defects. SKB's analyses should also include defects in the copper shell which can serve as guidance in the evaluation of the probability of the occurrence of stress corrosion fractures. These analyses should provide information on the greatest acceptable defect sizes both in the cast iron insert and the copper shell as well as a evaluation of whether these defect sizes can be detected with the use of NDT methods. The study should also include sensitivity analyses for variation of essential parameters including those that are important for fabrication, to demonstrate the robustness of the results. Internal stresses in the copper shell in connection with welding should also be taken into consideration, if these internal stresses prove to be important.

The strength of the canister from a shear due to an earthquake is highly dependent on the properties of the bentonite. SKI considers that the studies carried out by Börgesson and Hernelind (2006) provide a good basis for further analyses. SKB should carry out further studies:

- that verify in general how it can be guaranteed that the density of the bentonite does not exceed 2,050 kg/m3 since canister deformation increased relatively sharply with increased density of bentonite,
- to investigate and verify the properties of calcium bentonite which does not appear to have been studied sufficiently, and
- that verify that the case of cemented bentonite cannot give rise to even more rigid bentonite or that a larger part of the bentonite could be cemented than what has been assumed to date.

SKI notes that SKB intends to complement the analysis of canister strength for a shear movement with probabilistic analyses, which should provide better information about the probability of damage to the canister occurring. However, SKB should also report additional deterministic analyses and investigations that can verify that the actual rupture strain is not exceeded for the cast iron insert during a shear load, taking into consideration the large spread shown of the rupture strain of the cast iron insert, and the effect on the strain rate on the copper material and in the nodular iron insert so that such effects do not entail that the break elongation of the material is reached more easily than in the case of quasistatic load. SKB should also study the effect of defects in the nodular iron insert during a shear load.

SKB should also demonstrate that the planned damage tolerance analyses for the BWR canister also cover PWR canisters sufficiently well with respect to both strength and fabrication aspects.

The calculations of Börgesson and Hernelind (2006) report relatively great strains in the copper lid in the event of shear loads. SKB should suggest new analyses (for example, better analysis methodology, newer material data or re-design of the lid) to further demonstrate sufficient strength of the copper shell. In this context, SKB should investigate the effect of remaining internal stresses in the copper shell after a shear load and how it can affect the risk of stress corrosion in the event that it can be excluded that the environment may support a process of this kind.

SKI is positive to the analyses of the copper shell that have been carried out relating to creep. Initial calculations by SKB indicate that creep failure of the copper shell cannot be expected at a shearing of at most 10cm even if relatively high creep strains are anticipated. However, SKB should carry out additional studies with other creep models to be able to make a more certain assessment of the risk of creep failure of the copper shell after a shearing. Furthermore, interaction effects between plastic deformation and creep deformation in the analysis of the integration of the copper shell should be taken into account.

SKI considers that the analyses presented by SKB are not sufficient to reject the possibility of a shearing from an earthquake and isostatic load from a glaciation taking place at the same time (SKI, 2008). SKB should carry out further studies to shed light on how these loads might interact. These studies should include the effect of the model of the earth crust used (for example, viscoelastic or viscoplastic model as well as the effect of differently shaped thicknesses) and ice which are most relevant, the impact of pore pressure and cohesion as well as any three-dimensional effects. It may also be worth carrying out a strength analysis of the canister exposed for shearing with a simultaneous isostatic load from glaciation to study how its strength is affected. SKI's additional comments and opinions on respect distances and earthquakes are reported in section 6.8.5.

To sum up, SKI considers that SKB needs to continue work on analyses of both the insert and the copper shell for both glaciation load and shear load and, in appropriate cases, a combination of these loads. These analyses shall provide supporting documentation both to verify the strength of the defined design premises and to provide guidance for fabrication and manufacturing checks.

Stress Corrosion
This section contains a report of SKB's activities aimed at determining processes relating to stress corrosion of the outer shell of the canister.

SKB's Report

SKB reports that investigation of stress corrosion in acetate-containing water has been concluded during the period. Copper and welds in copper were investigated at various acetate concentrations by slow strain rate testing. No susceptibility to stress corrosion could be demonstrated in the environment in question. SKB states that the likelihood for cracking due to stress corrosion will be further investigated during the period.

SKI's Evaluation

Slow strain rate testing (SSRT) is a method that is often used to investigate whether fracture initiation through stress corrosion can occur. Furthermore, the time at which this testing takes place is rather short. This means that there is a great risk that no possibility is provided of any growth of fractures caused by stress corrosion.

SKB has previously reported on the prerequisites for stress corrosion. According to this report, an interaction of a number of different parameters is required. One parameter is the occurrence of sufficiently high tensile stresses on the surface of the canister in order

for fracture propagation and fracture lengths to occur. Since the copper canister in the repository is considered to be practically free from tensile stresses, this reasoning is used to reject the possibility of fracture formation and fracture growth due to stress corrosion.

In SKB (2006a), SKB reports on damage that may occur to the sealed canister. According to SKB, handling damage and cold working effects can occur on the sealed canister. The canister will also be exposed to tensile stresses for a long time after a glaciation.

SKI has previously pointed out that stress corrosion is a very complex problem and that it often occurs in metallic material in nuclear power reactors. For example, experiences from nuclear facilities have shown that over sufficient long periods, material that was considered to be immune to stress corrosion in a particular environment, which does not have any significant tensile stresses can none the less crack due to stress corrosion. The conditions that cause stress corrosion in such material have not been wholly clarified although it has been possible to show some relation to the surface having undergone moderate deformations with small remaining stresses.

In SKI's view, stress corrosion cannot be dismissed as a design process in the repository only on the basis of the size of tensile stresses during the initial phase of the repository.

The above arguments and the fact that this case involves an extremely long period of time are examples of factors that mean that more attention must be given to stress corrosion. SKB should either carry out such credible tests that it is possible to extrapolate the results for very long periods of time and thus show that stress corrosion can be dismissed as a design process, or show that even if a fracture occurs that growth is so slow that the integrity of the canister is not jeopardised. SKB shall also be able to investigate and report on the consequences of certain number of canisters lose their integrity due to cracking and fracture growth through the phenomenon of stress corrosion.

6.4.3 Copper Corrosion

In this section, issues are discussed concerning general and local corrosion of copper canisters (which is included in Chapter 23 of RD&D Programme 2007) and related research issues. Stress corrosion is reported, however, in section 6.4.2 of this review. Copper corrosion in anoxyic water is also discussed in this section.

SKB's Report

During the terminated RD&D period, SKB has studied intergranular corrosion on real welds from copper canister. In the now completed study, the conclusion was drawn that this type of corrosion is very improbable in a representative environment. No further studies are therefore planned in this area.

Copper corrosion in anaerobic chloride solutions with sulphide was studied experimentally. This process gives rise to a sulphide film which, if it remains intact will lead to extremely slow corrosion. In the event of stress on the boundary surface,

however, the growth of corrosion products will be nodular, which will lead to further growth of film. SKB has also studied how the original Cu2O film was altered in a sulphide environment into Cu2S film.

Experiments show that this process takes place in the boundary between oxide film and the water phase rather than through galvanic coupling. Experiments with copper corrosion in anoxic sulphide solutions will continue in the coming RD&D period. A special project on surface films on copper surface will also be carried out.

Experiments with sulphide corrosion on copper have also been carried out in the presence of bentonite with different densities and swelling pressures. The results of these experiments show that the corrosion rate reduces linearly with increasing bentonite density, which supports the current view on copper corrosion in bentonite. With the aid of new experiments, limits shall be established and quantitative measures of sulphide formation will be established, which are expected to result in supporting documentation for quantitative handling in the safety assessment. LOT experiments at Äspö HRL are also expected to lead to improved knowledge about sulphide corrosion in bentonite.

Comments by the Reviewing Bodies

SSI is positive to SKB's work on establishing criteria for microbial activity in the buffer. SSI considers that SKB should investigate whether it is only water activity that limits the microbial activity or whether there are also other important factors.

SSI considers that SKB's experiments on microbial processes have become more appropriate since they now involve microbes that occur naturally. In SSI's opinion, it is not particularly meaningful to study individual bacterial since it is the interaction between different types of microbes which is crucial. SSI considers that a broad approach is needed to obtain conservative concentrations for corroded substances, in which limitations such as energy sources and nutrients are taken into account. The microbial processes that involve nitrogen compounds must also be dealt with since they affect the risk of stress corrosion.

SKI's Evaluation

Like SSI, SKI is positive to SKB's plans to produce a more quantitative approach to deal with microbial activity in the buffer. Experiments with copper corrosion rates at different densities obtain a concrete application if scenarios with buffer erosion cannot be excluded in SR-Site. It is generally more defensible to start from a view where activity from microbial activity is expected to decrease apace with increasing density and reduced water activity, rather than show a limit above which microbial activity absolutely does not exist, Many years of research have shown that microbes can survive in more unfavourable conditions than was previously thought and that it cannot be excluded that this is the case in compacted bentonite as well. Long-term experiments should be included in studies of microbial activity in the buffer, and continue for a number of years before being terminated. Such studies can provide supporting documentation to confirm existing models. They may also show that there are habitation effects for microbial populations so that these become more active after an initial latent period.

SKI considers that further studies of the build-up of sulphide films on the copper surface are important. Studies of the imperviousness and properties of the film and how evenly the corrosion takes place on the copper surface should be carried out with and without a bentonite buffer. In conjunction with the SR-Can review (SKI, 2008), SKI and SSI pointed out that better supporting documentation is needed to exclude that the corrosion depth does not deviate more than marginally from an average value. Major deviations in corrosion depth induced, for example, by microbial effects could lead to a shorter canister lifetime. It needs also to be shown in more detail how any defects in the copper shell from the point of view of corrosion can affect the lifetime of the canisters.

SKI notes that the advection-corrosion case in SR-Can creates a need for supplementary studies of copper corrosion in a somewhat different environment. If the case is to be included in the future, questions about corrosion on copper surfaces directly exposed to groundwater need to be further investigated. The corrosion rate will be mainly governed by factors linked to groundwater chemistry and hydrology (see section 6.8). The size of the exposed area and its relationship to mass transport also needs to be better analysed. When the copper is no longer protected by the buffer, a biofilm can form on the surface which can speed up corrosion. SKI considers that SKB should consider experiments that can provide supporting documentation on how the properties and distribution of corrosion attacks are affected by any biofilm.

SKI considers that SKB may need to expand the set of long-term experiments for copper corrosion in in-situ environment (i.e. the activity at Äspö HRL). These experiments constitute a complement to laboratory experiments. It should be possible to use them to test different hypotheses and models relating to copper corrosion in a representative repository environment. SKB needs to consider whether the number of corrosion experiments at Äspö HRL is sufficient or whether there is a need for more experiments. There may, for example, be a need to interrupt tests prior to different decision points in the Swedish nuclear waste programme. SKI means, for example, that SKB should consider long-term corrosion experiments for copper surfaces with a protective bentonite buffer without a protective bentonite buffer in the in-situ environment. Studies of the reaction between groundwater and a direct-exposed surface in the in-situ environment should be able to provide supporting documentation to test the realism of existing models. However, the relevance of the experiments depends partly on whether the advection-corrosion case remains central for the estimated risk of the repository in future safety assessments.

To conclude, there may be reason to come back with more points of view on corrosion-related issues after an updated compilation of knowledge on corrosion has been published by SKB in collaboration with Posiva.

Corrosion of Copper in Anoxic Water

SKB does not discuss this issue in the programme. The issue became relevant just before RD&D Programme 2007 was published (September 2007) through an article in Electrochemical and Solid-State Letters during August 2007 (Szakalos et al, 2007). Experimental data are presented in this article, which indicate that copper corrodes in anoxic deionised water during hydrogen generation. The equilibrium pressure of

hydrogen at 73°C was found to be a factor 2,000 times higher than the pressure of hydrogen in the atmosphere.

Comments by the Reviewing Bodies

Chalmers University of Technology notes that the information that has recently emerged on corrosion of copper in anoxic pure water is not taken up in RD&D Programme 2007. It is further pointed out that it is doubtful whether the information per se is sufficient to initiate new studies on the subject. However, Chalmers considers that SKB should comment on the discussion that is taking place on this issue.

The Swedish Emergency Management Agency states the precautionary principle should always be applied for preventive purposes and to reduce the vulnerability of society through additional experiments being conducted to obtain more knowledge and to confirm the safety of the repository in a long-term perspective.

The Royal Institute of Technology (KTH) considers that SKB's research programme needs to be complemented during the coming RD&D period due to the above-mentioned research findings. In KTH's assessment, copper canisters are not immune during the initial period with increased temperature (60-90°C) to corrosion in anoxic water at the hydrogen gas pressure that exists in the repository environment (0.1 - 3mbar). This could lead to that the copper canisters lose their integrity prematurely due to corrosion during the initial warm period of approximately 1,000 years, that the bentonite clay is affected negatively and that hydrogen take-up in the copper leads to poorer mechanical properties for the canister. KTH does not exclude that the KBS-3 method may need to be further developed due to these problems, but it none the less considers that there should be a technical solution for these difficulties. KTH proposes, as a complement to further experimental work, that theoretical calculations and predications on corrosion products should be carried out. According to KTH, more detailed studies should also be carried out of partial pressure of hydrogen gas at repository depth.

The Swedish Society for Nature Conservation and Swedish NGO Office for Nuclear Waste Review have identified a number of questions that they consider not to have been sufficiently investigated and which are important for the long-term safety of the repository. One of these is the question of whether sufficient knowledge exists about the risks of copper corrosion, in particular about the newly published findings that copper can corrode in anoxic environments, in particular at high temperatures.

The Opinion Group for Safe Disposal and The Waste Network point out that new research findings have recently emerged that copper can corrode in certain conditions. Furthermore, they state that the Government should urge SKB to report without delay on the conditions in the bedrock that can have a negative effect on the copper canister and what weight these factors should be given in the assessment of the choice of method and site.

The Municipality of Oskarshamn considers that it is important that these research findings are followed up by the authorities so that questions do not remain when the licence application is reviewed.

SSI considers that it is too early to dispose of the process even if the impact on the copper canisters in the repository environment can be extremely slow. SSI's position is based on there being a lack of thermodynamic information about hydrogen-containing complex corrosion products and that experiments with oxygen isotopes make it difficult to dismiss the process based on chemical kinetics.

Westinghouse Electric Sweden AB (WSE) notes that information has recently been presented in published literature showing that the long-term corrosion properties of copper can be called into question in certain types of environments. WSE considers that the new findings should be taken into account and that additional investigations of the long-term corrosion properties of copper should be carried out within the framework of the RD&D programme.

The Brite Group's Evaluation

SKI has had their advisory expert group for engineered barriers (Brite) examine KTH's corrosion experiments (Apted et al, 2008). The group does not consider, based on the information in the aforesaid article, that it can be excluded that copper corrodes in anoxic pure water in the current research conditions. However, Brite considers that no more convincing analytical results have been presented for the proposed corrosion product (HXCuOY). The group urges KTH's researchers to publish additional data as soon as possible which can clarify this issue. Brite then intends to make additional review comments if justified.

Brite considers it improbable that the investigated reaction has been a dominant process in nature due to the abundant existence of native copper and that it cannot either be expected to be so in a repository with groundwater chemistry inside a bentonite buffer. This applies regardless of whether the process occurs under certain conditions in laboratory experiments.
The group further considers that the KTH researchers have exaggerated the importance of the canister material having to be thermodynamically immune to corrosion.

To sum up, Brite recommends that new experiments should be performed due to the prevailing uncertainty about this issue. They consider that this work should be performed by an independent body monitored by a panel of experts. The authorities should be represented on this panel.

SKI's Evaluation

SKI considers the research findings produced at KTH to date provide SKB with a reason to produce its own updated information about the proposed corrosion mechanism, which should be based both on experiments and theoretical calculations. The work of the Brite group with this issue (which is summarised above) has been a starting point for this assessment. The criticism put forward by the KTH researchers relating to previous studies needs to be taken into consideration in this context (for example, unintentional access to oxygen during the experiments). Published thermodynamic data for known copper (hydr)oxides provides no support for copper reacting directly with anoxic water (Apted et al, 2008). The findings of the KTH

researchers must therefore be regarded as unexpected, which should lead to scientific evaluation. The proposal on the generation of a wholly new hydrogen-containing corrosion product with different properties than known fixed phases is interesting but has to be regarded as speculative. It can be noted that very little is known about this possible phase's structure and properties.

An alternative to a study funded by SKB is that a wholly new study is carried out in accordance with the Brite group's proposal. However, this would require substantial resources from the new Radiation Safety Authority and SKI is unable to express an opinion at present.

According to existing corrosion models which were applied in, for example, the safety assessment SR-Can, copper is not immune to corrosion in a repository but reacts with sulphide in the groundwater. Long canister lifetimes and the low corrosion rate in the in-situ environment are based on calculations that show that the transfer of material in the buffer boundary/or rock around the deposition holes is very slow. Similar limitations of material transfers would apply for a hypothetical corrosion model in which removal of hydrogen from the copper surface is controlling. SKI further notes that the research findings produced to date have not shown corrosion of copper during the formation of hydrogen gas in a representative repository environment. In order to have any effect on a repository, this mechanism would need to be important in an environment with similar groundwater composition and corresponding PH and redox buffering reactions (the issue of hydrogen embrittlement is commented on by SKI in section 5.3.2.). SKI considers that these circumstances together with the incomplete nature of the results to date indicate that great caution should be considered before conclusions are drawn about the lifetime of the canister and any needs to modify the KBS-3 design.

Native copper has been seen to be stable for hundreds of millions of years, which argues against copper reacting directly with groundwater in a geological repository environment (Apted et al, 2008). While there is no complete information about the geochemical development in environments where both native copper and other copper minerals are found, observations of the forms of appearance of copper in different geological environments and at different depths constitute a valuable complement to studies of corrosion mechanisms in connection with laboratory and demonstration experiments. In SR-Can, the existence of copper in clay is discussed as a natural analog for a fuel repository with copper canisters (SKB, 2006b). SKB should consider expanding the report to make better use of the existing knowledge of copper in nature.

SKI considers that the discussion on this matter is an additional argument for SKB to review the set of long-term experiments for copper corrosion in in-situ environments. These experiments may, for example, be used to test the hypothesis about hydrogen-driving copper corrosion in the repository environment with representative temperature and groundwater chemistry.

6.5 Buffer

This section contains comments on Chapter 24 in RD&D Programme 2007, which deals with research on characterisation and the long-term evolution of the buffer. The

practical issues concerning fabrication, handling and deposition of the buffer are reported in section 5.2.

6.5.1 Specification of Requirements, Initial State and Choice of Materials

SKB's Report

In SR-Can (SKB, 2006b), SKI defined function indicators with appurtenant criteria which are linked to the buffer's safety functions. The criteria need not necessarily be complied with for the whole period covered by the safety assessment, although this assessment is simplified if this is the case. In RD&D Programme 2007, SKB summarises the requirements on the buffer and the links to the performance indicators. The appurtenant criteria must not be mixed up with acceptance criteria that only apply for the initial state.

In RD&D Programme 2007, SKB reports on work linked to the design and characterisation of the buffer's initial state. Certain aspects are defined on selection of the commercial product (bentonite composition), while other aspects are controlled by the design of the deposition hole (geometry, KBS-3V or KBS-3H) and bentonite block (water content, density). Previously, SKB had the commercial bentonite MX-80 as reference material, while a large number of similar materials are now being studied at the same time. At present, field tests are being run where 13 different materials are exposed to repository-like conditions for a longer period of time.

Comments by the Reviewing Bodies

Chalmers University of Technology notes that serious attempts have been made to describe the buffer and its function, although it considers that additional efforts are required in this area. Effects of different parameters have been studied individually. Chalmers recommends that SKB also carries out an extensive study where parameters are combined on the basis of a "worst case" scenario

The Municipality of Oskarshamn's expert Pereira states that if resaturation of the buffer takes place too slowly, there is a risk that resaturation of the bentonite will be uneven and this may disturb the position of the canister in a sideways direction. It is unclear whether SKB has a command of this situation.

The Municipality of Östhammar and the local safety committee at the nuclear power facilities at Forsmark note that the function of the buffer and the backfill are very important for safety in a repository. They also point out the that it may be difficult for SKB to study experimentally how bentonite reacts in long-term conditions in a new environment and asks whether SKB is planning field investigations of, for example, bentonite which has undergone glaciations.

SKI's Evaluation

SKI considers that SKB prior to the application needs to report and justify in relation to SR-Can an updated version of the buffer's safety functions including any limit values applied in evaluation of these (in SR-Can, sufficient information is lacking on buffer erosion, among other things). A clear specification also needs to be

formulated of the chemical and physical properties that a buffer material must have. SKI considers that a specification of requirements which, for example, only contains simple physical properties such as density and swelling pressure is insufficient. This is because bentonite has a complex and varying chemical and mineralogical composition which is important for the buffer's long-term development. Conclusions from experiments with bentonite, which were used as a basis for the safety assessment, may depend on the specific bentonite used in the particular experiment. There therefore needs to be a link to specific materials in the application, which have been thoroughly studied from the relevant perspective. However, this does not exclude that other materials can be introduced at a later stage. These materials must in this case be characterised to the same extent and be shown to have equivalent properties. Long-term tests also need to be carried out to show that new materials have as good long-term properties.

SKI considers that SKB besides specifying a minimum quantity of montmorillonite (which gives the bentonite favourable sealing properties) also needs to specify the content for other minerals in the clay that may have an impact on the long-term safety. It is, for example, well known that certain trace minerals are very important for the buffer's geochemical development.

SKI considers that it is positive that SKB has extended its programme for tests of buffer material. This sheds light on the importance of similarities and differences between materials from different suppliers and can provide a basis for demonstration of the best available technology. However, it is reasonable that far-reaching demands for investigations are only linked to the material included in the application and that other materials can be characterised in a simpler way. SKB should therefore produce a plan for which materials are to be included in new experiments in order to make the best use of resources.

6.5.2 Physical Processes in the Buffer

SKBs Report

The most important processes at an early stage after closure are:

- temperature increase and heat transport through the buffer due to the fuel's decay heat,
- transport of water in from the surrounding rock due to the negative capillary pressure,
- development of a swelling pressure in the buffer on absorbing water and subsequent mechanical interaction with the canister, the surrounding rock and backfill.

An important question for the development of temperature at an early stage is, among other things, the temperature offset in the gap that initially exists between canister and the buffer and the buffer and rock. This is important, for instance, for compliance with the temperature criteria of 100°C at the canister surface. A detailed evaluation of experiments at the Aspö Hard Rock Laboratory (The TBT experiment and the Prototype Repository) shows that the heat conducting properties of the buffer correspond to expectations from laboratory experiments and that heat transfer in the gap is slightly more effective than previously assumed. SKB plans to carry out detailed simulations

of the Prototype Repository, and to translate the knowledge obtained into work on designing the repository.

SKB has continued studies of the buffer's water saturation process by modelling and field test. Results from simulations show, for example, how water from the rock matrix and the backfill can contribute to the resaturation process if the rock around a deposition hole is not intersected by any water-bearing fractures. Resaturation processes have been monitored with sensors that measure the relative humidity in the large-scale field tests at Äspö (The Canister Retrieval Test, the TBT Experiment, The Prototype Repository). The results showed that full resaturation has been achieved in certain cases in the gap between canister and rock but not above and below the canister. However, this process takes place much more slowly in deposition holes with dry conditions. Modelling work will continue in future work and more detailed information will be obtained from field tests when these are concluded (through excavation of the buffer).

The buffer's swelling process is important for the buffer to have the desired properties such as density, filtering of colloids and limited/eliminated microbial activity. Swelling entails a high degree of homogeneity in the buffer even if certain gradients can remain due to friction against the walls of the deposition hole. Since swelling pressure is higher in the buffer than in the backfill, some upward penetration of the buffer bentonite must be able to take place (according to preliminary results approximately 8 cm). Swelling can also have the undesired effect that buffer material penetrates into water-bearing fractures, which may lead to erosion processes (see section 2.5).

SKB has carried out studies of buffer material which has been exposed over a long period of time to approximately 130°C and found that swelling has not been affected although the material has to some extent become more brittle than expected. This may, among other things, be important for the ability of the canister to withstand a shear movement in the rock. Calculations of canister deformation in this case have been carried out using Abaqus code. In the coming period, SKB plans to carry out additional laboratory tests of the swelling and homogenisations processes in a buffer. Experiments with calcium bentonite and modelling (including a new analysis of previously conducted scale tests) shall also provide better supporting documentation for the evaluation of the shear load case.

Comments by the Reviewing Bodies

The Municipality of Oskarshamn's expert Pereira states that SKB's programme for studying cementation of buffer material seems to be adequate. However, Pereira considers that definitive results cannot be expected at the end of 2009 and the inserts must be viewed in a longer time perspective.

SKI's Evaluation

SKI considers that SKB as a prerequisite for the analysis of the thermal effect on the buffer needs to better justify the temperature criteria of 100°C. There are other processes besides illitisation in which the temperature is an important factor. The prerequisites for the thermal calculations in the form of, for example, repository layouts, accepted deposition positions etc. also need to be better reported in comparison with the

supporting material for SR-Can. Rutqvist and Tsang (2008) pointed out in connection with the review of SR-Can that one uncertainty in the temperature calculations is whether a considerable drying up of the buffer could take place closest to the canister surface, which would reduce the thermal conductivity of the buffer and possibly lead to the temperature rising above 100°C. According to these researchers, the uncertainty around a drying up of this kind is mainly linked to the thermal diffusion coefficient which is not considered to be sufficiently well known. A careful analysis of the thermal evolution requires that links to the hydraulic and rock mechanic development have been well mapped (for example, resaturation, thermal spalling).

With respect to the evaluation of the hydrological resaturation process, SKI considers that SKB needs to analyse the process in bedrock with low permeability in more detail. Certain deficiencies in SKB's current analysis which were pointed out in the review of SR-Can need to be rectified. Examples are handling of boundary conditions in modelling, and knowledge of the rock's water retention curve and conductivity for a fracture free rock matrix. A fracture-free deposition hole is probably very favourable from several perspectives of the safety assessment, although it does not prevent this entailing that issues relating to the importance of matrix water and water in the backfill having increased importance for the buffer's resaturation. Issues relating to the significance of a buffer remaining unsaturated for a long period of time need to be dealt with in a clearer way than to date.

SKI considers that knowledge relating to the swelling properties of the buffer has improved. It is now clear that high salinity can be a problem for the backfill rather than for the buffer (Savage, 2005). SKB should, however, more clearly indicate the site-specific highest salinity that needs to be taken into account in the design of the buffer and more explicitly justify the criteria for maximum salinity in the buffer. Further characterisation work is also needs with regard to the swelling properties of the calcium bentonite. SKB also needs to investigate whether there are special conditions in the rock that can lead to an unfavourable upward penetration of the buffer in the deposition tunnel. If this is the case, SKB needs to show whether this can be dealt with through a method to identify and avoid such positions or whether it can be dealt with by other measures.

SKI considers that it is important that as much information as possible is produced, compiled and evaluated from the field tests at the Aspö Hard Rock Laboratory before SKB submits an application for the repository.

6.5.3 Integrated Evaluation and Coupled THM Modelling

SKBs Report

SKB considers that the coupled THM development during the early phase of the repository is not of crucial importance for the safety of the repository, but understanding is none the less required, for example, for evaluation of field tests. Important new results have been obtained in recent years from simulations with Code Bright and Abaqus as well as the evaluation of the TBT test and the Prototype Repository. In a model development perspective, most resources are invested in Code Bright, which is

considered to have greater potential than Abaqus. SKB has, among other things, evaluated the mechanical constitutive laws implemented in Code Bright.

With respect to laboratory studies, a doctoral dissertation has been presented in which the relationship between swelling pressure and the degree of saturation has been studied experimentally and theoretically. In the coming years, SKB intends to refine and further develop Code Bright for more advanced applications. The focus in international projects is on comparisons between model simulations and the results of large-scale experiments. Excavation of certain experiments is expected to provide supplementary and more detailed information. The interaction between dry rock and the buffer is being studied through the URL/Buffer-Container Experiment and the Prototype Repository. During the coming period, SKB will plan for new full-scale field tests.

SKB has also with the aid of the Abaqus code simulated the development of conditions in the buffer after loss of bentonite. In the event of large initial bentonite losses ("piping/erosion") or absence of bentonite rings, the empty space will be refilled although with a sharp reduction in density and swelling pressure due to friction against the rock. Piping inside the buffer has also been simulated and the results show that a very small cavity will remain even after the open piping has been closed.

Comments by the Reviewing Bodies

The Municipality of Oskarshamn's expert Pereira considers that it is positive that SKB has a strong programme in this area and points out at the same time that it is important that SKI can follow this work up through its own measures.

SKI's Evaluation

SKI is positive to the planned continued development of the simulation codes Code Bright and Abaqus. They are key tools to produce supporting documentation for SKB's planned application. Access to well-tested codes in connection with consideration of the application is also important to be able to investigate any new questions and supplementary cases that may arise. SKI considers that the simulation of buffer evolution in relatively dry rock can be a challenge where gaps and pellets may be very important, as well as interaction with the backfill. It is therefore good that SKB plans special studies of the interaction between the buffer and rock in cases where the rock has very low permeability. SKI considers that it is important that sufficient attention is given to the work taking place in international contexts such as Decovalex, Theresa and Task Force EBS. Comparisons of calculation results between different codes as well as comparisons with large-scale experiments ("benchmarking") are fundamental for the credibility of the code's capacity.

Another important element to obtain good supporting documentation to make decisions during different stages of SKB's programme is results from several years' in-situ experiments carried out in as realistic conditions as possible. There is a risk in certain cases that incorrect conclusions will be drawn from laboratory studies that cannot always be made wholly representative for the repository situation. In this context, in-situ experiments provide necessary supplementary information. They are a tool for testing the realism of results from laboratory experiments and can be indispensable for testing different hypotheses that emerge during consideration of the application. Field

tests are not only important for study of the buffer but also the canister, backfill, cement etc. The results can be very important for the different stages of the decision process concerning a possible repository for spent nuclear fuel.

SKI considers that SKB generally has a good set of in-situ experiments at the Aspö Hard Rock Laboratory (LOT, The Prototype Repository, TBT, The Canister Retrieval Test, Lasgit etc.). It is important that these are followed up according to a long-term plan and that data is evaluated and published as soon as possible. Information may be important for the new Radiation Safety Authority's review of SKB's application.

The time should also be ripe for carrying out initial planning of new supplementary experiments taking into account previous experience of experiments and findings concerning the importance of different processes in SR-Can. An open-minded inventory needs to be made of the experiments that may reasonably be of interest to perform and then a prioritisation on the basis of the needs of the safety assessment. New experiments can for reasons of time not serve as supporting documentation for the coming application but will be needed to provide information for any subsequent decision stages during the very long period of time for development of a repository. SKI considers that RD&D Programme 2007 is vague concerning plans for new field tests and considers therefore that more detailed plans are needed.

SKB should strengthen its methods for risk management in special long-term experiments (i.e. risks that the experiment will fail), ensure that planning of experiments takes into account decision time points, develop models for expected results which actual results can then be compared with and from the very beginning identify relevant examples which can support the safety assessment (see Hicks, 2007). Quality assurance is, of course, also an important issue. In the very long-term, planning is needed concerning experiment that is to be conducted at the Aspö Hard Rock Laboratory or a future designed tunnel for an actual repository.

SKI considers that a prioritised issue for continued work in integrated evaluation should be the development of a buffer in which an erosion processes has started. It was noted in connection with the review of SR-Can that the evaluation of two phases in the buffer (intact and partially eroded) needs to be supplemented with an analysis of what happens in the transition between these two phases. It may, for example, be the case that certain deteriorations in the buffer can occur before advective transport is possible (for example, increased diffusion and/or microbial activity). There are also substantial uncertainties about the geometry and swelling pressure distribution of the buffer during different stages of its development. SKB should therefore in parallel with studies on basic mechanisms for buffer erosion with the aid of modelling and possibly experiments, analyse in more detail the effects of erosion on an appropriate scale. SKI is aware that there are difficulties of investigating these coupled phenomena under realistic conditions since these processes are expected to occur only a very long time after closure of the repository.

6.5.4 Chemical Processes in the Buffer

SKB's Report

SKB considers that the sealing properties of the bentonite are not so much affected by salinity since the negative layer charge is mainly compensated by the counter ions of the montmorillonite even at high salinity. However, this assumes that relatively high densities are used both for the buffer and for backfill. An extensive laboratory programme has been carried out to study how the bentonite is affected by concentrations of calcium, magnesium, sodium, potassium and copper chloride. A LOT test has also been mined and exposed minerals show small changes arising from the salinity of the groundwater. SKB considers to particularly study calcium-dominating bentonites since the agreement between theoretical and experimental studies to date is not as good as for sodium-based bentonites. Sodium-based bentonites are considered to be well characterised with respect to osmotic effects and additional measures for these are therefore not considered necessary.

Ion exchange between sodium and calcium is particularly important to study since these are dominant anions in Swedish groundwater. Investigations have therefore been carried out of how swelling pressure is affected by ion exchange and buffer density. Considerable differences have been noted between the monovalent and bivalent counter ions for lower densities. Further work is needed above all for systems with bivalent ions. Long-term tests (LOT) show that besides ion exchange with calcium, ion exchange with copper (II) ions from canister corrosion can also take place. A comparison between tests which have been mined after one and six years respectively, showed, however, no additional increase in the quantity of ion-exchange copper after the initial uptake of copper after one year.

The basic structure of the montmorillonite is a prerequisite for the good sealing properties of the bentonite. The ability to absorb water depends on a sufficient layer charge. An increased layer charge through silicon release and fixation of potassium produces, for example, a material which does not bind water to a sufficient extent (illitisation). Release of silicon can also cause precipitation in the buffer which leads to a deterioration in the buffer's mechanical properties (cementation). Changed pH-conditions and uptake of iron can also change the montmorillonite and thus the good properties of the bentonite. SKB has, for example, found that high pH gives an incongruent dissolution of bentonite and that iron can be taken up by the clay matrix which gives non-swelling clay phases. SKB intends in the coming period to carry out a laboratory programme to verify the parameter values for verification of montmorillonite alteration. Analysis and modelling of the completed and mined LOT tests at the Aspö Hard Rock Laboratory will also be carried out. One example of a goal of the last-mentioned aspect is to obtain an in-depth understanding of the effects of metallic and structural iron.

Other minerals in bentonite, besides montmorillonite, such as calcite, quartz, feldspars, pyrite etc. may be important for the long-term performance of the buffer. SKB has carried out modelling work to study how the geochemical development is affected by these minerals. It was seen that some redistribution of minerals takes place due to the thermal gradient in the buffer, which can affect the reological properties (cementation).

Certain experimental information about this process has also been obtained from the LOT tests. During the coming period, geochemical modelling of the field tests will be carried out.

Comments by the Reviewing Bodies

The Royal Institute of Technology (KTH) states that the anoxic copper corrosion (section 6.2.3) produces positively charged copper ions, which can degrade the buffering capacity of the clay at an early stage. KTH further points out that another problem with the clay is that the copper ions formed due to anoxic corrosion will be continually captured and bound with the clay which will increase the corrosion kinetics at the same time as destroying the properties of the clay. This means that two of three barriers, the copper metal and the bentonite clay can be degraded at the same time during the warm period when the copper corrodes in anoxic water.

SKI's Evaluation

In SKI's view, SKB substantially has good supporting documentation for the evaluation of the buffer's initial chemical evolution based on laboratory experiments, field studies and modelling. It has been possible to partially verify SKB's findings with independent analyses (Marsal et al, 2008). In particular, for the slightly longer timescale, better attention should be paid to the existence of links between ion exchange/sorption and alterations of montmorillonite. These types of processes cannot be regarded as essentially separate since they are both strongly linked with the long-term development of pore water chemistry in the buffer. SKB should therefore consider a more integrated approach around interactions between bentonite and groundwater.

There are processes that are insufficiently clarified in RD&D Programme 2007, of which the most important is probably the cementation that may occur through the heating up of the buffer. Cementation can lead to poorer ability to withstand movements in the rock close to a deposition hole. The difficulty does not seem to be to predict how large a mineralogical alteration that can be expected but rather to translate this alteration into a particular effect on buffer's mechanical properties. SKI assumes that results from exposed tests which indicate some cementation are taken into account in the safety assessment. SKB needs to report measures to minimise or exclude this problem and, if this is not possible, to produce a method that takes the consequences into consideration.

SKI agrees with KTH that SKB needs to study the impact on the buffer of copper ions from corrosion processes. It is conceivable that the copper only ends up in ion exchange positions in the clay but a more damaging effect cannot be excluded. Results from experiments at the Aspö Hard Rock Laboratory should be able to provide some information. An evaluation of the potential importance of this process assumes that the copper corrosion during the thermal period can be predicted reasonably exactly (see section on copper corrosion). The results of experiments at the Aspö HRL should be able to provide some information. An evaluation of the potential significance of this process assumes that the copper corrosion during the thermal period can be predicted reasonably exactly (see section on copper corrosion).

The risk of a structural disintegration of montmorillonite needs to be taken into account in more detail than is reported in SR-Can. The analysis was focused on the temperature-dependence of illitisation, although SKI and SSI suggested in their review it should be possible to evaluate the impact of other factors such as the availability of potassium and reported on these at the same time to reinforce the credibility of the conclusions. A number of other mechanisms for a structural disintegration of montmorillonite which does not require potassium are also mentioned in SR-Can, which are not taken into account with reference to their not occurring frequently naturally or less well known. SKI agrees with SKB that the knowledge that illite is the predominant alteration product is an important argument, but also considers that more complete supporting documentation and reasoning are needed for the application without the gaps in argumentation that could be identified in SR-Can. The production of this supporting documentation should be an important issue in SKB's continued programme. Depending on the outcome of a coherent evaluation of montmorillonite alterations, a case may also need to be produced which illustrates the significance of hypothetical alterations for different time scales. SKI notes that SKB did not carry out such an analysis in SR-Can. SKI considers that SKB should test the chemical measuring methods for compacted bentonite that have been developed at VTT in Finland (Muurinen and Carlsson, 2007). These direct methods should improve the prerequisites for characterising pore water chemistry in a buffer and to evaluate the theoretical models for pore water chemistry needed for different applications in the safety assessment. Possibilities to carry out good measurements in natural clay formations can also increase the value of natural analogies for the buffer.

6.5.5 Colloid Formation in and around the Buffer

SKB's Report

In certain case, bentonite particles can be transported away with the groundwater flow, which can seriously damage the buffer's properties if the material losses are large. Two cases where this process is important are described in RD&D Programme 2007. The first case concerns piping in the buffer which is created a short time after deposition of a buffer before sufficient swelling pressure has been built up which would prevent the occurrence of such channels ("piping/erosion"). The problem is considered to be more critical for KBS-3H than for KBS-3V. The other case relates to loss of buffer material which has been pressed out into fractures that intersect the deposition holes. This process may be especially significant in connection with future glaciations when very diluted groundwater can penetrate the repository depth.

SKB notes that piping/erosion can probably be avoided in the event of inflows in deposition holes of around 0.01 dm^3/minut. A proposed strategy for dealing with the problem is therefore to selectively choose deposition holes with the intention of avoiding high flows or possibly sealing deposition holes. As feedback from SR-Can, it is noted, however, that knowledge about these processes is at present insufficient to be able to determine the limit values for when harmful erosion can take place. SKB plans to measure the eroded quantity for different flow rates and time intervals. It is expected to obtain an important confirmation of the extent of the process during in-situ conditions after an investigation of bentonite losses after mining of certain positions in the Prototype Repository.

With respect to the risk of erosion in the long term, SKB has carried out basic laboratory experiments at different ion strengths. An extensive project has been started up to produce a quantitative model for the quantity of buffer loss for the requirements of the safety assessment.

SSI's Comments

SSI considers that the new experiments reported in RD&D Programme 2007 are appropriate. Furthermore, the authority is positive to SKB starting a two-year project, Bentonite Erosion. In the authorities' joint review report for SR-Can, the authorities noted that buffer erosion is very important for evaluation of the buffer's safety function and consequence analysis, which means that this work is needed as supporting documentation for SR-Site. One of the goals in research work should be an in-depth theoretical understanding of the balancing of different forces (van der Waals force, electrostatic force, gravitation, viscous forces, etc.) around the stability of buffer colloids in different relevant conditions. The highest colloid concentration that can be transported in groundwater should be determined with better justification.

Another question that needs to be answered is whether buffer erosion is only associated with glacial meltwater, which can only be expected a long way in the future or if buffer erosion can also occur in an earlier phase of fuel dissolution (due to reduced ion strength under temperate conditions). Calculations are also needed of the extent of any erosion of the backfill. Measures to minimise erosion of the buffer and backfill need to be presented to justify optimisation and the best available technology. The consequences of transportation of bentonite colloid with sorbing radionuclides should be modelled taking into account the geometry of the colloid particles and other relevant conditions.

Besides chemical erosion, the importance of mechanical erosion needs to be evaluated. There may possibly be a thin layer of flow bentonite at the front of the buffer that swells some way into an intersecting fracture when buffer material there has attained liquid consistency. This layer acts like an ordinary Newton flow but with higher viscosity. This layer can erode and be continuously supplied independently of the chemical composition of the groundwater. Even if the process can be slow, SSI considers that SKB should still investigate the consequences of this process since they take place continuously after the buffer has become saturated by water.

Comments by Other Reviewing Bodies

Luleå University of Technology considers that SKB should put more effort into attempting to identify natural colloids and not simply assume that the colloids have a bentonite origin. The university further points out that SKB should test different methods to identify colloids both in groundwater and freshwater, and not only rely on one method.

The Municipality of Oskarshamn's expert Pereira considers it desirable that SKB reduces uncertainties about colloid formation "piping" and erosion of the buffer to avoid excessively cautious assumptions in the future SR-Site analysis. Furthermore, Pereira

considers it probable but points out that it is difficult to evaluate that the proposed programme is adequate for its purpose.

SKI's Evaluation

SKI considers that it appears to be possible to solve problems concerning "piping/ erosion" of the buffer through selection of deposition positions, possible sealing of deposition holes and other measures. As noted in the review of SR-Can, there are still uncertainties, however, about the duration of and mechanisms for erosion and what maximum concentrations of eroded buffer can occur. SKI considers that it is not only network data that is needed but also an increase in theoretical understanding of the process and a more detailed description of what SKB means by technical solutions to minimise the risk. What are reasonable demands on the supporting documentation for "piping/erosion" partly depends on how strict the criteria are which will be applied to the selection of deposition holes, which should therefore be clarified before the application. SKI agrees that mining of the Prototype Repository should provide valuable information about this process, but notes at the same time that it is not sufficient to base a limit value on a single experiment. SKB appears in RD&D Programme 2007 to only have vague plans for KBS-3V while work for KBS-3H seems to be better structured. SKI considers that the main alternative in SKB's application should have higher dignity than the alternative repository concept KBS-3H.

Buffer erosion due to diluted groundwater etc. is just now probably the greatest uncertainty in SKB's safety assessment. It will be difficult to take a position on an application where buffer erosion has an unclear and/or undefined importance (i.e. no upward limit has been set as in SR-Can). Even if formal requirements such as the risk criterion and the requirement for multilayer barriers can be achieved wholly without taking the buffer into consideration, there is no supporting documentation in this case for formulating requirements on the buffer. The buffer is, independently of any deficiencies in the very-long time scale, an important component for maintaining the multilayer barrier functions for the repository. The buffer should have a well-defined role for the safety of the repository as a starting point for the focus on measures needed for development, fabrication, emplacement and control of this component. SKI considers it therefore important that SKB carries out the research referred to in RD&D Programme 2007 and that the level of knowledge about this process achieves a mature level before the application. It is important that the level of maturity of knowledge relating to the repository system is at such a level that realistic assessments can be made at this time for the review of SKB's application. It is also important that there is supporting documentation in order to evaluate the time scale for possible erosion (to make it possible to evaluate the role of the buffer during different time periods) and that it is possible to evaluate how the properties of the rock govern the extent of the any erosion of the buffer.

There should be a good basic theoretical understanding of erosion mechanisms. In the review of SR-Can, mention is made, for example, of a better understanding of geochemical processes in the buffer which generate stabilising potassium ions, the diffusive exchange between the buffer and fracture, transportation of bentonite colloids as well as filtering processes, which can limit erosion. In these contexts, the choice of bentonite type (for example calcium bentonite/sodium bentonite) and the existence and

quantity of different trace minerals may be important for the likelihood of colloid formation in different geochemical conditions. SKI considers that SKB needs to carefully consider these factors in the selection of buffer material in the coming application. A modification of the composition of a natural bentonite through additions of certain minerals might possibly increase the resistance to erosion. If such measures or other technical solutions can provide considerable benefits, they should be investigated.

6.5.6 Radionuclide Transport in the Buffer

SKB's Report

SKB has produced a compilation of the sorption and transport parameters of different nuclides which is used as supporting documentation in calculations in SR-Can. According to SKB, sorption in bentonite is not a prioritised area, but the same set of parameters used in SR-Can will probably also be used for SR-Site (certain updates and adjustments may need to be made if new data becomes available in the literature). A project has, however, been started to verify with laboratory experiments the model for mass transport between the buffer and flowing water in a fracture. Tests will also be carried out within the field of radionuclide transport with colloids with a view to establish a filtering limit as a guide for when colloid transport through the buffer needs to be taken into account.

SKI's Evaluation

SKI considers that the previously published studies on sorption and transportation through the buffer are relatively comprehensive and have been made in a systematic and careful way (for example Ochs and Talerico, 2004). SKI therefore agrees with SKB that this is a mature area with well established knowledge. However, it should not be forgotten that there always remain some uncertainties in important parameter values, which, inter alia, depend on the difficulty of predicting the chemical evolution in bentonite pore water during long time scales. SKI proposes like Stenhouse et al (2008) that SKB should carry out sensitivity analyses to identify particularly important nuclides and parameters. On this basis, the supporting documentation can be reviewed and various improvement measures can be considered to increase the credibility of the most important parameters. SKB may also need to review the supporting data after choice of material for the buffer and after the site-specific hydrochemical data has been compiled.

SKB states that certain updates will be considered. SKI considers that SKB here needs a structured approach to ensure that published information which can add something significant to the supporting documentation is not missed. A similar reasoning can be made on the need to update, for example, thermodynamic databases.

SKI considers that the new findings on buffer erosion need to be taken into account in the perspective of radionuclide transport as well. There is, for example, a coupling between buffer erosion and colloid transport, partly in the perspective that the buffer mineral can generate colloids in the buffer's boundary, in the perspective that the buffer's ability to filter colloids is reduced so that colloids from the dissolution of the fuel can become important. SKI notes that SKB's plans are rather vague in this area.

6.5.7 Other Processes

SKB's Report

Some other processes in the buffer reported on by SKB are:

- freezing of the buffer,
- gas transport,
- radiation effect on bentonite and radiolysis in the buffer,
- microbial processes.

SKB considers that freezing of the buffer cannot reasonably occur, mainly because the large specific area of bentonite reduces the freezing point for water by more than 5°C. SKB therefore intends to carry out additional theoretical and experimental studies to verify the reduction of the freezing point in the buffer.

Gas transport through the buffer needs to be taken into consideration to evaluate the case with a damaged canister where the insert corrodes during formation of hydrogen gas. To this end, SKB has established a large-scale experiment (Lasgit) where gas transport can be studied in in-situ conditions. Experiments will start when the buffer has achieved an equilibrium state in the resaturation process.

According to SKB, it should be possible to exclude radiation-induced alteration of the bentonite as a significant process. However, the basis for this conclusion (Andersson, 1984) is not considered to be of sufficient quality. SKB will therefore seek additional supporting documentation in the literature and possibly carry out experiments.

Microbial processes in the buffer are relevant in the perspective of sulphide formation, which can corrode the canister and gas formation. SKB has carried out experiments with naturally occurring bacteria in bentonite. The results show that sulphide can be rapidly formed by bacteria in optimal conditions, but that considerable bacterial activity could not be shown in the event of fully developed swelling pressure. SKB intends to carry out more detailed tests to establish the limit values for microbial activity for the needs of the safety assessment.

SKI's Evaluation

SKI considers that SR-Can contains a good approach for handling the risk of freezing of the buffer. However, SKB needs to better evaluate remaining uncertainties, for example, air temperatures during a period of permafrost, for establishment of a safety margin against buffer freezing. Depending on the outcome of this analysis, it may be justified to report in SR-Site on the consequences if a buffer freezing should none the less occur. The case of freezing in a partially eroded buffer also needs to be updated in SR-Site with the perquisites provided by current knowledge about buffer erosion.

SKI considers that the case with gas transport through the buffer with the scenarios in SR-Can has become somewhat less important than previously given that the most probable case with canister failure is associated with a reduced resistance to gas transport. The Lasgit test is none the less considered to be able to provide useable results since, in the perspective of buffer erosion, it is the most unfavourable case of gas

transport through the buffer (i.e. gas transport when no significant erosion has yet taken place). A considerable difficulty for this type of test is, however, the long period for stabilisation of the hydraulic conditions and that it is not possible to say exactly when the buffer has reached a sufficient degree of saturation for the measurements. SKB should, in its future planning of tests, more explicitly (in comparison with RD&D Programme 2007) discuss time scales for measurements and identify and evaluate risk factors linked to the long time scales (that is risks that the test will not lead to the expected results).

According to SKI, additional measures are needed to understand the links between groundwater chemistry, microbiology and pore water chemistry in the buffer. This is coupled with the risk of sulphate reduction in the buffer with subsequent corrosion of the copper canister. The level of the microbial activity is an important factor both for intact buffer conditions and for a buffer with an ongoing erosion process (the latter if convincing arguments cannot be made why this case can be excluded). The formation of sulphides can have slightly different consequences depending on the solubility conditions in the buffer and this is therefore a very important connected issue which is commented on, among others by Stenhouse et al (2008). Hallberg (2008) pointed out in connection with the review of SR-Can that microbes can gradually adapt to the severe conditions in the buffer, which means that it is difficult to draw far-reaching conclusions from short-term tests. SKI recommends therefore that SKB review the extent of the long-term tests in process at the Aspö Hard Rock Laboratory to make experimental testing of this habituation effect possible.

6.5.8 KBS-3H

SKB's Report

SKB has also started fabrication of bentonite blocks intended for KBS-3H which need to be modified in relation to blocks intended for KBS-3V. For certain processes where there are evident differences between the two methods, there are special measures that also produce sufficient supporting documentation for KBS-3H. One example is "piping/erosion" where there is a risk that piping can be reinforced through a long deposition tunnel with many canisters. Tests to investigate this will continue. The swelling of the buffer is also different given the perforated outer container (which is only used in KBS-3H) is part of the picture. These processes will be studied in a full-scale experiment (Big Bertha). Integrated simulations of the swelling process for KBS-3H have been carried out and field tests may also be carried out in the coming period.

SKI's Evaluation

SKI notes that the besides excavation works, it is primarily the buffer's design and development that may require the most extensive measures to realise KBS-3H. Adjacent components such as the supercontainer, distance blocks, compartment plugs etc. can potentially change both the initial and the long-term development of the buffer in relation to KBS-3V. It is not only the practical issues relating to implementation of technology that need to be attended to but also the major measures required in modelling work and tests needed to obtain supporting documentation equivalent to KBS-3V for assessment of the long-term safety for KBS-3H. There is a risk that the size of the measures needed to produce requisite supporting documentation for KBS-3H may

have been underestimated. SKI considers that SKB should produce a plan for how a changeover from KBS-3V to KBS-3H could take place at such a level that equivalent supporting documentation is available for both the methods if/when SKB intends to change over from vertical to horizontal deposition. Timetables, the requisite tests and descriptions of how important issues are to be dealt with should be included here. It is, of course, important that issues where KBS-3H contains possible disadvantages such as piping/erosion, reactions between metallic iron and bentonite are reported with especial care. These processes could entail loss of buffer material and chemical alterations. It also needs to be established which long-term and demonstration tests need to be carried out for KBS-3H.

6.5.9 SKI's Overall Evaluation - Buffer

SKI considers that SKB generally has a good programme for the buffer. However, uncertainty exists concerning the buffer material that may come into question and the composition these materials need to have. SKI therefore considers that SKB needs to produce a more detailed specification of requirements for the buffer and propose concrete materials as suitable alternatives for use in a repository. According to SKI, SKB should better justify the temperature criteria for the bentonite buffer and investigate in more detail the risk of an extreme drying up of the buffer. Implications of a buffer remaining unsaturated for a long period also need to be studied in future. SKI is positive to the development of simulation tools for coupled processes in the buffer and considers that there should be good opportunities to address the above issues. It is also important that SKB presents before the application as much information as possible from the large-scale demonstration tests at the Aspö Hard Rock Laboratory.

SKI considers that the time is ripe for planning the additional tests that need to be done during the construction phase of a repository. However, SKI can note that the plans in RD&D Programme 2007 are very vague in this area.

With respect to chemical processes in the buffer SKI considers that SKB should better take into account cementation processes, the link between ion-exchange processes and alterations of smectite, and the risk of a structural decomposition of smectite clay. Chemical processes in the buffer are also important to calculate the extent of buffer erosion, which at present is the most important uncertainty around the buffer's long-term performance. SKI notes that SKB seems to have a good research programme on buffer erosion. In SKI's opinion, it is very important that knowledge achieves a sufficient level of maturity in this area before SKB submits an application to construct the repository. Limits need to be set for the negative consequences of the process and the buffer's role in SKB's safety concept needs to be able to be defined in the perspective of the possibility that it cannot be assumed to be wholly stable in the time scale of the safety assessment.

6.6 Backfill

This section discusses issues relating to the long-term function of the backfill (Chapter 25 in RD&D Programme 2007) and related research issues. The practical issues around fabrication, handling and deposition of the backfill are presented in section 5.4.

6.6.1 Overview of the Backfill and Specification of Requirements, Initial State and Choice of Materials

SKB's Report

SKB plans, based on the results of SR-Can, to prioritise use of pre-compacted blocks consisting of natural swelling clays. Blocks consisting of a mixture of crushed rock and bentonite have also been evaluated. Results from tests and the safety assessment SR-Can indicate, however, that this alternative entails a poorer safety margin in relation to the performance requirements identified for the backfill. The concept of pre-compacted blocks also includes use of pellets which fill up the hard-to-access space closest to the rock. New methods for backfill are being developed (see section 5.4) in the Baclo project, which is important for the backfill (see section 5.4).

In RD&D Programme 2007, Friedland clay in particular, is mentioned as an example of an appropriate natural clay with an average-high content of montmorrillonite. However, there is other similar material which is being investigated by SKB. The initial state of the backfill at the time of emplacement is also defined by the choice of materials and by the dimensions and density of the block, and the initial water quantity. After emplacement of block in a deposition tunnel, the interaction, in particularly with groundwater, will relatively quickly affect functions relating to the state of the block associated with groundwater chemistry, hydrovariables, temperature etc.

Comments by the Reviewing Bodies

The Local Safety Committee at the nuclear power facilities at Forsmark notes that SKB in the programme (page 311) states that the backfill is not a barrier as such, even if it is considered important to prevent water transport in tunnels and ventilation shafts. The tunnel from the ground surface to the repository depth as well as the ventilation shafts can constitute a potential route for transport of water from and to the repository. The committee also asks whether the backfill should be regarded as a separate barrier from a risk perspective.

The Opinion Group for Safe Disposal (Oss) and The Waste Network notes that SKB has investigated several alternative backfilling materials, but has still not selected reference alternatives. In RD&D Programme 2007, information is lacking on clear and updated performance requirements for the backfill, which is important information now that the company is indicating that the bentonite buffer around the canister does not need to function longer than until backfill has taken place.

RD&D Programme 2007 does not make clear whether the selection of Friedland clay as backfill material is appropriate at all from the point of view of the long-term safety bearing in mind that the clay does not comply with the quality requirements made by SKB itself.

SKI's Evaluation

SKI considers that SKB's programme for the backfill has been concretised and that measures have been taken to handle the relatively large uncertainties that exist on the

long-term performance of the backfill. The problems in this context are that the existing well tested concept with an in-situ compacted backfill (which was tested, for example, during the "Backfill and Plug test") does not provide sufficiently low hydraulic conductivity, and that different types of erosion processes can affect the performance of the backfill. SKB has moreover in the early phases of its programme concentrated more on the buffer with a limited level of ambition for the backfill. SKI considers, however, that there is now a clearer and more extensive programme which should make it possible to obtain sufficient supporting documentation for a licence application and future stages of SKB's programme. SKB should consider the alternative with both rectangular and spherical blocks adapted to a full-face bored tunnel (see section 5.4).

It is a deficiency that RD&D Programme 2007 does not contain a good overview and discussion about the clays that may be suitable and are at present being investigated. Only Friedland clay is mentioned in the text, while the other materials are included in different figures in Chapter 25. SKB needs to produce a structured programme in which materials that need to be included in the experimental studies bearing in mind that important differences should be illustrated, and efficient use of resources for the planned investigations. As for the buffer SKI considers that SKB should mention specific materials in its application to construct a repository. There should be a compilation of desired and actual chemical and mineralogical composition of these materials, based on characterisation work. It needs to be discussed whether impurities can occur which have a negative impact on the performance of the backfill and the long-term safety of the repository (organic material, sulphides etc.). If this is the case, limit values need to be established. Correspondingly, determinations of minimum quantities of minerals that contribute to the desired properties of the backfill (for example for smectite) are needed. In the review of SR-Can, SKI and SSI observed that considerably more detailed descriptions of the initial state of the backfill would be desirable prior to SR-Site.

6.6.2 Water Transport in the Backfill

SKB's Report

SKB has carried out laboratory studies for different backfill material with the intention of investigating which *dry density* is needed to achieve a sufficiently low hydraulic conductivity. The requirement for maximum hydraulic conductivity (10-10 m/s) is achieved at a clay density of between 1,100 and 1,500 kg/m3, while a mixture of clay and crushed rock requires a density greater then 1,700 kg/m3. In practice, however, density in the lower interval is not permitted due to the requirement that a backfill shall withstand the swelling pressure that arises in connection with buffer becoming saturated. The higher safety margin produced by natural swelling clay is a considerable advantage, as well as that a higher degree of homogeneity can be achieved. SKB plans to possibly carry out supplementary measurements with the most important alternative materials and with samples from an excavation of "Backfill and Plug tests".

The lower hydraulic conductivity for natural clays entail that the resaturation time is considerably longer in comparison with mixtures of clay and crushed rock. SKB has carried out simulations that indicate resaturation times that vary between 1-150 years.

Besides the choice of material, the distance between water-conducting fractures in a deposition tunnel is the most important factor when calculating the resaturation time. SKB intends during the coming RD&D period to make new calculations where the alternative of pre-compacted blocks is studied in more detail. Knowledge about the wetting process is very limited for this alternative and new laboratory studies will therefore be considered as a complement to simulations. Since this alternative moreover means that pellets have to be used, additional questions arise about the integrated function of block and pellets. The resaturation process needs to be studied both in conditions of low and high inflows.

SKI's Evaluation

SKI considers that SKB has identified and started suitable activities to obtain sufficient supporting documentation for assessment of the hydraulic development with the new alternative pre-compacted blocks and pellets. The results of laboratory measurements and computer simulations often depend, however, on prerequisites that can only be safely checked by large-scale tests. Results need to have been obtained at the latest before commissioning of a repository that show that SKB's new concept for backfill functions under realistic conditions. SKI considers that RD&D Programme 2007 is unclear as regards the plans for new such large-scale tests. It should be noted that significant results are already available from large-scale tests although the tunnels in, for example, The Prototype Repository and "Backfill and Plug test" were backfilled by a method that differs in certain significant respects from the method now prioritised.

During SR-Can, the review noted that there were questions about the handling of boundary conditions for modelling of the early hydraulic development, and representation of the rock's hydraulic properties in unsaturated conditions. Furthermore, further studies may be needed of the interaction between backfill of the buffer for certain potentially unfavourable cases where the bedrock is partially very dense. A dense bedrock can also entail certain advantages such as reduced erosion risk and slower radionuclide transport out of the tunnel system. Further studies around the performance of the backfill in dry rock are particularly important in the case of the establishment of a repository in the fracture-poor Forsmark lens. Given the fact that SKB has now presented a main alternative based both on new material and new fabrication methods, it needs to be shown not only that previous problems are soluble (that is that the new backfill has a lower hydraulic conductivity) but also that there are not other unknown problems around implementation or long-term performance. SKI therefore considers that SKB should review the extent and focus of the activity at the Aspö Hard Rock Laboratory which aims to improve knowledge of implementation of technology for the buffer and backfill.

6.6.3 Swelling of the Backfill and Erosion Processes

SKB's Report

SKB has made measurements on a laboratory scale of how swelling pressure are affected by the clay void ratio for natural clays and mixtures of clay and crushed rock. Experiments have been carried out with groundwater of two different salinities (3.5 % and 7 % respectively). Results show that all materials comply with the requirements at all clay void ratios. However, the margins are greater for the natural clays. The criteria

for evaluation of the performance of the material are, besides swelling pressure, also hydraulic conductivity and compressibility. SKB is at present carrying out tests of the materials' self-healing capacity through experimentally studying how effectively openings in a material are closed. It was seen that mixtures of clay and crushed rock have a much poorer self-healing capacity and this is also the foremost reason why SKB will prioritise the natural clays in further work. In the coming RD&D period, SKB will mainly study the homogenisation process and the interaction between the components backfill, buffer and rock.

The programme for the backfill also includes tests to investigate the significance of erosion in the buffer. Initially, piping can take place before full swelling pressure has developed, which leads to loss of material. SKB states that salinity and water flow are the most important factors when calculating the extent of erosion. The uncertainties in the evaluation of the importance of erosion are still very great, however. The process is largely analogous to the buffer since the self-healing ability is poorer, the effects may be more lasting. During the coming RD&D period, SKB will continue studies of erosion processes with the aim of being able to set limits for the quantity of eroded material before complete sealing against the rock has been achieved.

SKI's Evaluation

SKI considers that despite the identified uncertainties around erosion processes there should be prerequisites to design backfill that meets requirements with respect to swelling pressure and density. The possibility of sealing deposition tunnels to minimise flow and inflow of deep salt groundwater are important in this context. However, with the current level of knowledge, it is not possible to exclude a reduction of the density of the backfill in the long term. SKB should therefore produce supporting documentation to evaluate the risk of long-term erosion also for the backfill and evaluate the impact on the long-term safety.

RD&D Programme 2007 lacks a discussion of the risk of erosion of the backfill by glacial meltwater. SKI and SSI also observed in connection with their review of SR-Can that SKB has not included this process in this context either. Given that there is a prioritised research project for erosion processes in the buffer SKB should to some extent use future results from this project to also evaluate the importance for the backfill. Differences relating to both processes and implications need, however, to be specially clarified.

SKI considers that SKB has a good programme to evaluate and handle the risk of "piping/erosion" during the initial resaturation phase for the backfill. Besides the purely empirical information needed to set limits for the size of erosion during different conditions, a better theoretical understanding is also needed of the mechanisms involved. In this case as well, there are considerable differences between the buffer and backfill which need to be dealt with. The location of the deposition tunnels is, for example, not as flexible as the location of deposition holes, which means that "piping/erosion" cannot be dealt with by the simple flow conditions that SKB discussed in the case of the buffer.

The performance of the backfill is probably more sensitive to the salinity of the groundwater in comparison with the buffer and it is therefore important that SKB can justify the maximum salinity that a particular backfill is designed for. An increase of the density of the backfill should, for example, entail greater tolerance for salt groundwater. SKB should, in the site-specified evaluation of the groundwater-chemical evolution show that the limit values for maximal salinity for the backfill can be met.

6.6.4 Integrated Studies of the Performance of the Backfill and Radionuclide Transport

SKB's Report

SKB plans through sampling during mining of parts of the existing prototype repository test to obtain supplementary information about the state of the backfill a longer time after installation. Different materials are being investigated with the Baclo project for the new concept with pressed blocks and pellets. In the chapter on the buffer, SKB states that a new prototype repository for KBS-3V is being planned.

With respect to radionuclide transport, SKB is working on further development of programme codes for the cases with advection /corrosion and shearing of the canister. SKB is not planning any additional studies around sorption or transport parameters for the backfill. Within radionuclide transport a special case has been simulated with 100 times higher conductivity for the backfill. This change was of limited importance for the results in SR-Can.

SKI's Evaluation

SKI is positive to there being plans for new large-scale tests, even if the report on this is very brief in RD&D Programme 2007. Since the original Prototype Repository was installed, deficiencies have been noted and the concept for the backfill is quite different. More detailed knowledge now exists on the initial development of the repository and better capacity to carry out simulations for linked processes. SKI therefore considers that new instrumented tests at the Aspö Hard Rock Laboratory are important. Installation of a new prototype repository would also provide supporting documentation for evaluations of the feasibility of the current design of the repository prior to future stages of SKB's programme. It is important that a new prototype repository, of the same type as the existing one, includes a part for the backfill.

SKI is positive to SKB's adaptation of modelling tools for radionuclide transport for the cases which are most relevant from the perspective of risk assessment. With respect to parameters for radionuclide transport, SKI considers that SKB needs to make an updating/reconciliation of existing databases so that these are also applicable for the choice of materials and the design of the backfill that the application will be based on. It is, of course, a positive result that the conductivity of the backfill was only found to have limited effect on flow conditions around the repository (Hartley et al, 2006a, Hartley et al, 2006b). SKI considers, however, that more detailed studies of this case are justified to ensure that this conclusion applies to the actual repository design. As a basis for such simulations, better supporting documentation is also needed that shows how the properties of the backfill may be affected by erosion processes etc.

The reporting on the backfill in RD&D Programme 2007 is limited to physical processes and radionuclide transport. SKI considers, however, that SKB should also take into account (bio) chemical processes in its programme. Understanding of chemical processes in the backfill may, for example, affect the evaluation of the risk of erosion due to glacial meltwater. Sulphate reduction in a backfilled tunnel could also possibly affect the supply of sulphide to the copper canister. Although the mechanical properties of the backfill and its effect on chemical processes (for example, interaction with cement) are not as important as those of the buffer, a report on these processes is needed for the sake of completion.

6.6.5 Backfill of Other Spaces besides Deposition Tunnels

SKB's Report

RD&D Programme 2007 lacks a specific section on this topic. A link to the long-term safety which SKB, however, does have in RD&D Programme 2007 is that backfilled tunnels above the repository level will freeze during periods of permafrost. This is described in the section on freezing of the backfill (section 25.2.5). A freezing of backfilled tunnels is not only affected by the depth but also by the specific surface being lower for these materials than for the buffer. Experimental and theoretical studies of these phenomena are planned.

SKI's Evaluation

SKI considers that it is a deficiency that RD&D Programme 2007 lacks a section on backfill of transport tunnels, main tunnels, the central area, shaft and ramp. While it is a long time before such activities may take place, the prerequisites for closure of a repository need to be evaluated when considering SKB's future application.

SKI considers that SKB needs to develop the concept for closure of all areas in a repository for spent nuclear fuel. SKB should moreover take into account FOI's comments (section 5.4) and report on how the design of the backfill can prevent intentional excavation. Consequences of freezing and subsequent thawing in the form of the effect on the buffer, rock, radionuclide transport etc. should be included in SR-Site. It is therefore good that SKB has produced a plan to investigate these issues.

6.6.6 SKI's Overall Evaluation - Backfill

SKI notes that considerable measures remain to be done before knowledge of both practical management issues for the backfill and analysis of long-term evolution is at the same level as for canisters and buffer. SKI considers, however, that SKB in RD&D Programme 2007 has raised the level of ambition for work with the backfill and that there are today concrete plans for filling in the most important gaps in knowledge.

SKI considers that the backfill material that SKB is presently investigating has not been properly reported in RD&D Programme 2007. As in the case of the buffer, SKI is also requesting a clearer specification of requirements for the backfill with respect to, for instance, chemical and mineralogical composition. According to SKI, more concrete plans are needed for large-scale demonstration tests that need to be carried out to investigate the performance of the backfill in as realistic conditions as possible.

SKI considers that SKB has an appropriate programme to limit and predict the initial erosion risk that exists during the early resaturation phase. Greater attention needs to be given, however, to the risk of long-term erosion of backfilled tunnels. In both cases, SKB should endeavour to obtain better theoretical understanding of the controlling erosion mechanisms. Consequences of a gradual reduction of the density of the backfill should also be investigated. SKI considers finally that RD&D Programme 2007 lacks a report on the chemical processes in the backfill and information about backfill of other repository areas besides deposition tunnels.

6.7 Geosphere

In this section, SKI presents comments on Chapter 26 Geosphere in RD&D Programme 2007.

General Comments from Reviewing Bodies

The Municipality of Oskarshamn (The Safety Group) considers that some of the process descriptions for the geosphere are well developed while others have hardly started. Furthermore, the municipality points out that further research remains to be done to obtain a complete picture of which processes affect safety. Furthermore, the Municipality of Oskarshamn (the Misterhult Group) points out that the RD&D programme is dominated by models, giving the impression that there is great credence in models, so great that the question must be raised of whether the models are creating the reality and not vice versa. The group considers that the requirement for model validation, that is that the models produce a picture of reality which is consistent and not contrary to actual conditions, is important. SKB uses comparisons of different models which the group considers, together with the use of intensifying words such as in the phrase "very good agreement", can lead the reader to believe that one has come closer to reality only by obtaining agreement between different models. The group points out furthermore that it is desirable that validation is made clearly and that results and forecasts created by the model are checked by actual processes.

The Swedish Research Council points out that a large part of SKB's results are based on simulations and modelling. The Swedish Research Council considers that it is not so clearly shown how well the simulations agree with actual observations but only that they have been evaluated. Furthermore, the Swedish Research Council considers that the need of further model development indicates that the models are not the reliable tools needed. The Swedish Research Council points out that SKB should be clearer in reporting the quality of the models used in simulations of the groundwater flow, microbial activity, gas formation/gas solution, methane ice formation and salt exclusion. Finally, the Swedish Research Council considers that the overall impression of the geosphere section is that SKB has a good picture of what has to be done and how this is to be done although it can be called into question how realistic it is to do this by the end of 2009.

The Municipality of Östhammar points out that some of the results from the site investigations and the Aspö Hard Rock Laboratory may be difficult to use in risk

assessments, at the same time as it is important also to include qualitative results in the assessment. The municipality therefore asks the question of how SKB handles qualitative data in the risk assessment.

The Municipality of Östhammar and the local safety committee at the nuclear facilities at Forsmark state that results from models of the rock and its properties sometimes conflict with actual observations and asks how SKB deals with a conflict of this kind.

6.7.1 Initial State in the Geosphere

SKB's Report

SKB starts by defining the initial state as the state that exists in geosphere when the repository has just been closed. The analysis of the long-term safety is based on this. Assessment of the effect requires knowledge of the state that existed before the repository was built. The repository is affected during its lifetime by a large number of different processes included under the concepts of thermal, hydrological, mechanical and chemical processes. SKB also points out that the result of the site investigations are the primary basis for supporting documentation to determine the post-closure state of the repository with reference to Part II of the RD&D programme.

SKI's Evaluation

As far as SKI can determine, SKB has identified the processes that may affect the long-term safety of the repository after closure. SKI notes that SKB has taken into account the comments made by the authority in the previous RD&D programme that it is at least as important to attend to disruptions that occur due to the blasting of the repository, which affects the rock mechanics and initial thermal state in addition to the effect on groundwater flow, groundwater pressure and groundwater chemistry in comparison with the prevailing state prior to start of construction.

SKB should also have reported on the resources and readiness and flexibility that exist to deal with site-specific issues that require some type of renewed research measures based on the experiences from the site investigations.

6.7.2 Heat Transport and Thermal Movement

SKB's Report

Work on developing, calibrating and verifying methods for determination of thermal properties has continued, as well as work on translating the result into thermal models on different scales. A thermal model for the Prototype Repository at the Aspö Hard Rock Laboratory has been produced with the aim of testing and verifying the usability and reliability of the thermal model. The result shows that the modelled temperature development accords well with measured data that shows that the differences are less than 2ºC.

SKB also mentions that development work within the framework of the site investigations has focused on alternative determinations of the thermal conductivity of different rock types.

SKB considers that the risk of canister damage due to thermomechanic load is in practice negligible. SKB then assumes that no deposition holes will be intersected by fractures with a length exceeding 700 metres in the dip direction.

Within the framework of the Apse test, SKB has analysed thermally generated movements and stress changes. The thermomechanic evolution of the Prototype Repository will be analysed by a method similar that applied to the Apse test and based on verified thermal analysis.

Comments by the Reviewing Bodies

The Opinion Group for Safe Disposal (Oss) and The Waste Network considers that a comprehensible analysis of how temperature conditions in the repository change during the period of operations is lacking; from the time that canisters start to be deposited and then onwards for the next thousand years. They also lack reasoning and a consequence assessment of the circumstance that the rock matrix will gradually be heated up to a temperature of between 60 and 100°C and then slowly cool down for centuries to be around 60°C after a thousand years.

The Opinion Group for Safe Disposal (Oss) and The Waste Network also consider that a well prepared analysis must answer the question of the importance of temperature differences and temperature gradients for the stress conditions and fracture formation in the rock and how this will affect groundwater movements in the area. An analysis of this kind must be made for both Forsmark and Laxemar to make it possible to determine the importance of these factors for site selection.

SKI's Evaluation

SKI can note that SKB has been successful in developing thermal models for Forsmark and Laxemar. SKB has also been able to demonstrate good compliance between temperature development in the rock mass and the buffer in the Prototype Repository Test and the numerical calculations, including the gap effect between canister and buffer.

SKI supports SKB's programme for quantification and limitation of uncertainties in the temperature calculations in different scales and in particular the plans to apply geostatistic methods to determine spatial variation and upscaling of thermal properties and its link with the geological site models.

SKI considers that there is a risk of both shorter and longer fractures in surrounding rock around a deposition hole through thermomechanical load can start to propagate from the end of a fracture and start to combine with other fractures. This can in turn lead to increase of the groundwater flow around the deposition tunnel and deposition holes. None of the methods described in SKB's planned programme for thermal movement deal with this problem.

6.7.3 Movements in Intact Rock, Reactivation, and New Fracturing

SKB's Report

Movements in Intact Rock
In previous studies, criteria were compared for different types of failure that can occur around openings in the repository. In tests of the site models, SKB has found that there is a great risk of thermally induced spalling a few years after deposition in dry deposition holes. SKB considers that if the deposition tunnels are oriented parallel to the major horizontal stress direction there is little risk of spalling during the construction phase.

The Apse Pillar Stability experiment at the Aspö Hard Rock Laboratory has provided SKB with new knowledge about the prerequisites for spalling and propagation along the walls of the deposition hole. A moderate counterpressure from a bladder was sufficient to counteract spalling. SKB draws the conclusion from this that swelling pressure from the bentonite counteracts spalling in the deposition holes. The immediate plans are to study in a small-scale field experiment whether a non-water saturated pellet filling up against the wall of the deposition hole would prevent spalling.

Reactivation – Movement along Existing Fractures through Earthquakes
In RD&D programme 2004, SKB referred to studies on the role of the fracture system for deformations in the vicinity of tunnel excavations and drilling of deposition holes and also to shear movements due to earthquakes. SKB has carried out dynamic simulations of seismically induced shear movements at fractures. The results indicate that the statistical contribution to the induced fracture movement is predominant, which may possibly mean that it is sufficient to carry out purely statistical analysis as presented in SR 97. Documented earthquake-induced damage to the designs underground show that the effects in the form of deformations are limited to the area closest to the earthquake (SKB, 2002).

Calculation with the code Udec show that tunnels in the repository would need to be situated at a distance closer than 20m from each other for the effect of the tunnels (to constitute a plan of weakness) to be other than negligible.

To analyse the effects of earthquakes, SKB frequently uses the discrete element code 3Dec. In studies carried out, the size was determined of the secondary shear movements that may be induced in fractures at different distances from an earthquake. The results show that the maximum calculated shear movement at fractures at 200, 600 and 1,000m distant from an M6 earthquake was less than 10 cm by a broad margin, which is the current canister shear limit. SKB considers that the results also apply to M7 earthquakes.

The calculation method in SR-Can is based on an estimated annual probability of earthquakes of magnitude 6 or greater, which is normalised to a circular area with a radius of 5 km around the repository. The total probability is distributed equally between all known deformation zones within the repository area. SKB considers that this is a conservative although realistic assumption. The probability of greater earthquakes should reasonably be higher for certain zones, since there are considerable

rock mechanic and geometric differences. This issue is to be considered in future studies.

Thermohydromechanic effects of future glaciation/deglaciation on a repository has also been studied within the framework of the Decovalex project (Phase III 1999-2003).

Through application of Dinsar technology, SKB mentions that no movements could be observed during the studied period in any regional lineament or in any fracture zone in Forsmark.

New Fracture Formation
SKB mentions that the essential aspects of the Apse experiment have been evaluated. As regards safety aspects of the excavation-disturbed zone, this has been dealt with within the framework of SR-Can where SKB considers that no safety problem exist with up to one and half orders of magnitude higher conductivity although a fundamental prerequisite is that tunnelling is carried out in accordance with quality-assured practices.

Comments by the Reviewing Bodies

The environmental organisation Friends of the Earth (MJV) notes that Chapter 26.2.7 of the RD&D report describes model calculations of secondary shear movements induced in fractures at different distances from an earthquake. The result in Figure 26-7 shows that the maximum movement would be 60 mm in fractures with a diameter of 300 metres at a distance of 200m from an earthquake of M 6 on the Richter scale. The threshold value for canister damage is a 100 mm movement.

MJV notes that it is not stated how the above model actually coincides with real conditions. The calculations were made on the basis of M 6 and are also considered to apply to M 7. It is not stated whether the result also applies to M 8. If this is not the case then MJV considers that the calculations should be made again based on M 8. If the result is affected, the distance to the nearest earthquake corridor should be increased.

Milkas (Mörner) considers that a meaningful seismic risk assessment must include paleoseismic data with reference to observed field data which confirms that a greater number of earthquakes with a magnitude >6 have occurred during the past 12,000 years.

Milkas (Mörner) also points out that the statement about the existence of stable rock pillars can be called into question. In support of this, Mörner cites two examples from Finland and Greece. In Finland, a fault has cut straight over an intrusion dome despite the zones of weakness surrounding the dome which should have taken up the movement according to SKB's theory. In Greece, an earthquake occurred in 1981 which did not follow old fault lines but caused a completely new line which destroyed a village 10 km from the old fault line. According to Mörner, such processes are rather the rule than the exception along regional fault zones.

The Opinion Group for Safe Disposal (Oss) and The Waste Network point out that it is evident that a lot remains to be done within the areas of rock mechanics and other geological investigations before anything certain can be said about rock movements and fracture formations in a project of this kind. This is the case regardless of whether the

short perspective (the construction and operation phase) or the longer repository phase of millions of years is under consideration.

SSI notes that the respect distance to fracture zones and criteria for choice of deposition holes is potentially very important for the sensitivity of a repository to postglacial earthquakes. RD&D Programme 2007 does not provide any good overall picture of the critical uncertainties relating to the evaluation of the importance of the earthquake or the measures that need to be taken to minimise the risks of harmful effects on the repository. SSI considers that SKB, on basis of an overall problem description, should derive and report a programme for continued work that clarifies development of models to assess the effects of an earthquake, methods for identification of fractures and deformation zones, additional work with discrete network models and development of respect distances and criteria.

Uppsala University mentions the geoscientific perspective which is related to the physical stability of an area, both geotechnical issues in connection with the design and use of the underground facility and the effects of any tectonic movements including earthquakes. Since these movements are slow and episodic by nature, long-term measurements of any deformations are necessary.

The university further notes that the great majority of earthquakes take place in faults that already exist, that is to say the fault is "reactivated". Reactivation can occur, for example, because of a change in load, for example related to ice load during a glaciation cycle but also as part of the constantly ongoing deformation related to the earth's linked tectonic plate systems. However, in RD&D Programme, reactivation is discussed almost exclusively as being dependent on a major earthquake, i.e. a secondary phenomenon, which seismologists refer to as aftershocks. Discussion about the primary reactivation, the major earthquake, is limited, however, almost exclusively to glacial earthquakes. Investigating glacially induced earthquakes is necessary in the long-term perspective but since the first thousand years is in many ways the most critical from the fuel activity point of view, the earthquake risks are linked to tectonic background seismicity, i.e. activity taking place in present conditions. The low background activity in Sweden means that the quantity of data is limited. There is not sufficient data to shed light on what the maximum magnitude in Sweden might be. Indirect arguments based on the country's geology indicate that large earthquakes (magnitude 7 and 8) might occur although the probability of such earthquakes is small. According to existing data and the Gutenberg-Richter concept, an earthquake of magnitude 6 is expected in or close to Sweden about once a century, a magnitude 7 once per thousand years, etc. It is therefore important that the seismic activities in the country continue to be monitored for a long period of time to gradually provide greater insights into the distribution of earthquakes and thus to be able to improve the evaluation of seismic risks. Issues should also be taken into account as to whether the greatest risk comes from large or repeated smaller quakes.

The university further states that an increasing quantity of data indicates that seismicity is episodic by nature and that activity can move over geographically large areas in a timescale extending over years or decades. Seismic measurements only in the vicinity of a repository would not provide sufficient overall monitoring of seismicity. SKB now

contributes to an appropriate seismic monitoring of Sweden. It is important that this work continues as a long-term undertaking.

SKI's Evaluation

Movements in Intact Rock
SKI agrees with SKB that the Apse experiment has provided SKB with new knowledge about spalling in deposition holes with credible conclusions about the rock's properties when exposed to thermomechanic load.

SKI also agrees with SKB in the assumption that if the deposition tunnels are oriented parallel with the major horizontal stress direction, then the risk of spalling during the construction phase is considerably *less* than for orientation in other directions. This is confirmed by the conclusions of SKI's consultants Backers & Stephansson (2008) concerning Forsmark although the consultants have found that spalling fractures occur with lower stresses (more superficial) than what Martin (2005) states in his report on spalling. Backers & Stephansson also note that swelling pressure from the bentonite brakes the development of rock breakouts although this leads to fracture initiation and increased fracture length for tension fractures in the main stress direction. This has still not been discussed by SKB.

Movement along Existing Fractures, New Fracture Formation
SKI has in different contexts pointed out the lack of studies concerning strength and deformation of large fractures and fracture zones. This type of study is important in the light of regional and local modelling which are needed for analysis of stress states, the strength of the rock mass and issues concerning linked processes. SKI cannot find that this has been dealt with in a good way in SKB's programme.

SKI also considers that SKB should in future present sensitivity analyses for modelling carried out where the mechanical properties and fractures and fracture zones vary. Reference is made to Figure 26-7 of the RD&D Report as an example where the issue can be raised of how sensitive the result is for variation in the friction angle (SKB states 34º) of assumed fractures and other pore pressure.

With respect to the Udec simulations concerning planes of weakness, it is not stated whether the analyses cover different kinds of load (hole-making, heat, swelling, glaciations) and simulation of the whole rock mass or only large fracture zones since no reference is given.

SKB also needs to report its opinion on whether the repository itself can constitute a plane of weakness and thus constitute a failure initiation in connection with future earthquakes.

In continued TM-modelling of the near-field at Forsmark and Laxemar, for determination of expected changes in transmissivity in fractures in the near field caused by construction, thermal load, swelling of the buffer and glaciation, SKB should take into account the possibility of the formation of new fractures, fracture propagation and linking of existing fractures in the vicinity of the deposition hole. SKI considers that the new fracture pattern from each stepwise type of load can change the flow and transmissivity in the near field of the deposition hole. This means that the 3Dec code

needs to be modified to be able to simulate new fracture formation, propagation of fractures and linking of fractures in thermomechanic near field models.

With respect to SKB's reasoning and starting points for the calculation methodology in SR-Can for earthquakes, SSB works on the basis of an assumed annual probability of earthquakes of magnitude 6 or greater. In SKI and SSI's opinion, SKB has a good approach for handling earthquake-related problems in SR-Can. This method is based on a breakdown of the problem with well-defined prerequisites and criteria for the sub-areas. The selected breakdown of requirements on the engineered barriers and the rock provide a good starting point for further work. The authorities considered, however, that the analysis in SR-Can was based on a number of insufficiently justified assumptions, which need to be reviewed prior to SR-Site. A detailed discussion is lacking, for example of the significance for safety of earthquakes of different magnitudes.

SKI considers as well as SSI that SKB, on the basis of an overall description of problems, should derive and report a programme for further work that clarifies the development of models to evaluate the effects of an earthquake of magnitude 6 or greater, methods for identification of fractures and deformation zones, additional work with discrete network models and development of respect distances and criteria for choice of deposition positions.

On the basis of the authorities' review of SR-Can, SKI considers that SKB's plans for use of respect distances and criteria (The FPC and EFPC criteria respectively) for choice of deposition positions should provide good prerequisites for being able to specify a repository for which the contribution to risk from earthquakes complies with authority requirements. It is, however, evident that the current calculation results in SR-Can are based on very preliminary information, and there is accordingly a continuing need of a number of measures and additional investigations, for example SKB should account in more detail for procedures before and during construction of the repository which contribute to site-specific information to avoid deposition holes which are intersected by discriminating structures.

SKB also needs to state which investigation methods are going to be used in blasted tunnels, in which there is possibly a greater risk of missing circumferential fractures compared with bored tunnels. SKI considers that SKB has not yet shown that no deposition holes will be intersected by fractures with a length exceeding 700m in the strike direction. It also remains for SKB to demonstrate that fractures of a smaller extent need not be taken into account in the analysis.

With respect to the formation of new fractures SKI considers, like Mörner, that this cannot be excluded a priori. More detailed reasoning is needed than reported to date. SKI also considers that even if there are few indications of postglacial earthquakes at Forsmark and Laxemar according to SKB and the probability for future earthquakes according to Hora and Jenssen (2005) is small, SKB should none the less address the issue of future formation of new fractures at both Forsmark and Laxemar.

With respect to the excavation-disturbed zone and its effect on transmissivity in blasted tunnels, SKI can refer to what was stated in the review of SR-Can. The deficiency of knowledge on the hydraulic properties of the excavation-disturbed zone needs to be

rectified by SKB in some way. SKI therefore considers that SKB needs to further development methods that indicate the possible existence of flow in the excavation-disturbed zone along the length of a blasted tunnel (see also comments in sections 5.1 and 5.1.3).

6.7.4 Time-dependent Deformations and Erosion

SKB's Report

The result of a literature survey conducted concerning time-dependent deformations shows that it can be assumed that the relationship between stress and strength must exceed certain threshold values in order for any creep to occur. SKB is now proposing a coordinated study which is to investigate and gain a better understanding of the occurrence of microfractures, subcritical fracturing and creep and also cover various aspects of thermally induced microfractures.

Long-term erosion of the geosphere has been judged by SKB to be of subordinate importance for the long-term performance and safety of the repository. A study has shown that the average depth of the glacial erosion of the bedrock was estimated at between 0.2 and 4 metres and that the extent of erosion is least over gently dipping zones of bedrock.

SKI's Evaluation

SKI notes that SKB has responded to the request to establish a special programme focused on time-dependent deformation and fracture dynamics, in particular, thermally induced microfractures and time-dependent processes such as sub-critical fracturing and creep. The result from a study made by SKI's consultants Backers & Stephansson (2008) shows that time-dependent fracture initiation and propagation is of subordinate importance at the repository depth in question and the prevailing rock stress.

With respect to glacial erosion, SKI refers to comments presented in section 6.2 where one conclusion is that glacial erosion, unless it can be excluded on good grounds, should be taken into account in considerations on the appropriate depth for a repository.

6.7.5 Groundwater Flow

SKB's Report

SKB reports progress which has been made within groundwater modelling, which has been carried out within site modelling, in the safety assessments and in independent projects since RD&D Programme 2004. SKB points out that the further development work is strongly linked to the codes ConnectFlow, Darcy Tools and Mike She. SKB considers that the needs which can be related to SR-Site are largely well provided for. However, SKB plans some further development, for example, particle tracking in ConnectFlow and Mike She and modelling of resaturation in backfilled tunnels with DarcyTools. SKB plans moreover to improve the calculations of the surface hydrological water balance with appurtenant model calibrations and to develop understanding of the water exchange between soil and rock. Furthermore, SKB reports

on plans for modelling of several glaciation cycles with improved realism in assumptions and an evaluation of the hyperconvergence concept.

Comments by the Reviewing Bodies

The Swedish Energy Agency raises the question of how SKB takes into consideration extreme climate scenarios that lead to major changes in surface and groundwater movements.

Karlstad University (KU) notes that the selection of the candidate sites now under consideration Forsmark and Laxemar cannot be considered as complying with the requirements of environmental legislation on safety-related optimisation since neither of the sites has been selected in a process where the hydrogeological properties of the bedrock has determined this selection. KU further states that SKB recommends coastal sites which entail an increased risk of fast transport of radioactive substances up towards levels close to the surface in the event of leakage from the repository. KU assumes that SSI and SKI will request the Government to instruct SKB to supplement the site selection process as regards the flow patterns of groundwater so that this measure corresponds to the optimisation specified in SSI's instructions on geological disposal (SSI FS 2005:5).

KU points out that there is a lack of site-specific hydrogeological data which would make it possible to carry out advanced assessments of how great the safety-related benefits are that can be achieved from selection of an inland site on good hydrogeological grounds. Furthermore, KU states that there are methodological deficiencies in the groundwater modelling, which have been well documented by SKI's and SSI's experts (Geier, 2006 and Dverstorp, 2007).

KU considers that it is embarrassingly unscientific of SKB to calculate hypothetical flow waves to a depth of as much as 2.5 km for the KBS-zone's groundwater for the normal case referred to in the calculations when SKB in other contexts reports that it is impossible for this light groundwater to reach such depth bearing in mind that there is a markedly denser highly saline groundwater below at a depth of just below 1 km, as shown by SKB's borehole data from Laxemar.

KU considers that the report in RD&D Programme 2007 is wholly unacceptable both as an actual report on the problems of repository surrounded by a mobile and near-surface groundwater and as justification of the relatively shallow repository depth, approximately 500 metres. According to the university, the repository depth of 500m was adopted since only fragmentary knowledge was available about hydrogeological conditions at greater depth.

Luleå University of Technology states that it is positive to SKB actively studying surface-near ecosystems and possible interactions between deep origin and near-surface systems.

The Nuclear Waste Secretariat of the Environmental NGOs, Milkas (Mörner) points out that when the ice grows and presses down the bedrock, the geoide surface is deformed which will cause the groundwater flow to change direction from a general lowering to a general rising. Furthermore, Milkas (Mörner) states that the water tends to move

towards the zero level (for water) of the geoide and what is “hidden in the depths” can then come up to the rock surface under the covering mass of ice. Milkas (Mörner) also considers that one must expect that fast flows to the surface may occur within a time span of 100,000 years.

Milkas (Pettersson) states that SKB does not provide any information about minimum and maximum flows of water for the deposition holes. Furthermore, Milkas (Pettersson) states that when transport and deposition tunnels have been excavated that the Baltic Sea’s saltwater will penetrate the repository with a series of negative consequences.

Milkas (Pettersson) considers that SKB evidently wishes to be able to control the water inflow into the deep repository but does not report on the reasons for this nor how it is to be achieved. Furthermore, Milkas considers it should be a prioritised issue to prevent unknown surface water from penetrating into the test boreholes. Milkas also points that Swedish and international research shows that a site selection inland is favourable from the point of view of groundwater due to stagnant an slower water flows and that groundwater at the coast can be pressed upwards and outwards into the sea.

The environmental organisation Friends of the Earth (MJV) points out that regional groundwater movements can indicate the most suitable site for a repository. MJV considers that location in an recharge area, for example further from the coast, should delay the transport time of the groundwater to the discharge areas close to the coast such as Forsmark and Laxemar and thus reduce the risk of radioactive substances reaching the surface or coming out into the Baltic Sea. Furthermore, MJV states it supports SKI’s and SSI’s view that more knowledge is needed.

In MJV’s opinion, Forsmark and Laxemar cannot reasonably be suitable sites for a repository according to the KBS3-method since the intended sites for the repository have been under water for several thousands of years.

The Swedish Society for Nature Conservation and the Swedish NGO Office for Nuclear Waste Review (MKG) consider that SKB’s treatment of the issue of the importance of regional groundwater flow for long-term environmental safety in section 26.2.3 is very circumstantial and hard to understand. The organisations further point out that a siting where the current site investigations are made in discharge areas provides very short breakthrough times in the range of 50 to 100 years in the event of a leakage. These organisations state that it would take up to 50,000 to 100,000 years before a leakage reached the surface in a siting in a recharge area. They draw the conclusion that radioactivity, in the event of leakage, has considerably more time to decay before it reaches humans and the environment. The two organisations consider that both inland and coastal siting alternatives should be included in the site investigation phase in a systematic site selection process and that safety aspects must be given greatest weight in the selection of a site.

The Swedish Society for Nature Conservation and MKG refer to SKI and SSI pointing out in a joint letter that SKB has not drawn conclusions from its modelling of regional groundwater flows. The organisations consider that SKB should add on such work in the RD&D plan.

The Swedish Society for Nature Conservation and MKG also pose the question of how any increased precipitation would affect groundwater conditions in a repository.

The Municipality of Oskarshamn (The Misterhult Group) points out that SKB should not only model lowering of the groundwater during the construction, operational and closure phase but also deal with the consequences this has in the models. To the best of the group's knowledge, the biosphere model, for example, does not include the effects of a hundred-year lowering of groundwater.

The Municipality of Oskarshamn (Pereira) points out that the sensitivity analyses in SR-Can for the effect from excavation-disturbed zone, EDZ are too limited and that the underlying spalling model is oversimplified. The municipality therefore considers that a more site-specific study of the thermal and hydraulic properties at Forsmark and Oskarshamn respectively should be carried out during the period.
The municipality further states that it is positive that SKB intends to continue to study the hydraulic conductivity in the excavation-disturbed zone.

The Municipality of Oskarshamn (Pereira) notes that SKB intends to investigate the highest permissible inflow of water into the deposition tunnel in connection with installation of the backfill. The municipality poses the question whether it is intended to do this before or after the application has been submitted.

The Opinion Group for Safe Disposal (Oss) and The Waste Network consider that a well-prepared analysis must provide answers on the importance of temperature differences and temperature gradients for stress conditions and fracture formation in the rock and how this affects groundwater movements in the area. The Opinion Group for Safe Disposal (Oss) and The Waste Network further point out that an analysis of this kind must be made for both Forsmark and Laxemar so that it is possible to determine how important these factors are for the choice of site.

The Opinion Group for Safe Disposal (Oss) and The Waste Network state in addition that the rock's hydrogeological properties are of crucial importance for site selection since the KBS-3 method is based on the principle that leaking radionuclides are to be diluted by the groundwater and adjacent recipients such as the Baltic Sea. The Opinion Group for Safe Disposal (Oss) and The Waste Network note that RD&D Programme 2007 shows that the site selection process has not been scientifically governed and not been governed by the hydrogeological properties of the bedrock. The Opinion Group for Safe Disposal (Oss) and The Waste Network further consider that this conflicts with the requirement for BAT and optimisation of radiation protection.

The Opinion Group for Safe Disposal (Oss) and The Waste Network consider that SKB has not carried out any unconditional analysis of the groundwater problem since SKB has not openly reported on and evaluated current conditions that can argue against previous standpoints. Moreover, they state that based on the starting point "that the forecast is favourable for the indicated candidate sites at Forsmark and Laxemar as regards the ability to meet the requirements on the long-term safety capacity of the repository", SKB has chosen not to take into account recharge and discharge problems as a selection criterion for the site but refers to "verification problems" and that SKB will take into account all hydrogeological aspects later in the process. The Opinion Group for Safe Disposal (Oss) and The Waste Network consider that SSI's review of

the most recent report confirms that it is difficult to find the "best" site from the point of view of the groundwater. SSI's external expert review group considers that it is easy to show on the basis of the modelling carried out and site-specific data that SKB has chosen the wrong area with regard to Laxemar. The Opinion Group for Safe Disposal (Oss) and The Waste Network point out that SSI's expert Clifford Voss has shown with his own calculations that it is possible to identify inland sites with hydrogeological conditions that can provide significantly higher barrier effects compared with Laxemar, "a site that would never have been selected if using the site selection criteria". The Opinion Group for Safe Disposal (Oss) and The Waste Network consider that Voss is very clear when he summarises his review by stating that "SKB has not used hydrogeology as a positive siting factor". The Opinion Group for Safe Disposal (Oss) and the Waste Network consider furthermore that the Government should require that SKB supplements the report on the regional groundwater problem so that it will be possible to evaluate the relevance of the issue for site selection and how the company's standpoint corresponds to SSI's requirements for optimisation.

Sveriges energiföreningars riksorganisation (SERO) [*The National Organisation of Swedish Energy Associations*] asks how SKB intends to handle the effect on groundwater according to the Environmental Code and EU's water directive.

The Geological Survey of Sweden considers that studies of the significance of the permafrost for the flow and composition of the groundwater seem to be have been made on a very conservative bases and that the programme for further study of this is reasonable.

The Swedish Research Council points out that SKB should more clearly report on the quality of models used for the simulations of the groundwater flow.

The Municipality of Östhammar and the local safety committee at the nuclear facilities at Forsmark point out that the groundwater flows in the rock are one of the most important components of the safety assessment. Moreover, the municipality and the safety committee state that the age of the groundwater, which SKB has estimated during the site investigation phase, can be linked to the water flux in the rock. It is considered that SKB has not used the age of the water in modelling of the water flow in the safety assessment SR-Can and asks whether this will be done in SR-Site.

The Municipality of Östhammar points out that the water flows at Forsmark are high in the upper layer of the highly fractured rock and decrease with increased depth and less fractured rock. The municipality poses the question of whether the remaining depth between fractured rock and planned repository depth is sufficient as a safety margin for future water penetration.

SKI's Evaluation

SKI considers that the programme on groundwater flow presented by SKB has an appropriate level of detail and is in general appropriate. The programme has a clear link to issues raised in connection with the SR-Can report. SKI considers that SKB has made progress in hydrological modelling and has obtained important practical experiences through application of the models in site modelling and the safety assessment SR-Can.

SKI lacks in SKB's programme links from the report on groundwater flow to other disciplines and sections in the programme. For example, the clear links to glacial hydrology, geochemistry, piping/erosion of buffer and backfill, the biosphere chapter and rock mechanic processes that have an impact on hydrogeology, are not discussed. SKI considers that it is important to evaluate these links if SKB is to handle remaining issues in an appropriate way.

SKI considers that the issue remains of what are valid boundary conditions and structural configurations in the groundwater modelling. SKI considers that aspects which SKB should develop further are how composite parameters and discretisations in time and space are handled in modelling. How different site properties are to be parameterised and scaled up or down are not simple questions not least bearing in mind that models are used both in the site modelling and in the safety assessment.

SKI is positive to SKB's plans to study methods for calibration and other forms of comparisons of model results with measurement data in connection with the surface-hydrological modelling. SKI considers, however, that SKB also should continue to develop testing and verification of the hydrogeological models. One element of this can be an evaluation of the confirming hydrotests carried out. SKI further considers that SKB should continue the development of methods for long-term monitoring of groundwater pressure, flows and composition, not least bearing in mind the difficulties that SKB has had to obtain high resolution measurements of groundwater pressure during the site investigations.
SKI considers that SKB has made great progress in the modelling of flows and mixture of groundwater types with different composition. SKI considers, however, that a verification of the hydromodels with the aid of these transport models has limitations since the results seem to be sensitive for the initial conditions.

SKB points out that the variability of the fracture aperture and the associated F factor is usually neglected in models with a large number of fractures. SKI considers that this practice should be reviewed bearing in mind the "persisting channelling" concept introduced by Öhman et al (2005).

SKI considers that SKB in calculations of groundwater draw down should take into account how precipitation can conceivably vary during the operating period of the repository.

SKI is positive to SKB's carrying out additional modelling (Eriksson et al, 2006) to investigate the flow patterns of the groundwater in the event of hypothetical inland and coast sitings. SKI and SSI notified in a letter to SKB (SKI dnr.2007/598) that it illustrates flow conditions in eastern Småland in a more detailed way without prior conditions compared with previous studies (for example SKB, 2003 and Follin & Svensson, 2003). The authorities consider further that the study can provide good supporting documentation to evaluate the significance of major regional groundwater flow for the siting of a repository. However, the authorities agree that SKB should supplement the study in the following points and that these supplements can be reported in the licence application for the repository.

- To justify more clearly critical assumptions and simplifications which can affect the ability to identify long flow routes, in particular choice of model depth and the model for the position of the groundwater surface.
- To carry out a more detailed evaluation of the calculation results, which makes it possible to compare hydrological differences between specific sites in the pilot study municipalities Oskarshamn and Hultsfred and to describe the factors that make certain sites in the model associated with long transport routes and transport times from the repository depth.
- Engage in a discussion on whether there are evident local site properties that can break up regional flow patterns in the hydrogeologically interesting areas.
- Illustrate what any site-specific differences in the regional flow pattern mean for the results of the safety assessment, for example, taking into consideration future coast line and climate changes.

SKI is positive to a site-specific application of the hyperconvergence concept. However, SKI considers that SKB should clarify the strategy for a parallel application of a modelling approach of this kind together with ConnectFlow and DarcyTools since these show considerable conceptual differences. SKI further considers that SKB should clarify how the hyperconvergence concept affects the interpretation of hydraulic measurements from the site investigations and the carrying out an interpretation of measurements planned during the construction and operating phase.

SKI considers that it is positive that SKB is continuing work to produce a discrete fracture network model (DFN) for density-driven flow.

SKI is positive to SKB's efforts to update the concept of groundwater modelling in Forsmark (Follin et al, 2007). SKI considers that SKB should further develop the groundwater modelling to reflect the fact that groundwater pressure in the Quaternary deposits seems to follow the topography while groundwater pressure in the underlying rock (in particular, in domain RFM029) seems to be insensitive to the topography. SKI considers that an in-depth link between the hydrogeological and surface hydrological analyses could contribute to increase understanding. SKI further considers that SKB should analyse how the groundwater modelling results are consistent with the results from the hydrogeochemical studies.

6.7.6 Advection/Mixing – Groundwater Chemistry

SKB's Report

SKB plans that continue to carry out site-specific mixture calculations to obtain improved understanding of changes in the chemical composition of the groundwater. SKB also plans to carry out calculations of the evolution of salinity in the event of extensive climate changes. SKB refers to Chapter 26.2.3 Groundwater Flow for the development of groundwater model water flow.

Comments by the Reviewing Bodies

The Swedish Society for Nature Conservation and the Swedish NGO Office for Nuclear Waste Review (MKG) consider that the salinity of the groundwater is an important

factor from an environmental perspective. These organisations point out that the issue of the existence of saltwater in the event of different sitings of the repository does not seem to be a research issue for SKB.

SKI's Evaluation

SKI is positive that SKB intends to increase understanding of paleohydrogeology at the sites with the aid of additional mixture calculations and that the developed M3 model is to be verified. SKI is also positive to SKB's plans to calculate the evolution of salinity.

SKI considers that a more detailed account is lacking of the handling of important issue of how advection and mixture affect transport of corroding substances to the repository. Given the remaining issues around buffer erosion, canister corrosion assumes an important role in the safety assessment. The issue of the transport of corrosive substances is taken up in section 26.2.25, Integrated modelling – hydrogeochemical evolution but no future activities are planned in the area. Issues that should be dealt with are, for example, the significance of advection for sulphide and methane quantities, oxygen penetration down to repository depth and transport of organic material. Another important issue that SKB should also shed light on is how advection/mixture of different groundwater types affects buffer erosion during periods of downward penetration of glacial meltwater. SKB should also clarify its plans for further investigation of the effect of advection on mass transfer between the buffer and the groundwater which is taken up in section 24.2.23 Radionuclide transport – diffusion (in the buffer).

6.7.7 Advection/Mixing – Radionuclide Transport

SKB's Report

SKB presents plans to produce a developed version of DarcyTools to evaluate future investigations of dispersion and mixture. SKB also plans to evaluate the difference between mixture and dispersion in transport models if these are to be used to a greater extent.

Comments by the Reviewing Bodies

The Nuclear Waste Secretariat of the Environmental NGOs, Milkas (Hultén) considers that SKB's strategy for handling leakage of radionuclides from the repository is based to a great extent on the principle of dispersion and dilution. Milkas (Hultén) would have preferred SKB to highlight this underlying understanding and to problematise the chosen strategy.

The Swedish Society for Nature Conservation and the Swedish NGO Office for Nuclear Waste Review (MKG) state that SKB should report that dilution of radionuclides from a leakage into groundwater and the sea is one of the principles of the KBS method. The organisations therefore consider that SKB must include dilution in the sea in the safety assessment and the long-term environmental effects that this will produce.

SKI's Evaluation

SKI is positive to SKB's plans to evaluate the differences between mixture and dispersion in groundwater flow models. Furthermore, SKI considers that SKB based on these investigations should show that the models for non-reactive transport which are used to explain geochemistry, for example calculations of the evolution of the salinity of the groundwater, accord with the models uses for radionuclide transport calculations. Ultimately, this may be a way of addressing issues concerning transport of corrosive substances to the repository which in this review are taken up in the chapter on the significance of advection for groundwater chemistry.

6.7.8 Diffusion – Groundwater Chemistry

SKB's Report

SKB does not report any plans in this area. However, there is a preparedness to use data from investigations on Greenland if these should prove useful.

SKI's Evaluation

SKB's investigations of matrix water (SKB, 2007) indicate that water with low salinity has circulated at depths down to 700m. SKI therefore considers that the conclusions from RD&D Programme 2004 that the groundwater system at a depth exceeding 500 m is unaffected by other types of dynamic processes can be called into question. SKB should carry out additional studies of the evolution of groundwater layering over time. For example, to understand through further efforts the matrix water compositions and paleohydrogeology at the candidate sites (see section 26.2.15 Reactions with the rock – groundwater and rock matrix and 26.2.11 Advection/mixing – groundwater chemistry).

6.7.9 Diffusion – Radionuclide Transport

SKB's Report

SKB plans new analyses within the long-term diffusion and sorption experiment (LTDE-SD) at the Aspö Hard Rock Laboratory. The emphasis is on sorption data since these have considerable uncertainty intervals. However, SKB hopes that it will also be possible to obtain diffusion later on. In addition, diffusion experiments will be performed in the laboratory to permit comparisons with in-situ data from site investigations. SKB also plans studies of a diffusion profile in a fracture.

Comments by the Reviewing Bodies

In the opinion of the Municipality of Oskarshamn (Pereira), it is desirable to reduce the uncertainties linked to the effect of microbial processes on matrix diffusion.

SKI's Evaluation

SKI considers that SKB should clarify how it plans to remedy the insufficient supporting documentation of site-specific data for sorption and diffusion of radionuclides. Bearing in mind that the LTDE-SD experiment is of limited extent, SKI

considers that SKB should consider supplementary measurements of D_e or Da for sorbing radionuclides for relevant rock types. In-situ resistance measurements that have been carried out only produce D values for chloride. Likewise, matrix water measurements in the laboratory of diffusion out in to the rock indicate D values for chloride.

Diffusion parameters are an important input data for the development of scaled up parameters for radionuclide transport. SKI considers that SKB should analyse "single well injection withdrawal" (SWIW) tests that have been carried out. The goal should be to verify, as far as possible, the laboratory measurements, to investigate uncertainties, and thus increase confidence in the parametrisation of the transport models.

SKI considers that SKB should take up issues relating to in-situ measurements for electric resistance and supplementary laboratory measurements. It needs to be shown that measurements reflect the diffusion of ions in porewater and are not affected by conductive minerals in the rock.

SKI considers that SKB should clarify the strategy for quantification and model parametrisation of matrix diffusion depth. According to RD&D Programme 2007, the matrix diffusion depth is at least one metre. In the SR-Can calculations (SKB, 2006c), a triangular distribution with a maximum diffusion depth of ten metres was assumed. SKI considers that SKB should link quantification of matrix diffusion depth with the rock's properties, for example different types of microfractures, the extent of mineral alterations and accessibility of the rock matrix for diffusion.

6.7.10 Reactions with the Rock – Groundwater Rock Matrix

SKB's Report

SKB plans to continue sampling of matrix water in the site investigations. The analysis of these samples shall also serve as the basis for an evaluation of whether additional research is needed.

Comments by the Reviewing Bodies

Luleå University of Technology (LTU) considers that an example of insufficient interaction of SKB with other actors is the problem of identifying the origin and age of different matrix pore water in the rock. LTU points out that one approach could be to work with Sr isotopes. It is also stated that research at the university has shown that the variations in salinity of the Baltic Sea over time are reflected in changes of isotope composition of Sr and that more use could potentially be made of Sr isotopes than SKB has done. LTU further considers that Cu and Fe isotope studies could also be used by SKB.

The Swedish Research Council wishes to propose making available funds for highly-quality basis research for investigation and modelling of the mobility of groundwater in rock and the chemical interactions that take place between the groundwater and the surrounding rock.

SKI's Evaluation

SKI is positive to the further investigations of the matrix water. These analyses provide valuable information about matrix diffusion and understanding of the geochemical evolution of the sites. However, these analyses will not, as far as SKI can see from SKB's Report, provide complete information about reactions within the rock matrix, which can affect in-situ pH values and other chemical parameters which are significant for radionuclide transport. Further studies of reactions which control redox such as iron (II)-mineral and microbial processes are therefore justified.

6.7.11 Reactions with the Rock – Dissolution/Precipitation of Fracture Minerals

SKB's Report

SKB plans to continue tests with weathering of ferrous fracture-filling minerals and studies of the occurrence of microbial processes in experiments. In addition, SKB plans to investigate further the problem of dating various water /mineral processes.

Comments by the Reviewing Bodies

The Municipality of Oskarshamn (Pereira) points out that experimental studies of the bedrock under the Greenland ice can contribute to interesting information relating to SKB's opinion that it would be unfortunate to associate the presence of glacial meltwater to oxidising conditions (page 347 in the programme).

SKI's Evaluation

SKI is positive to the planned activities. SKI considers, however, that SKB should take into account the comments made in the review of SR-Can concerning the modelling of penetration of oxygen to repository depth. SKI and SSI stated there in summary that SKB prior to SR-Site should supplement the modelling with an analysis of uncertainties of both the rock's reducing ability and the models for infiltration of glacial meltwater. The authorities also considered that SKB should produce an integrated description of all relevant redox processes and, on this basis. justify an appropriate model structure for further treatment within the safety assessment.

6.7.12 Reactions with the Rock – Sorption of Radionuclides

SKB's Report

SKB plans to continue the modelling of sorption and reactive transport. The LTDE-SD experiment is also to continue. One aim of the experiment is to compare in-situ and laboratory data to be able to interpret the latter correctly. The doctoral project concerning electrical methods for measuring Kd values was finished during the period.

Comments by the Reviewing Bodies

Chalmers University of Technology (CTH) considers that it is positive that SKB has pointed out the difficulties of translating laboratory-determined Kd values and ion

exchange capacities to in-situ parameters. Further, CTH considers that SKB's programme seems to be relevant to increase understanding of this problem.

The Municipality of Oskarshamn (Pereira) considers that it would be desirable to reduce uncertainties about Kd values and the effect of microbial processes on matrix diffusion.

SKI's Evaluation

SKI considers that it is important that SKB produces a well-supported strategy for simultaneous use of site-specific laboratory and in-situ sorption data and generic sorption data in future safety assessments. In addition in SKI's opinion, SKB should link conceptual models for radionuclide sorption to the rock's properties, for example the extent of mineral alterations, microfractures and accessibility of the rock matrix.

SKI considers that SKB has not reported in a clear way how the programme in section 12.3.9. Determination of sorption parameters relates to the programme in this section. SKB points out in section12.3.9 that simplified equipment for determining Kd and/or cation exchange capacity (CEC) will be developed, while SKB under this heading points out that an assessment will be made of whether electrical technologies developed in a doctoral project can be used in production or not.

6.7.13 Microbial Processes

SKB's Report

SKB plans to continue research in the Aspö Hard Rock Laboratory around microbial processes that affect the sulphide content, reduce oxygen or buffering the redox potential. Furthermore, SKB plans to quantify mobilisation and immobilisation of radionuclides in different conditions. SKB intends to start a new modelling project focusing on microbial processes that may affect the barrier functions and the safety of the repository.

Comments by the Reviewing Bodies

The Municipality of Oskarshamn (The Safety Group) asks whether bacteria in the rock mass can affect radionuclide transport or safety in any other way.

The Opinion Group for Safe Disposal (Oss) and The Waste Network point out that sulphide is a very important agent with respect to the issue of copper corrosion and that the copper canister is the most important barrier. Furthermore, The Opinion Group for Safe Disposal (Oss) and The Waste Network state that SKB has detected in long-term tests (LOT and the Canister Retrieval Test) that sulphide can be formed rapidly at repository depth and that the concentration can be high. According to The Opinion Group for Safe Disposal (Oss) and The Waste Network, this is of crucial importance for the long-term safety of the repository. Furthermore, the Opinion Group for Safe Disposal (Oss) and The Waste Network state that it is evident that a lot remains to be done for SKB in this area. The Opinion Group for Safe Disposal (Oss) and The Waste Network consider that the Government should urge SKB to report on the significance that recent research findings on microbial processes may have for long-term safety and on the significance for site selection.

SSI considers that SKB's results have become more meaningful since SKB's tests have been carried out in repository environment (the Aspö Hard Rock Laboratory) with naturally occurring microbes. Furthermore, SSI is positive to SKB wishing to start new projects intended to model microbial processes.

SSI considers, however, that there are still uncertainties in understanding of the microbial activity in the near-field round the repository environment. Taking into account that various types of microbes occur in the repository environment and which interact in their metabolism, but which can also compete with one another on access to different types of energy sources and nutrient resources, SSI considers that studies of individual bacteria can hardly shed light on the complete role of the different microbial processes in canister corrosion. For example, the processes that concern nitrogen circulation at increased concentrations of ammonium and nitrite will have a negative impact on stress corrosion of the copper canisters.

SSI considers that SKB's research programme should adopt a broader approach to shed light on the interaction between different microbes and the limitations produced by available energy sources and nutrients. The intention of modelling should be to produce conservative values of the concentrations of the different corrosive substances.

The Swedish Research Council (VR) wishes to propose that funds be made available for high-quality research on modelling of the importance of microbial processes to reduce oxygen and methane and, to what extent, these produce sulphides. VR points out furthermore that SKB should more clearly report on the quality of the models used in simulations of microbial activity.

SKI's Evaluation

SKI considers that the research planned by SKB is important. The most significant issue, in particular, in the case of buffer erosion, must be considered as understanding how active sulphate-reducing bacteria can be assumed to be during the long-term development of the repository. The ability to predict the extent of copper corrosion partly depends on how well limiting and controlling factors can be identified and investigated. It was assumed in SR-Can that methane quantities completely governed the extent of sulphate reduction. This assumption should be further studied based on experiments and field studies. SKI notes that SKB did not discuss in SR-Can microbial activity during periods of permafrost and glaciation, which needs to be dealt with in some way in SR-Site.

6.7.14 Degradation of Inorganic Engineering Material

SKB's Report

SKB plans to carry out leaching experiments with low-pH-cement to investigate whether leaching affects the radionuclide absorption of rock.

SKI's Evaluation

SKI considers that the planned experiments are important. Furthermore, SKI considers that SKB should also shed lights on any effects of cement leaching on the engineered barriers.

6.7.15 Colloid Formation – Colloids in Groundwater

SKB's Report

SKB has carried out experiments in a laboratory environment to study the stability of bentonite colloids in different conditions. Furthermore, SKB has studied the interaction of radionuclides in a laboratory setting with bentonite colloids, fracture filling material and fulvic acid. SKB has also carried out tests to compare latex colloids and bentonite colloids. The site-specific studies at Forsmark and Laxemar have continued.
SKB plans to supplement the studies of the stability of colloids in different conditions. A colloid transport test is being planned at the granite block in Canada and possibly at the Aspö Hard Rock Laboratory. In addition, SKB aims to participate in a colloid test at Grimsel in Switzerland.

Comments by the Reviewing Bodies

The Waste Network Association considers that SKB's presentation under the heading Colloid Formation – Colloids in Groundwater is confusing. The Waste Network states that SKB sheds light on radionuclide transport with the aid of colloids has taken place in the vicinity of a detonation site for nuclear weapons in Nevada but also that SKB did not find any significant transport in diluted water at the Aspö Hard Rock Laboratory.

Luleå University of Technology (LTU) considers that SKB should put more effort into trying to identify natural colloids and not only assume that colloids have a bentonite origin. Furthermore, LTU considers that SKB should test different methods to identify colloids both in groundwater and fresh water and should not only rely on one method.

SKI's Evaluation

SKI is positive that SKB has initiated and is continuing studies of colloids and their mobility in natural conditions and in a laboratory environment. SKI considers, however, that SKB's report does not provide a clear picture of which remaining problems are most important to study and what kind of strategies are needed to tackle these. SKI considers that SKB should clarify the links between the planned activities in this section and the studies described in section 24.2.18 Colloid release/erosion and 24.2.8 Piping/erosion in the RD&D report.

6.7.16 Colloid Formation – Radionuclide Transport with Colloids

SKB's Report

SKB reports that a development and verification of the program code Farf33 has been made to be able to model transport of radionuclides by colloids and that SKB has

participated in the EU project FUNMIG. SKB plans in situ experiments in a bore core to study the retention of actinides when colloids are present.

Comments by the Reviewing Bodies

The Municipality of Oskarshamn (Pereira) considers that SKB's programme for experiment and radionuclide modelling seems to be adequate even though it is difficult to assess. The municipality further considers that it is unclear whether results from the programme can be used in SR-Site, which is considered desirable.

SKI's Evaluation

SKI is positive to the planned activities but also considers as in the section above on colloid formation in the groundwater that SKB's Report does not provide a clear picture of the remaining problems that are important to investigate and the strategies needed to tackle these.

6.7.17 Gas Formation/Dissolution

SKB's Report

SKB plans to further development equipment for gas sampling and analysis.
SKB points out that studies aimed at understanding the origin and transport of methane and hydrogen are of importance for the safety assessment. Furthermore, SKB discusses the possibility of analysing inert gases to obtain information on infiltration temperatures of the different types of water.

Comments by the Reviewing Bodies

The Royal Institute of Technology (KTH) points out that one must, of course, know about the different sources and depressions of hydrogen to be able to make predictions about future water content and thus the lifetime of the canister. KTH therefore considers that SKB should take up in this section analyses and predictions on future hydrogen content in the geosphere.

The Swedish Research Council points out that SKB should more clearly report the quality of the models used in simulations of gas formation/solution.

SKI's Evaluation

SKI shares SKB's view that studies of the origin and transport of methane and hydrogen are important. SKI is positive to SKB's plans to develop equipment and analyses for gas sampling.

6.7.18 Methane Ice Formation and Salt Exclusion

SKB's Report

SKB plans to continue studies of methane formation in mines in Canada. SKB considers that information from the site investigations can contribute to tracing previously earlier

permafrost depth, salt exclusion and methane ice formation. SKB also plans modelling of salt exclusion in connection with SR-Site.

Comments by the Reviewing Bodies

The Nuclear Waste Secretariat of the Environmental NGOs, Milkas (Mörner) points out that SKB should as soon as possible investigate explosive dehydration of methane ice which is a fundamental process and constitutes a threat to the safety of the repository. Milkas (Mörner) further states that this process is lacking entirely in the programme despite being pointed out in the review comments to RD&D Programme 2004.

The Swedish Research Council points out that SKB should more clearly report the quality of the models used in simulations of methane ice formation and salt exclusion.

SKI's Evaluation

SKI shares SKB's assessment that further measures in these areas are called for. SKI has, however, difficulties in assessing whether SKB's studies in mines in Canada are appropriate.

6.7.19 Integrated Modelling – Hydrogeochemical Development

SKB's Report

SKB is not reporting any plans for activities for this area but refers to the site investigation programme and the safety assessments.

Comments by the Reviewing Bodies

The Swedish Chemicals Agency (KemI) makes the observation that only limited space is devoted to chemical aspects in SKB's RD&D Programme 2007. KemI further states that, for example, a detailed description is lacking of which types of chemical compounds that one wishes to prevent spreading from the repository. KemI therefore considers that it is not possible to assess the relevance of the proposed spread models in section 2.7.

SKI's Evaluation

SKI does not share SKB's view that no further method development is necessary in this area and refers to the comments on section 26.2.11 Advection/Mixture – Groundwater. SKI considers like the County Administrative Board in the County of Uppsala that it is important that SKB, in connection with an application according to the Environmental Code, draws attention to the risks of chemical-toxic effects on human health and the environment. Among other things, different materials which may be brought to the repository such as grouting used to seal fractures in the rock.

6.7.20 Integrated Modelling - Radionuclide Transport

SKB's Report

SKB reports on work that has taken place in the tracer retention understanding experiment (TRUE). This includes studies of fracture filling material and tracer tests. Among other things, the results show that small fractures are important for radionuclide retention. A project which aimed at building a bridge between site and safety assessment modelling has recently been concluded. The model code Farf31 has been updated to improve handling of input and output data. In addition, SKB started on the development of a new code for radionuclide transport modelling called Porss. SKB has further studied radionuclide transport in connection with channelling in fractures.

SKB plans to complete the TRUE project and expects, among other things, to be able to use the results for the evaluation of SWIW tests in connection with the site investigations. SKB also plans, in collaboration with Posiva, to implement the Porss method in the code Marfa. SKB intends to carry out tests of this code based on SR-Can calculations, which also require development of the ConnectFlow code. Furthermore, SKB intends to enhance if there is interest in increasing the credibility of Marfas making an international comparison. Furthermore, SKB plans to develop codes for reactive transport modelling. These are, inter alia, intended to be used for creating a site-specific transport model for fractures at the Aspö Hard Rock Laboratory. The model can be used to study how radionuclide retention is affected by geochemical conditions.

Comments by the Reviewing Bodies

Chalmers University of Technology (CTH) states that the radionuclides which are expected to be most mobile in the event of leakage are also to a great extent the most difficult to measure for they emit pure β radiation. CTH therefore considers that it would be of interest, within the near future, to start to develop automated detection methods for these nuclides that are difficult to measure in a natural groundwater environment.

CTH points out that the transformation of measurements to parameters in transport models is not always completely simple and that certain generalisations must be made. CTH therefore considers that SKB should also include uncertainties and natural variation in the use of data and that SKB also focuses on understanding of the parameters which are very important for radionuclide transport.

The Municipality of Oskarshamn (Pereira) considers that the development of the Marfa code is an interesting contribution to the analysis of long-term safety but points out that there are no references to the code. The municipality asks whether SKB intends to use the code in SR-Site.

The Municipality of Oskarshamn (Safety Group) points out that the vertical transport between the transition in the rock to the recipient is most important for the radionuclide transport and that it affects the ecosystems concerned. The group further points out that the most important variable is the water flux and that surface water movements affect how different biosphere objects are coupled. The Municipality of Oskarshamn (Safety

Group) considers that it would be of interest to know how permafrost, tundra or glaciation can affect the water transport of radionuclides. The group asks, for example, whether there are transport routes that have not been taken into account by SKB. The group also asks whether bacteria in the rock mass can affect the radionuclide transport or have any other effect on safety.

The Municipality of Oskarshamn (Safety Group) considers that the dose forecast during the operating period is of less interest since the exposure route passes through water that is pumped away and can thus be checked.

Uppsala University (UU) states that the main risk is leakage and transport in fracture zones. UU therefore considers that it is important that fracture zones and their properties in the areas intended for final disposal are very carefully investigated and that suitable modelling studies have been carried out, etc. UU also points out that SKB has carried out extensive studies of this, which should naturally continue.

SKI's Evaluation

SKI considers that the programme reported by SKB is appropriate. SKI is positive to SKB's plans to transfer knowledge from SWIW tests in the Aspö Hard Rock Laboratory to the evaluation of the site investigations. SKI further considers that it is good that SKB plans evaluations of the new code Marfa. In order for SKB to be able to use the code in a meaningful way in safety assessments, it should, however, be documented and sufficiently well tested, which also entails an adequate site-specific parameterisation and uncertainty analysis. SKI therefore considers that SKB should make additional efforts to deal with issues relating to how results from relatively short retention experiments shall be transferred to transport models for long-term safety. SKI further considers that the programme for radionuclide transport in the geosphere should be linked more clearly with the corresponding programme for the biosphere. In particular, the interface between the geosphere and the biosphere is of interest to obtain an appropriate quantification of dose and risk. As in SR-Can, the review would like to see SKI analyse in more detail where emissions reach the biosphere after canister failure.

6.7.21 SKI's Overall Assessment - Geosphere

SKI is positive that SKB has, in the programme's geosphere chapter, to a great extent based itself on important questions identified in the safety assessment SR-Can.

In the RD&D programme, the geosphere has been divided into 26 sections and this structure allows a detailed description related to many different processes. SKI considers, however, that the links required to tie together the key issues with the relevant processes are not clear in the presentation. The key issues linked to the geosphere are, for example, radionuclide transport, buffer erosion and copper corrosion. With SKB's arrangement which takes into account processes without linking them structurally to open key issues, there is a risk that important issues will not be sufficiently clarified.

One issue which is explicitly part of the chapter arrangement is radionuclide transport which is contained in four sections. SKI considers, however, that it is important to identify the most significant needs for further research and development based on the

whole system. Accordingly, SKI considers that SKB should plan and report research and development for transport of radionuclides in an integrated way for significant aspects of both the geosphere and the biosphere.

SKI shares the viewpoint of a several reviewing bodies that state that SKB should continue work on testing and verifying the models applied. SKI considers that it is important to achieve as good credibility of the model results as possible. SKI further considers that the level of ambition for such tests and appurtenant uncertainty analyses should reflect the importance of the models for the site description and the safety assessment.

Heat Transport and Thermal Movement
SKI considers that none of the methods which are described in SKB's planned programme for thermal movement deal with the problem that fractures in surrounding rock to deposition hole can start to propagate from an fracture end through thermomechanic load and combine with other fractures. This can in turn lead to an increase in the groundwater flow around the deposition tunnel. SKB should take this into account in its further work concerning thermal movement.

Movements in Intact Rock
SKI agrees with SKB in the assumption that if the deposition tunnels are oriented parallel to the direction of major horizontal stress then the risk of spalling during the construction phase is less than in the case of orientation in other directions. This is confirmed by SKI's consultants Backers and Stephansson's conclusion in a recently published SKI-report on Forsmark.

Reactivation –Movement along Existing Fractures, New Fracture Formation
SKI has in various contexts pointed out the lack of studies concerning strength and deformation of large fractures and fracture zones. This type of study is important in the light of regional and local modelling needed for analysis of stress states, the strength of the rock mass and issues relating to linked processes. SKI cannot find that this has been taken up in a good way in SKB's programme, which is a deficiency.

SKB also needs to report its points of view on whether it considers that the repository in itself can constitute a plane of weakness and thus a failure initiation in connection with future earthquakes.

With respect to formation of new fractures, SKI considers that this cannot be excluded. SKI would like to see detailed reasoning and estimate of uncertainties relating to future new fracture formation at the candidate sites Forsmark and Laxemar. SKI also considers that the 3Dec code needs to be modified to be able to simulate new fracture formation, propagation of fractures and connection of fractures in thermomechanic near-field models.

SKI considers that SKB needs to further development methodology and show any existence of flow paths in excavation-disturbed zones along the route of a blasted tunnel.

SKI like SSI considers that SKB, on the basis of an overall problem description, should derive and present programme for continued work that sheds light on development of

models to evaluate the effects of an earthquake of magnitude 6 or greater, methods for identification of fractures and deformation zones, additional work with discrete network models and development of respect distances and criteria for choice of deposition positions.

6.8 Biosphere

Since SSI is an expert authority in the area of the biosphere, SKI has decided not to make any comments of its own on the biosphere chapter (Chapter 27) in SKB's programme. Instead, SSI's statement to SKI is presented in extenso apart from the references that SSI has referred to in its text. SKI does, however, present initially in this section points of view put forward by some reviewing bodies.

Comments by the Reviewing Bodies

Milkas (Hultén) states that the association looked forward to receiving a report of SKB's work on the biosphere in the RD&D programme with great interest since this has been postponed to the site investigation phase. Unfortunately, the chapter (Chapter 27) is a disappointment. The text gives the impression of great energy and a high level of ambition but is imbued by a short-term approach and a not wholly mature understanding of what a system-ecological approach entails.

Hultén notes that SKB points out (page 362) that "the approach is system-ecological" and that it is "holistic". However, already on the same page, it is stated that the system-ecological approach has not been fully adopted. In a system-ecological perspective, there is quite simply no "final destination" (as stated in SKB's text) – not given a holistic perspective at any rate. Secondly, Hultén considers that the sea is a poorly chosen example of a final destination if such were to exist.

The Municipality of Oskarshamn notes that knowledge about the biosphere is important since it is there that any disseminations of radionuclides would produce consequences for health and the environment.

The municipality's expert Pereira notes that SKB in SR-Can has introduced a new concept for biosphere modelling namely landscape models. In order to be able to achieve a broad experience and a deeper understanding of how to apply the models, it would, according to Pereira, be interesting to use the Chernobyl area as a test for the modelling strategy since the results can be compared with field data, even if this is not wholly without objections.

The municipality considers that it is still important to carry out the announced study in RD&D Programme 2004 in the form of a "compilation of knowledge on the importance of permafrost and the tundra for radionuclide transport in the biosphere" (page 375).

The Opinion Group for Safe Disposal (Oss) and The Waste Network note that local differences in the biosphere – drainage, watercourses, lakes, etc. are important for long-term safety and are thus a factor for complying with the siting rule in the Environmental Code and SSI's requirement for optimisation of radiation protection.

This optimisation must take into consideration great variations over time linked to climate and other changes. The organisations also consider that the Government should clarify the necessity of a report on the selection criteria on which the site selection is based and how the company has given priority to dilution in the in the groundwater and the biosphere.

The Municipality of Östhammar and the local safety committee at the nuclear power facilities at Forsmark note that climate models at the site investigation locations show possible evolutions of, for example, the biosphere under different climate conditions and in this way provide a picture of how radionuclides can be transported to and through the biosphere. The municipality considers that it is important to include different local climate scenarios which cover variations of temperate climate (for example, dry or rainy climate) and link them to radionuclide transport through the biosphere.

6.8.1 Introductory Comments

SKB states that one of the most important measures for the biosphere research programme is to achieve sufficient understanding of processes and phenomena to be able to simplify and make numerical models required for dose calculations. SSI's assessments below apply above all to models for dose calculations in the safety assessment.

In SR-Can, SKB produced an integrated landscape model that includes several ecosystems in the succession of landscapes after isostatic uplift. In the review, the authorities considered that this method is a step forward in the development of the risk assessment although there are a number of deficiencies in methodology, which need to be rectified if it is to be used in SR-Site:

- The method gives a dilution effect in the dose calculations .
- Relevant transport processes have not been included in the model description.
- Validation of the models against field data is insufficient.
- An uncertainty analysis is lacking.

SSI is aware that SKB has not been able to take into account in RD&D Programme 2007 the authorities' comments on the biosphere in the review of SR-Can. Despite this, SSI refers back to these comments often, partly because SR-Can show how SKB uses knowledge from the biosphere programme in a safety assessment and partly because, according to SKB's planning, it is the last safety assessment before the application. SSI considers that it is important that SKB clarifies how the authorities' points of view on SR-Can and on RD&D Programme 2007 will be dealt with in the continued biosphere programme. More detailed points of view are given below under the headings in section 27 Biosphere in RD&D Programme 2007.

6.8.2 Understanding and Conceptual Models

SKB's Report

SKB states in the introduction that the development of process-based models is considered to be a feasible way to demonstrate understanding, at the same time as these models provide numerical results that can be used in the safety assessment. SKB has further developed the landscape model through linking together the ecosystem models in time and space. Organic carbon is used as a basis to calculate an ecosystem's production, a human being's annual food intake and how many people an ecosystem can support.
With the aim of efficiently communicating newfound knowledge and understanding between the implementer of site investigations and site analysis to research and safety assessment, has established the network SurfaceNet. This network includes a broad selection of representatives from different subject areas which is important for near surface ecosystems.

SSI's Evaluation

SSI considers generally that the terminology makes difficult understanding of SKB's description of the biosphere in RD&D Programme 2007. For example, there are many different names for models; ecosystem model, radionuclide model, dose model, biosphere model, process-based model and mechanical model. SSI assumes that the concepts process-based model and mechanical model are synonyms for the models that describe detailed processes in ecosystems in different references to SR-Can, for example, the carbon flow model or the Coup model. The other model names are assumed to refer to the models used in the safety assessment.

As mentioned in a previous RD&D review, SSI considers that it is a deficiency that there is a lack of an overall description of processes which are relevant for producing the models used to calculate doses in the safety assessment. This deficiency also made difficult the authorities' review of SR-Can.

In SR-Can, the authorities have reviewed SKB's landscape model and the details can be found in the report (SKI, 2008). SSI is positive to SKB's development of an integrated model to describe the distribution of radionuclides in the environment. However, there are many issues relating to the application of this model in the safety assessment. SSI stated, among other things, that it is difficult to see the link between the landscape model and the process-based models. The radionuclide transport models included in the landscape model are largely the same as that used in SR-97 and thus do not reflect the updated process understanding obtained in the past ten years. SSI is positive to SKB's creation of the network SurfaceNet which can contribute to better process understanding and a holistic view of near surface ecosystems.

6.8.3 Model Development

SKB's Report

SKB has developed the tool Pandora which replaces the previous tools Biopath and Prism. Pandora has been adapted to the probabilistic tool Eikos to be able make probabilistic calculations more easily. SR-Can was the first safety assessment in which Pandora was applied. SKB states that the advantages of Pandora are that process-based models can be used. Moreover, SKB states as deficiencies in the models used in Biopath and Prism for previous safety assessments, for example SR-97 and SAFE, that they are mainly based on generic transfer factors (or transfer and bioaccumulation factors). SKB also considers that transfer factors are in many cases based on empirical data and lack a mechanical basis for explanation. SKB states that the use of process-based models solves some of these problem since the transfer between reservoirs will, besides via water flows, be based on natural processes such as photosynthesis, degradation, food intake, metabolism and nutritional requirements.

SSI's Evaluation

SSI is positive to SKB's development of advanced numerical tools which can solve large and complex models. However, SSI wishes to emphasise the importance of the numerical tools being quality assured. SSI's picture of SKB's model development is that SKB works at the same time with the landscape model and the process-based models. SSI considers that the description of the link between the process-based models and the landscape model is unclear.

Another lack of clarity is to the extent to which SKB takes into account the physical and chemical properties of radionuclides in the evaluation of flow paths and distribution between different ecosystems. SKB states that flows based on the turnover of organic material and to these flows are associated with proportional flows of radionuclides and that the models are general for all radionuclides. No reference is given for this assumption. SSI considers that SKB should provide an account of how radionuclides which wholly or partly do not follow the same flow paths as organic material are taken into account.

6.8.4 Transport Processes

SKB's Report

SKB states that "The transport processes determine which ecosystems and organisms which will be exposed to radionuclides and how great the dilution will be. The transport processes comprise an important part of the calculations in the safety assessment. The most important transport-related variable is water flux." SKB also states that the preliminary sensitivity analysis of LDF shows that the topography is of great importance and notes that it is positive from a modelling viewpoint that the doses are affected by relatively easily predictable properties such as topography.

Different models have been used to study transport processes. Simplified Gis models have been compared with different types of more advanced hydrological models in Gis or in special tools such as Mike She and Shetran. Mike She has also been used to study

water flows and the accumulation of substances in a mire and solute transport from rock to soil layers and onward through the surface system. A number of activities have been planned, for example, particle transport in the sea, a study of radionuclide transport in the Krycklan area and surface hydromodelling. As part of the site description, SKB plans an overall report dealing with conceptual models and transport properties in the transition between geosphere and biosphere for both sites.

SSI's Evaluation

SSI agrees with SKB in that transport processes are important in the safety assessment. However, SSI wishes to emphasise that, in addition to water flux and the topography which SKB mentioned, there are other transport processes which may have a great effect on doses in the environment, for example sorption, exchange in the hyporheic zone and spread in the Quaternary deposits.

SSI is positive to SKB having carried out modelling studies that increase knowledge about surface hydrology and transport processes in the transition between geosphere and biosphere and in the external environment. However, SSI cannot see that this knowledge has been transferred to the landscape model used in SR-Can. One example is that the results from the modelling study for mires have not bee applied in the simplified mire model in the safety assessment. Another example is the modelling study with Mike She that shows how great the contaminated area can be from a release area over 100m down in the rock. Knowledge from the study has not been linked with the landscape model, for example, how to identify the size of the biosphere object in the landscape model. Otherwise, SSI considers that the modelling study is of interest although there are weaknesses in the study that can be improved, for example, by placing the assumed release source at the repository depth planned for the repository (approximately 500 m). Furthermore, SSI considers that SKB should make further study of the reason for dispersion in the modelling.

SSI lacks in the biosphere programme similar field studies with trace element tests which exist in the geosphere programme, and which can contribute to increasing the understanding of the transport process and predictive ability for the models used in the safety assessment. SSI considers that SKB should investigate if a limited programme for tracer tests in near surface sediments/Quaternary deposits and in selected watercourses could contribute to verifying parts of the models or reducing critical uncertainties from SR-Can (including the issues taken up in the authorities' review). Bearing in mind that the uncertainties in dose transformation factors for the biosphere can be very great, SSI considers that it can be problematic to replace to too great an extent a good process understanding by a pessimistic treatment in the safety assessment.

As regards planned activities, SSI considers that it is important that SKB can link all knowledge from these activities to the final safety assessment model.

6.8.5 Terrestrial Ecosystems

SKB's Report

SKB has developed the forest model for use in the safety assessment. At the same time, the development of the process-based Coup model has continued and it has been adapted to be able to deal with transport of radionuclides in different ecosystems. SKB states that the forest model will be supplemented with knowledge about the most important mechanisms for radionuclide transport. Knowledge comes from development and sensitivity analysis of the Coup model. Parts of the forest model may also be possible to validate with data from an upcoming study of the age of organic material in the soil.

SKB states that mires and wetlands are important recipients and that it is probable discharge points from the geosphere. It is therefore important to study processes that may affect radionuclide transport and potential exposure paths in connection with mires and wetlands.

SSI's Evaluation

SSI considers that SKB's work on developing the forest model for use in the safety assessment is valuable. Both the knowledge support from the process-based Coup model and the validation of the forest model in relation to observed data makes a positive impression.

As regards mire and wetland, SKB does not present a clear plan for the model development. In the review of SR-Can, an external reviewer, K. Stark, considered that SKB needs to use more wetland models to cover the diversity of prerequisites in different types of wetlands. SSI shares this viewpoint.

6.8.6 Aquatic Ecosystems

SKB's Report

SKB states in the introduction that radionuclides in many discharge areas will pass through as sediment layers and that these will thereby influence on spread and dilution patterns. "There will be a marked change in redox conditions, salinity and biological activity in the boundary layer between sediment and water, which can influence the radionuclide flow. In the short term, these processes will probably reduce the discharge of radionuclides and result in lower doses." In the long-term, however, radionuclides can accumulate in sediments, only to be released later due to isostatic uplift, resuspension and the like, which can result in higher doses.

Through focused research, SKB has obtained an expanded knowledge base on sediment formation, reworking processes and accumulation. SKB mentions three references and states that the knowledge in them has been directly applied in the safety assessment SR-Can.

Prior to SR-Site, SKB intends to compile available knowledge from the site in a report on lakes and streams and in a report on the sea. Comparisons will be made in these reports with other scientific literature on aquatic ecosystems. Further development of dose models is planned for lake ecosystems.

SSI's Evaluation

SSI shares SKB's view of the processes for radionuclide transport through sediments. SSI wishes to add that knowledge about how radionuclides spread in sediments is important because this spread affects the extent of the contaminated area, which in turn affects the final dose. SSI has objections to SKB's statement that knowledge from the three references has directly been applied in SR-Can. The authorities pointed out in the review of SR-Can that the results from SKB's modelling study have not been applied in the mire model. The model to describe radionuclide transport in running water has not been used in SR-Can either, which SSI pointed out previously. SKB states that a further development of dose models is planned for lakes but does not present any concrete plan, for example, for the way in which the further development is to take place or which processes are to be included. It is difficult for SSI to evaluate whether SKB's further development will respond to the authorities' comments on SR-Can.

6.8.7 Reporting of the Biosphere in the Safety Assessment

SKB's Report

SKB states in the introduction that one of the most important tasks of the biosphere research programme is to achieve sufficient understanding of features, events and processes be able to simplify and create numerical models needed for dose calculations. SKB further states that a number of ecosystem models have been updated as well as radionuclide specific data for dose conversion, Kd and transfer parameters. It is the first time that data from candidate sites has been used in the models. An analysis of the impact of the repository on the environment is presented in SR-Can for the first time as well.

SKB intends, prior to SR-Site, to continue to develop models that use element flows and replace or supplement transfer factors with mechanistic models. Sensitivity studies of landscape models will facilitate the prioritisation of parameters and provide an overview of whether the model captures essential processes. SKB also intends to describe in more detail what the biosphere might look like in conditions of permafrost and study alternative evolutions of wetlands from a sea bay.

SSI's Evaluation

Unlike the previous risk assessment in SR-97, where only one ecosystem was analysed at a time, SKB uses an integrated landscape model in SR-Can, which includes several ecosystems in the succession of landscapes following on from isostatic uplift. This is a step forward in the development of the risk assessment. New elements in the assessment include, for example, the log-normal distribution method, which makes it possible to determine the most exposed group in the event of leakage from the repository. As

previously mentioned, SSI considers that there are a number of deficiencies in the new concept, which need to be rectified if it is to be used in SR-Site.

Dose calculations are based on calculations of radionuclide concentration in different environments and in different foodstuffs (for example, through transfer factors). SSI's impression is that SKB places great importance on developing models that use element flows, where transfer factors are replaced or supplemented by mechanistic models. SSI has no objection to make to SKB developing new models/methods provided that there is a good discussion on the applicability of the new models. SSI notes, however, that a programme for verification and validation is lacking in RD&D Programme 2007. Model validation is mentioned on a single occasion in the entire description of SKB's biosphere programme. SKB does not either mention how uncertainties in data and models are to be dealt with in connection with dose calculations.

No plan is mentioned in RD&D Programme 2007 of how the environmental impact is to be reported in future safety assessments. In the review of SR-Can, the authorities stated that SKB's report of the environmental impact should be supplemented for SR-Site. SKB should report how great the uncertainty is for estimated activity concentrations and provide a description of exposure routes for biota.

6.9 Other Methods

In this section, SKI presents comments on Chapter 28 Other Methods in RD&D Programme 2007.

General Comments by the Reviewing Bodies

The Waste Network Association (AKF) notes that KBS-3H can hardly be regarded as an alternative since the method is in principle very close to the main alternative KBS-3V. The remaining method is then WP-Cave which is perhaps not better than KBS-3 although it merits more than the scant treatment it has received over the years. AKF therefore insists on resumed, renewed and more extensive research on the method WP-Cave, to an extent that enables it to be weighed against KBS-3 on similar terms.

Lund University of Technology (LTH) points out in its statement that the work reported in SKB's RD&D Programme 2007 gives an impression of having been very thorough and is moreover uncommonly focused on the long term. LTH considers, however, that it is not sufficient to rely on a single method at this stage, even though it is very promising. LTH therefore recommends that SKB, besides following the path already embarked upon, the main proposal (KBS-3), also puts great resources than at present into alternative technologies, for example, transmutation with reactor/accelerator or disposal in deep boreholes.

The environmental association Friends of the Earth (MJV) refers to environmental lawyer Peggy Lerman's statement at a Kasam seminar (now the Nuclear Waste Council) on alternative methods that SKB's report on alternatives is insufficient. According to MJV, more research is therefore needed on alternative solutions. MJV also considers

that it is now high time that SKB opens the way for a dialogue on research on alternatives.

Milkas (Mörner) points out, as was done for the previous RD&D programme, that SKB must take into account the DRD method as an alternative to KBS-3 and compare the advantages and disadvantages of the respective method.

The Swedish Society for Nature Conservation and the Swedish NGO Office for Nuclear Waste Review (MKG) state that considerably more extensive studies must be made to obtain satisfactory supporting documentation to enable the authorities, the Environmental Court and the Government to make statements and take decisions on the selection of method for a repository for spent nuclear fuel. In this perspective, the levels of ambition as regards studies of alternative methods are far too low in the research programme RD&D-07. Furthermore, the industry opts to call the alternatives "other methods" for legal purposes prior to the environmental assessment. Only two alternatives are mentioned – deep boreholes and transmutation – and the alternative deep boreholes is treated far too briefly. No zero alternative is taken up. It is evident that the industry has narrow-mindedly focused on developing only one method, the value of which in relation to other methods has never been seriously considered.

The organisations consider furthermore that there are accordingly very poor prerequisites for the industry now, as little as previously, to work to clarify in a serious way the prerequisites for carry out the method of deep boreholes and to clarify the long-term environmental safety of the method. The industry now says openly that it does not have any such intentions and places considerable resources in preparing alternative reports for future applications where the aim is to make the alternative method of deep boreholes appear unrealistic and unsafe.

The Safety Group in the Municipality of Oskarshamn notes that in previous RD&D reports, the method of deep boreholes has been presented as appropriate to make a comparison with the KBS-3 method. The authorities have suggested that SKB make a comparison on safety grounds. In the RD&D programme, SKB states that the uncertainties are so large that it is not meaningful to make such an assessment. The safety group wishes to know whether the authorities share this view.

The Opinion Group for Safe Disposal (Oss) and The Waste Network look forward to SKB's future and final alternative report and the subsequent environmental assessment where the deficiency of clear performance requirements and directives and the lack of a clear societal purpose of the repository project will be evident and hopefully attract attention.

The Swedish Research Council considers that it is not appropriate to rely completely on one solution now (KBS-3) even if it has been dominant for more than three decades and therefore recommends that SKB, in a supplement to the proposed programme, also start a programme for basic research about the future repository.

6.9.1 Partitioning and Transmutation

SKB's Report

SKB starts with a brief description of the meaning of partitioning and transmutation (P&T): that certain long-lived radionuclides in the nuclear fuel can be burnt out, transmuted, in different systems of nuclear reactors. For this to be possible, it is necessary that these radionuclides are first chemically separated from the nuclear fuel with high efficiency. In this way, the radioactive radiotoxicity of the remaining residual products can be considerably reduced and the time for which a repository needs to be safe can be reduced from hundreds of thousands to thousands of years compared with direct disposal of the spent fuel. Although SKB does not mention this explicitly, a prerequisite for P&T is that an actual nuclear fuel cycle is used with reprocessing and recycling of uranium, plutonium and other heavy elements such as americium and curium.

SKB continues to report the conclusions from the review of P&T in RD&D Programme 2004. It is noted that the authorities' review did not give rise to any deviating viewpoints on the conclusions presented by SKB in this programme.

In its presentation of newfound knowledge internationally since 2004, SKB briefly highlights the following points:

- The financial support for P&T in the EU programme has levelled off although it still has a prominent role in the programme for future nuclear power and nuclear fuel cycles
- The previously strong interest in accelerator-driven systems (ADS) has declined somewhat in favour of fast reactors, which could ultimately take over the role given to ADS for burnup of americium and curium
- The fuel tests of plutonium nitride which were initially planned to take place at the Studsvik R2-reaktor will now be performed in the Netherlands (Petten).
- Research in partitioning has made great progress and it is therefore now possible to focus more on developing a functioning process technology.
- The importance of P&T for Sweden has been evaluated by SKB. One conclusion of the study that the long lead and operating times for a system with transmutation mean that responsibility is shifted to future generations. It also requires long-term investment in nuclear energy production on a time scale of 100 years or more.

SKB also refers to Kasam's state-of-the art report (SOU 2007:38) which, among other things, draws the conclusion that further research on transmutation in the Swedish programme is reasonable bearing in mind the ethical principle of not compelling future generations to develop new technologies to solve problems. Kasam also considered that research also could pay off in ways which are of value in other areas, for example, nuclear physics, chemical partitioning technology and materials technology.

In its future programme, SKB states that it will continue to examine technology development and assess whether and, if so, how the technology will affect the Swedish nuclear waste system. Support will continue to be given to ongoing research at universities and within a broad international collaboration, in particular, within the EU.

The extent of SKB's work, which has been in the order of SEK 5 million per year in the past five years, needs to increase to between SEK 6-7 million per year for the period 2008-2010. SKB justifies this with the need to be able to follow up work within the EU on future advanced systems, since an increase and broadening of this work is taking place in the EU.

Comments by the Reviewing Bodies

The Waste Network Association emphasises the benefits of first partitioning the most long-lived substances plutonium and americium before disposal to then manage these in a different way. The association considers that if this measure is carried out a spectacular retrieval will be unnecessary at the same time as it shows good and genuine concern about future generations.

Chalmers University of Technology points out that a better way to use the fuel while at the same time shortening storage times of the spent nuclear fuel is partitioning and transmutation. The work that SKB supports in this area, including work relating to wet chemical processes for separation of actinides from the spent fuel has been successful. Chalmers therefore considers it important that this work receives continued support and that Sweden can retain its leading position in this area.

The Swedish Energy Agency points out that processing and transmutation are only fleetingly mentioned in the programme text, at the same time as SKB invests over SEK 5 million per year on research around these technologies. The Energy Authority would therefore like to see a deeper account of the interaction of these technologies with the energy system.

Karlstad University says that it shares the evaluation that transmutation should not come into consideration. The university asks why an account is given of the treatment alternatives partitioning and transmutation as if this were a possible disposal method, in particular as the supervisory authorities pointed out this difference as early as 1998.

Lund University of Technology recommends SKB, besides following the path already embarked upon, the main proposal KBS-3, to invest considerably more resources at the same time on alternative technologies, such as transmutation with a reactor.

The Friends of the Environment for Nuclear Power proposes that SKB should also take into account the future potential of transmutation for considerably reducing the dangerousness of nuclear waste.

The Municipality of Oskarshamn (Pereira) does not consider that partitioning and transmutation is a realistic alternative to a geological repository. However, the municipality considers that the method is the only attractive programme in training of nuclear researchers and is therefore needed to retain and develop nuclear competence in Sweden. The municipality therefore considers that SKB's budget of between SEK 6 and 7 million per year during the period 2008-2010 is justified.

The National Association of Swedish Energy Associations, SERO, considers that it is not justified for SKB to use funds for research on processing and transmutation since neither can be expected to be of relevance for Sweden. Current funds should instead be reduced and only extend to monitoring literature, in SERO's opinion.

Uppsala University considers that SKB's anticipated increase in the budget for transmutation of 20-40 % is probably based on a correct assessment. The university asks moreover if this proposed increase is not too low bearing in mind the relatively swift international development in this area.

SKI's Evaluation

The starting point for SKI's evaluation is as well as for previous RD&D programmes is that P&T cannot at present be regarded as a realistic alternative to direct disposal of the spent nuclear fuel. In SKI's opinion, it is none the less very important that Sweden through SKB's efforts maintains and develops competence in this area.
As reasons for this viewpoint, SKI wishes to state:

- In order for SKB's programme to be as comprehensive as provided for in the Nuclear Activities Act, it must also include technologies which may appear less realistic at present for economic and political reasons.
- Sweden must participate in development in this area in an active way to maintain the prerequisites for an independent assessment of the potential of the technology – it is not sufficient to passively follow developments.
- Participation in the international exchange of research in the field of transmutation will provide prerequisites for Sweden to be able to benefit from knowledge which is also important for the current nuclear waste programme and other areas of nuclear technology.
- Last but not least, SKB's programme in the area of partitioning and transmutation contributes to maintaining a level of research which is important not only for future application but also for dealing with existing nuclear waste.

SKI wishes to encourage SKB to continue to carry out or participate in system studies. In-depth studies should as to date take place in fields where Swedish research has proven capable of making serious contributions. Given these prerequisites, SKI has no objection to make to the announced expansion of SKB's work in the coming years.

6.9.2 Deep Boreholes

In the concept of disposal of spent nuclear fuel in deep boreholes, deposition of canisters of spent fuel at a depth of between two and four kilometres is discussed where groundwater conditions are probably very stable (Grundfelt and Wiborgh, 2006). At these depths, the rock is the most important barrier for isolation of the waste while the performance of other conceivable barriers such as the clay buffer and canister will be more difficult to predict due to high rock stress high temperature and groundwater with extremely high salinity.

SKI mentioned at the time of its statement on SKB's supplement to RD&D Programme 1998 the difficulties that investment in the deep borehole alternative would entail. As

examples were stated the selection of system design, conditions at repository level and the need for technology development for barriers, bore- and deposition technology.

SSI considered in its review of RD&D Programme 2001 that a report, which, among other things, included a safety assessment of deep boreholes could justify the requirement for an alternative report referred to in the Environmental Code. SKI stated in its review of the same programme that the need and extent of a safety assessment for deep boreholes should be discussed within the framework of the consultations between SKB and the authorities which the Government decided upon in 1996 and 2001.

In the review of RD&D Programme 2004, SKI considered that there were good reasons for clarifying the report prior to final choice of method and prior to consideration under the Environmental Code and both SKI and SSI considered that a more careful comparison should take place with the KBS-3 method. SKI also considered that such a comparison should take place with a systematic based on the same principles developed by SKB through previous safety assessments of the repository and agreed with SSI that this comparison could be illustrated by simplified calculations. SKB has, however, made the assessment that the uncertainties are so great that an assessment of this kind would not be meaningful. Instead, a modelling study was made of Kemakta (Grundfelt and Wiborgh, 2006). This study showed that flow times from the repository level up to the surface would be in the range of 1-100 million years.

Kasam (The Nuclear Waste Council) considered in its statement on RD&D Programme 2001 that sufficient reasons were lacking to carry out the outlined RD&D programme for deep boreholes and proposed that SKB instead continue development work focused on direct disposal according to the KBS-3 method. Kasam also considered in its statement on RD&D Programme 2004 that deep boreholes were not a realistic method.

SKB's Report

SKB notes that the concept of deep boreholes is based on the assumption that groundwater conditions are very stable at great depth although an assumed high salinity, high temperature and high rock stress entail that one cannot expect any long-term safety function from the canister and the buffer. The only remaining barrier in the concept is thus the rock which shall alone fulfil the requirement of long-term safety. SKB also considers that equipment for deposition is lacking although the technology for drilling deep holes is available but needs to be developed.

SKB presents the history of studies carried out on alternative methods which was called for by both SKI and the Ministry of the Environment. Based on the alternative studies of the repository carried out carried out (Pass) deep boreholes received the lowest ranking with respect to technology, long-term performance, safety and costs. In the more recent studies performed, KBS-3 and medium-long holes were considered to have the greatest potential while a research programme for deep boreholes at the same level as KBS-3 would entail over 30 years' delay and considerable additional expense. SKB also notes that no other country in the world has recommended deep boreholes as its first-hand alternative for taking care of spent nuclear fuel.

Under the heading newfound knowledge, SKB argues that a repository several kilometres deep would be exposed to greater stresses in connection with a glaciation

caused by increased frequency of earthquakes than a KBS-3 repository at less depth. SKB further considers that glacial earthquakes could theoretically lead to the transport of radionuclides between the repository and the more superficial flowing groundwater between the repository and the ground surface.

SKB's evaluation from the two preceding RD&D programmes remains the same, i.e. that nothing argues in favour of deposition in deep boreholes being able to increase the safety of disposal of spent nuclear fuel. SKB's evaluation is based on identified weaknesses in principle of the concept such as poorly controlled deposition, a sole barrier after a short time and great uncertainties about fuel dissolution during, in particular, a glaciation. SKB therefore considers that a research programme on deep boreholes is not justified.

Comments by the Reviewing Bodies

The Waste Network Association completely shares SKB's and the authorities' view of deep boreholes. None the less, AKF considers that there must be an alternative method to disposal for purposes of investigation, which can be compared as an alternative or reference to KBS-3.

Karlstad University points out deficiencies in the report on alternative disposal methods, among other things, knowledge is lacking about whether the reported alternative method is feasible in Sweden. The Government should therefore instruct SKB to report alternative methods at a level of knowledge that would make possible comprehensively and well supported comparisons, and that this, for the deep borehole method, would require an upgrade of current knowledge. These R&D measures should initially be focused on clarifying whether the method's hydrogeological prerequisites can be met within Sweden.

The Swedish Society for Nature Conservation and the Swedish NGO Office for Nuclear Waste Review (MKG) consider that there are very poor prerequisites for the industry now, as little as previously, being able to work in a serious way to clarify the prerequisites for carrying out the method of deep boreholes and clarifying the long-term environmental safety of the method.

The Swedish Society for Nature Conservation and MKG also notes that the industry points out in the programme that no additional work would be invested in the deep borehole alternative other than following developments elsewhere. At the same time, it is evident to the organisations that knowledge is lacking to draw the conclusions about the method that the industry does. Additional studies are needed, among other things, the central function of the salinity barrier at a depth of 1-2 km and that it is not disturbed by glaciations should be verified. The organisations consider that the industry works against a build-up of knowledge in this field. The Government must therefore ensure that the authorities receive commission and resources to produce their own supporting documentation to be able to assess the alternative method deep boreholes prior to an environmental assessment where alternative assessments are of key importance.

The Municipality of Oskarshamn (Pereira) considers that the uncertainties attached to the deep borehole alternative are too great and that it is more of internal scientific interest to microbiologists, geologists, hydrologists, physicists and chemists etc.

The Opinion Group for Safe Disposal (Oss) and The Waste Network consider that the Government should require SKB to carry out the number of test drillings required to show that groundwater can be expected to be stagnant at greater depth and thus ensure whether the alternative deep boreholes can be an alternative to the KBS-3 method or not.

SSI considers in its statement to SKI that bearing in mind the positive results obtained to date on the barrier function of the rock for the deep borehole concept that SKB should produce more complete supporting documentation for the planned comparison with the KBS-3 method, both as regards feasibility and long-term radiation protection.

SSI is aware that great uncertainties are associated with both drilling technology and, in particular, the disposal process. SSI considers however, inter alia, on the basis of Kasam's seminar on deep boreholes on 14-15 March 2007, that current knowledge of drilling technology is sufficient to be able to make a more detailed study that SKB has done to date. SSI also considers that SKB should further clarify the consequences of mishaps in connection with disposal (for example, getting stuck in the deposition hole), as well as possible measures to deal with such mishaps. A formal expert hearing of experts from adjacent areas of technology could be a way to shed light on issues relating to implementation and deposition in deep boreholes.

As regards the long-term safety and radiation protection, the critical issue according to SSI is whether the salt groundwater at great depth can be really expected to be sufficiently immobile to retain the radioactive substances for hundreds of thousands of years. SSI considers that there are simplifications in SKB's calculations, in particular the limited size of the model domain, which should be investigated for further clarification of this issue. SKB points out in RD&D Programme 2007 that there are great uncertainties about how a future glaciation could affect the stagnant groundwater. SSI sees, however, no impediments of principle for SKB to make an analysis of these issues. Effects of postglacial earthquakes are, despite considerable uncertainties, an integrated part of the safety assessment for a KBS-3 repository and should be possible to carry out for deep boreholes as well. In order to make a fair comparison with the KBS-3 method SKB should also produce better arguments for the limited design lifetime (1,000 years) for the analysed canisters in the deep borehole concept.

SSI considers that the principle question of whether deep boreholes comply with SKI's regulatory requirements for several barriers if the canister cannot be guaranteed to be sealed in the repository environment is of interest. However, reasoning of this kind should be placed in the perspective of it not being possible in the KBS-3 to guarantee that the canisters will be intact over a long time, which is illustrated by the results in SR-Can. This issue is also linked to the design and choice of material of the canister (design lifetime).

To sum up, SSI considers that SKB should make additional studies of the deep borehole concept prior to the licence application to be able to make a meaningful comparison

with the main method. The intention should be to be able to assess whether deep boreholes are a repository concept that can be developed and to make a comparison with the KBS-3 method as regards the long-term protective capability taking into account the uncertainties of both the methods.

The National Association of Swedish Energy Associations (SERO) considers that the deep borehole alternative seems to be technically possible. SERO further considers that there is a lot less research on deep boreholes available as support so that many statements in the RD&D report should rather be regarded as assumptions in the lack of facts. SERO considers that the result of the research which has now started in the United Kingdom in 2007 will hopefully provide answers to a number of question.

Uppsala University considers that there are a number of strong factors that are considered to mean that disposal in deep boreholes is less attractive than the KBS-3 method. However, the alternative is discussed in the document and the university therefore does make some comments:

- A test drilling programme would greatly increase understanding of the chemistry, hydraulics and the biosphere at this depth. This knowledge would in turn increase the credibility of the safety assessments of the KBS-3.
- It can be added to the discussion on deep boreholes that a repository, or if there are several, must be sited with greater consideration for seismic activity since the nuclear waste will then be kept at seismogenous depth. Specific site selection will be difficult to make since seismicity is low and moreover episodic in time and space by nature.

The university further considers that a programme for test drilling deep boreholes would be of great value for understanding of stress conditions at depth in Sweden, and thus for understanding of the seismic activity. Stress sensors in holes could furthermore provide a lot of information about the size, direction and stability in time of the extension field, which can be translated into stress information. Electromagnetic measurement methods in the boreholes could be used to map salinity and salt layers in the groundwater.

SKI's Evaluation

SKI notes as was done in the review of RD&D Programme 2004, and also on the basis of the present level of knowledge, that the only barrier that may be assumed to work for the deep boreholes concept is the rock, provided that the bedrock at repository depth is sufficiently homogeneous. It is difficult to evaluate short and long-term properties of bentonite or other buffer material in the borehole as regards protecting the canister against major rock movements and chemical effects at great depth. It is similarly difficult to predict the imperviousness of the canister for shorter periods due to the high prevailing rock stress and the aggressive chemical environment at repository depth.

SKI wishes to remind that a repository concept which from the very beginning is based only on the rock as sole barrier is in conflict with SKI's regulations (SKI FS 2002:1) on safety in disposal of nuclear materials and nuclear waste.

SKI is surprised about the arguments that SKB put forwards with regard to the effect of earthquakes on a deep borehole repository even if SKB receives some support in its arguments from Uppsala University. This surprise is based mainly on SKB previously having argued that the closer to the surface a repository is located (for example, a DRD repository) the greater will be the impact and the consequences of an earthquake, which is diametrically opposite to the arguments now put forward. Clarification on this point is required from SKB.

On the basis of the discussions and reasoning presented by SSI at Kasam's (now the Nuclear Waste Council) seminar on deep boreholes in March 2007 and SSI's comments and reasoning in the statement on this RD&D programme, SKI can, despite the objections raised above, support SSI's reasoning that SKB should produce better supporting documentation on deep boreholes for a comparison with the KBS-3 method. SKI also agrees with SSI that the supporting documentation which the new authority needs to be able to compare deep boreholes with the KBS-3 method needs to be strengthened prior to the application for construction of the repository for spent nuclear fuel. SKI also considers as SSI also proposes that the report can be followed up within the framework of continued consultations with SKB.

7 Social Science Research

In this chapter SKI presents its opinions on the social science research undertaken by SKB that is described in Part V of RD&D Programme 2007 and which corresponds to Chapters 29-33 in SKB's report. SKI's presentation is divided into three sub-chapters. In the first SKI presents its view of SKB's social science research programme, while the second deals with individual research fields and projects. The third sub-chapter contains SKI's overall evaluation.

SKI welcomes the social science research accounted for in the framework of RD&D Programme 2007. This research provides greater understanding of the economic and social dimensions of the repository. It is important to clarify the link between SKB's social science research and other activities, the Environmental Impact Statement for instance, which form part of the preparations for SKB's application for the repository. Such an approach would be of benefit for greater integration of the presentation of the socioeconomic dimension of the repository, a longer time horizon and enhanced geographic delimitation.

7.1 Overview – Social Science Research

SKB's Report

SKB's presentation of social science research refers primarily to SKB's social science research programme, which was established in 2004. The aim of the social science research supported by SKB is to:

- broaden the perspective on the societal aspects of the nuclear fuel programme,
- provide new, more detailed knowledge and also extend and raise the quality of material on which decisions are made,
- contribute data and analyses for research on the societal aspects of large industrial and infrastructure projects.

After taking into account previous research activities and discussions of their results – including SKI's response – SKB has identified four general areas of research that are particularly relevant for SKB. These four research areas on which SKB's social science research is based are the following:

- Socioeconomic impact – macroeconomic effects.
- Decision processes.
- Public opinion and attitudes – psychosocial effects.
- Global changes.

SKB's social science research programme has previously been evaluated as part of RD&D Programme 2004. The social science research accounted for in RD&D Programme 2007 is based on funding granted in 2005 and 2006. The areas given priority in 2005 and 2006 are the following:

- The use of media in relation to future concerns, democracy and risk awareness.
- Studies of the attitudes of young people to technology, democracy, risk and safety in relationship to new technologies and possibilities of influencing the world around them and their future.
- The ethical assessments and priorities of social institutions and stakeholders in relation to determining the location of a repository.

General Comments by the Reviewing Bodies

The Waste Network considers that the narrow contemporary approach which imbues the social science research is narrow-minded and restricted and the network would on the whole reject it. If, against all better judgement, direct disposal of the spent fuel continues to be the aim, a great deal more is required in terms of methods and programmes in order to anticipate future structural changes in society.

The National Board of Housing, Building and Planning considers that the emphasis placed in RD&D Programme 2007 on social science research is essential for the creation of conditions that will enable long-term sustainable management of the nuclear fuel programme.

Chalmers University of Technology is of the opinion that the social science research places issues about the repository in a social perspective and can provide the management tools that are fundamental for all safety assessments of the repository. However, the university considers that the research programme referred to in RD&D Programme 2007 is very unspecific in view of the need for a research programme before 2010 whose contents will fulfil the requirement to shed light on different social aspects. The university specifically identifies the need to deal with global aspects in terms of risk, safety and changes in the threats posed to spent nuclear fuel and repositories. The university also points out that one important element in this respect is social science research that evaluates the system-analysis approach embodied in safety assessments and the use of such assessments as the basis for decisions in a wider perspective than a purely scientific/technological context.

Gustaf Öberg from Lund notes that in RD&D Programme 2007 SKB seems to assume that it will be completely possible on mainly technological-scientific grounds to provide the kinds of answers to decision-makers' questions about the secure disposal of spent nuclear fuel that will be satisfactory in all essential respects. Öberg points out that things look entirely different if, instead, the planning is based on the more general conditions in which conclusive decisions will be taken, which is that they cannot be made without taking into account that they concern phenomena that are to a great extent inadequately understood and will cover a very long period of time. Öberg also notes that SKB states that these decisions must be made in a state of uncertainty but that the wording of the technological presentations nevertheless suggests a belief in final safety in a deterministic sense with no explicit provision for the probabilistic elements in its material.

The Swedish National Council for Nuclear Waste and the environmental organisations have previously expressed a desire for social science research that is not funded by SKB. The Municipality of Östhammar sympathises with this point of view and proposes

that the Swedish National Council for Nuclear Waste should be given the power to fund and determine the focus of research in the field of nuclear waste.

The Swedish Society for Nature Conservation and The Swedish NGO Office for Nuclear Waste Review consider that nobody who has followed nuclear waste issues can fail to see that the questions that were specified as of special interest in the call for applications for funding from SKB's social science research programme in 2007 were intended to steer the research in a direction that suited the industry. As the industry has launched its social science research programme there is also a risk that this will restrict the possibilities of researchers acquiring funding from other sources for work on nuclear waste issues. One important question when reviewing RD&D is how a change in the prevailing circumstances can be brought about so that social science research in the field of nuclear waste can become less dependent on the industry.

The opinion of the Municipality of Oskarshamn is that the social science research programme is ambitious and has commendable breadth. However, given its basis in already completed research the municipality feels that there may be grounds for future research projects to go into greater depth and to have a degree of concretisation that means that findings can be made even more useful for the parties involved. The Municipality of Oskarshamn is more than ready to take part in the process of identifying such areas for research. One such area could be the current research situation in nuclear power technology and its position in both energy supply systems and environmental systems as this will have an impact on the nuclear waste programme. Research with greater focus on the future and on global issues is therefore desirable. Broader and spin-off studies with greater depth could offer one example. Technology transfer models that involve the use and development of technology and research findings from SKB's undertakings in other industrial operations could be another. Another type of research could comprise follow-up research in which researchers continually study how process-owners discharge their tasks. There would be continual feedback of the conclusions and observations of the researchers. The aim of this kind of research is to contribute to improvement of the process and ensuring greater support.

The Municipality of Oskarshamn also remark on SKB's ambition that the contents of the research programme will by 2010 already have provided the necessary illumination of various social aspects. In the technological area there are no such time limits and the development of disposal technology will also continue after a permit decision has been reached by the Government and the appropriate municipality. In view of the complexity of this issue, the municipality considers that there is every reason not to close the door on continued social research and social studies after the date stated in the programme as well.

The Opinion Group for Safe Disposal (Oss) and the Waste Network consider that several of the conclusions presented by the various research projects have indicated factors that could be improved but this seems to have had little if any relevance or impact on the disposal process. The company also states in RD&D Programme 2007 that the main aim is that experience gained from this research *"can benefit other similar projects"*. This enhances the impression that SKB's social research has no significance for the implementation of the disposal project and raised the question of whether this research really falls within the company's area of responsibility. In order not to jeopardise the credibility of the project the Government should recommend SKB to

transfer what it calls its social science research to a body that is independent of the industry.

Uppsala Regional Council has no objections to SKB's social science research programme.

SSI considers that the flexibility and openness to new ideas in the planning surrounding the social science research programme is commendable. In SSI's opinion, the social science research serves a function. The authority focuses, however, on what is important for radiation protection, which is considered by the authority in this context mainly to consist of future actions caused by human beings, such as intrusion into a repository. Events of this kind are referred to as FHA (Future Human Actions).

SKB explains how the results of the research are accounted for to those concerned and other stakeholders. SSI cannot see, however, how the results are applied in the work of SKB.

Uppsala University considers that the RD&D programme relating to social science research seems to offer good coverage of the field but notes the lack of information about the funding available, which makes it difficult to assess what can be undertaken within the financial parameters. The university also points out that it would be better if the social science research were to be reported under the heading of "humanities and social science research" which is the current official classification and would offer greater visibility to a wider group of researchers and departments at universities. The university also considers it important for SKB to take the initiative in arranging a seminar to which a wide range of researchers in the humanities and social sciences could be invited before new applications are invited for research funding.

The Municipality of Östhammar also points out the importance of retaining possibilities of continued social research after 2010 as well.

SKI's Evaluation

In its evaluation of RD&D Programme 2004, SKI expressed a desire for a clearer description of both the relationship between SKB's social science research and other documents produced for the application process and also a more explicit description of the process that has been developed around SKB's social science research programme.

RD&D Programme 2007 contains a description of the relationship between the social science research and other documents. This analysis deals primarily with the difference between social surveys and social research. SKI's viewpoints on previous programmes still apply and have not been responded to fully in RD&D Programme 2007, especially when it comes to clarification of the relationship between licence applications and environmental impact statements and the social science research.

In its evaluation of RD&D Programme 2004, SKI requested a clearer account of how the process surrounding the development of the programme – inviting funding applications, selection, criteria and appraisal – had been designed and implemented. In addition some of the reviewing bodies expressed the desire for a clarification from SKB

about the relationship between social research, licence applications, environmental impact statements and surveys.

SKI can see that in RD&D Programme 2007 SKB provides clarification of the aims of social research and how its results are presented. It appears that the information is not primarily specific for any municipality but is intended to offer new and general knowledge. SKB also points to the differences between surveys and research, in which surveys are based on an explicit assignment while the terms on which research is undertaken are not defined in advance. In addition SKB points out that research is characterised by a high degree of independence when it comes to formulating research issues, selecting methodology and drawing conclusions from the results obtained. SKI considers that this is a sound approach.

It is SKI's opinion that even though some clarity has been established about the basic principles for SKB's social science research, further clarification of the scientific review of the programme could be desired. This applies mainly to the criteria used to identify the research areas in which invitations for funding have been invited, how research projects have been selected and how funding has been shared between the different research areas.

In RD&D Programme 2007, SKB has described the relationship between social science research and other documents. This analysis applies primarily to the difference between social surveys and social research. SKI considers that further clarification is desirable on the relationship between social science research, licence applications and environmental impact statements. In SKB's survey it is said that one of the aims of SKB's social research programme is to broaden the perspective on social aspects of the nuclear fuel programme. In addition mention is made of Kasam's (now the Swedish National Council for Nuclear Waste) publications and seminars as well as the work undertaken by SKB from 1993 to 2000, in which considerable attention was paid to social aspects. The link between the knowledge acquired earlier, including Kasam's projects and pilot studies in the municipalities as well as the inventory of research drawn up by SKB during 2003, should have been made clearer.

SKI considers that a longer time frame would have been advisable for SKB's research and that the social science research should continue after 2010 and the Government has reached a decision on permissibility.

7.2 Review of SKB's most recent results

The projects undertaken in the four general research areas in RD&D Programme 2007 have added to our knowledge, in particular with regard to demography, local economic conditions and developments linked to the establishment of a repository in a municipality. Added knowledge has also been gained about attitudes to the time horizon of a repository with a focus on the local conditions in Östhammar and Oskarshamn.

The account below shows what SKB has achieved and what developmental needs or potential SKB's future research displays with regard to the following aspects:

- A comprehensive knowledge view.

- The time perspective.
- Geographical range.
- Global issues.
- Open issues and topics not dealt with by SKB.

7.2.1 Socioeconomic Impact – Macroeconomic Effects

SKB's Report

In the introduction to Chapter 30, Socioeconomic Impact – Socio-economic Effects, SKB describes its intention to gain better knowledge and understanding of the impact of a new facility on the local community's economy and population structure. Socioeconomic impact includes both economic aspects and also socioeconomic effects such as travel, movement into and out of the area, its reputation and attractiveness.

The chapter contains descriptions of the results of two research projects: "Local Development and Regional Mobilisation around Technological and Large-Scale Projects" and "Long-Term Socioeconomic Effects on Small and Medium-Size Communities". The final reports of these projects were published during the autumn of 2006 and the spring of 2007.

The Local Development and Regional Mobilisation around Technological and Large-Scale Projects project studied changes in population development and commercial structure in two nuclear power municipalities and a few reference municipalities over a period of 50 years. The aim of the study was to investigate the long-term socioeconomic effects of investment in nuclear power at municipal level.

The Long-Term Socio-Economic Effects on Small and Medium-Size Communities project used a questionnaire survey to pose the question of what local economic and diffusion effects would ensue from the disposal of spent nuclear fuel. A survey was also made of commercial activity in the two municipalities with a focus on the difference in capacity between suppliers and the procurement needs of the municipalities. This project led to a follow up in the form of a procurement study implemented in Oskarshamn and Östhammar in 2006-2007.

Comments by the Reviewing Bodies

Luleå University of Technology stresses the importance of a longitudinal perspective in which 2010 cannot be set as the cut-off date. The socioeconomic effects must be monitored continually. One shortcoming in the programme is its far too one-sided focus on the macro-perspective and structural analyses. The university considers that the socioeconomic research should be supplemented by a broad longitudinal micro-perspective in which SKB studies to a greater extent how the lives and behaviour of those concerned have changed from an economic and social perspective.

SSI considers that SKB offers a good example of when research gives rise to studies at local level but poses the question of what SKB intends to achieve in the area for the next RD&D report as no programme for socio-economic influence is included.

The Municipality of Östhammar considers that the research now starting should focus on issues that will be of practical benefit in the remaining phases of the nuclear fuel programme. From a municipal point of view it would be interesting if the social science research developed to include the geographical area that comprises the municipality. Yet another proposal is for research that attempts to provide answers about what prompts the positive development of a municipality, like for example what aspect of the 'Gnosjö' spirit is positive for municipal development. Research into the formation of opinions can be highly significant for future decisions on nuclear waste issues.

SKI's Evaluation

SKI considers that an integrated account of the results in the context of earlier research findings would have enabled a more complete appraisal of the socio-economic impact and the socioeconomic consequences for a municipality.

In SKI's opinion, the results of the research projects should have been accounted for in greater detail, primarily by taking into account the issues presented as part of the Local Development and Regional Mobilisation around Technological and Large-Scale Projects project.

SKI considers, as does Luleå Technological University, that there is a need to illuminate socio-economic issues in a longitudinal time perspective that takes into account both demographic and economic developments. It would moreover be desirable for further research to take a broader grasp of economic development and socioeconomic impact.

A retrospective overview of earlier research and studies in the field, especially SKB's pilot studies and the social surveys undertaken on SKB's behalf would also be desirable to offer a supplementary image of results and the further research required.

7.2.2 Decision Processes

SKB's Report

Research in the field of decision processes is described in Chapter 31 which offers a survey of the research intended to provide a platform of general knowledge about decision-making processes in complex issues.

Two projects have been completed in this field in SKB's social science research programme since RD&D Programme 2004. These are: "Public, Experts and Deliberation", which was published in the autumn of 2006 and "Resource or Waste? – International Decision Processes on Spent Nuclear Fuel", published in the autumn of 2007. The Public, Experts and Deliberation project studies the consultation process about disposal of spent nuclear fuel in order to supply knowledge about the relationship between experts and the public in participatory processes.

The Resource or Waste? – International Decision Processes on Spent Nuclear Fuel project is intended to use comparative studies of other countries to shed light on the way in which various social dimensions influence political decision-making process and techno-political processes of change. The time frame is from the period when nuclear

power was established up until the way in which the nuclear power issue is managed today. The countries studied are Finland, Germany, Russia and Japan.

A new research project, "Impressions of the Site – Risk Assessment and the Legitimacy of Decisions" was initiated in 2007 and deals with how the decision-making process is perceived in its entirety, primarily at municipal and regional level.

Comments by the Reviewing Bodies

The Swedish Research Council considers that SKB's research is to a large extent based on approaches and needs at the technological and decision-making level. The RD&D report does not offer an adequate picture of the important contact interface and the need for unambiguous dialogue with the public, at both local and national level.

SSI emphasises the importance of understanding subjective anxiety and of attaining knowledge about the complexity that surrounds the communication of risk in order to be able to deal with issues raised by the public. As one aspect of this intention SSI cites Report SOU 2007:38 from Kasam which goes into the subject of risk in relation to the nuclear waste issue in depth.

SSI also points out that SKB states that the issue is linked to both local community planning and to national energy policies. In spite of this, no attention has been paid to the development of energy and environmental policy. SSI considers that SKB and the licensees for nuclear power stations need greater preparedness for any changes that may be made in Sweden's energy policy so that they can deal with these links. SSI also maintains that all that can be said today about the long-term plans is that they are more than likely to require modification.

As SSI points out, the plans for commissioning the repository facilities for the disposal of short and long-lived nuclear waste (i.e. the gradual expansion of both SFR and SFL) in this RD&D report are based to far too great an extent on assumptions about the rate at which the Swedish nuclear power programme will be phased out. The risk is that in future this will require the industry to adapt the decommissioning of plant until repositories become available just as the dismantling of the Barsebäck station has had to be postponed.

The Municipality of Östhammar points out that results from social research form part of the basis for decisions made by the municipalities. If the decision-making process is to benefit fully from social research, it is important to give those involved more opportunities to participate in the process of defining areas for research in SKB's social science research programme. It is also necessary to extend the possibility for those interested to be involved in the researchers' presentations of their projects. The municipality proposes that the researchers should to a greater extent present their results to the appropriate municipalities.

SKI's Evaluation

SKI considers that the studies of decision processes make an important contribution in this field and value in particular the work on experiences in other countries. As in other

areas, integration of the new research results in a more coherent and comprehensive overview based on earlier research would have added to this value.

The chapter's introductory paragraph points to the complexity of the question of the disposal of spent nuclear fuel in view of the complexity of the operation and the difficulty of evaluating and understanding the time perspective. In addition, the issue has links with both

local community planning, national energy policies and international developments. It can moreover be noted that there is a large number of Swedish and foreign studies of decision-making processes to learn from.

A number of interesting and relevant issues are presented in the description of the project "Public, Experts and Deliberation" but these are only partly answered. A further description of the research findings would be of value.

The Resource or Waste? – International Decision Processes on Spent Nuclear Fuel project deals with one aspect that is otherwise largely overlooked in the social science research programme, which is the possibility of transferring experience from other countries. However, the results of this study are not presented as they had not been published when the RD&D programme was drawn up. The application of experiences from other countries in Sweden's disposal process should lead to enhancement of the Swedish programme.

SKI considers that the studies not fully reflect the complexity of this area, for instance the significance of decision processes at various administrative and political levels in Sweden and elsewhere as well as the question of the long time-perspective and changes in decision processes and cultures over time. SKI also believes that it would be desirable to attain greater support from and feed back to the main participants in this process, in particular the municipalities.

7.2.3 Public Opinion and Attitudes – Psychosocial Effects

SKB's Report

The introduction to Chapter 32, Public Opinions and Attitudes – Psychosocial Effects, states that this area of research is subject to change and characterised by different motive forces. These include not only specific events and communicated messages but also deep-seated values and norms, group identification, experienced fears and anxiety and here SKB identifies the importance of shedding light on the "symbolism" surrounding the repository and its activities.

Three research projects were initiated in this area in 2004: "Identity and Security in Time and Space – Cultural-Theoretical Perspectives on the Existential Dimensions of the Nuclear Waste Issue", "Public Opinion and Attitudes towards Disposal of Spent Nuclear Fuel" and "Nuclear Waste – from Energy Reserve to Disposal Problem". Another project "Like Night and Day despite the Same Nuclear Origin" which studied the way the mass media deal with the nuclear waste issue was completed in 2006.

The Identity and Security in Time and Space – Cultural-Theoretical Perspectives on the Existential Dimensions of the Nuclear Waste Issue project studied the underlying thought structures that deal with time and space in the discussion taking place about disposal in repositories in Östhammar and Oskarshamn. One of the aspects studied was the concept of time. The study reached the conclusion that both the time up until the decision was made to locate a repository and the actual time taken to construct it were perceived as conceivable. On the other hand the repository period was considered inconceivable and there was great uncertainty about whether one could rely on future social developments.

The Public Opinion and Attitudes towards Disposal of Spent Nuclear Fuel project involved collecting data about attitudes and the perception of risk in relation to repositories for spent nuclear fuel in Östhammar and Oskarshamn, in the control municipality of Finspång and the nation as a whole.

The "Nuclear Waste – from Energy Reserve to Disposal Problem" depicts long-term historical shifts in value patterns at national level in connection with nuclear waste. The project accounts for changes in the formation of opinions about nuclear waste at the national level from the 1950s, when this waste was regarded as a valuable source of energy, to today's discussions about suitable sites for repositories.

The final project, "Like Night and Day despite the Same Nuclear Origin", analyses how the formation of opinion in the media at national and local level from the beginning of site investigations at the end of 2001 until the end of 2005.

Comments by the Reviewing Bodies

In its response to RD&D Programme 2004, the Municipality of Oskarshamn indicated the need for further research dealing with the differences in the attitudes of men and women to nuclear waste. In its comments on RD&D Programme 2007 the municipality notes with satisfaction that additional research funding has been granted for more detailed studies in this area.

SSI points to the great importance of research into the subject of opinions and attitudes for the implementation of repository. On the other hand, SSI sees no direct, although possibly an indirect, link with radiation protection. For this reason the authority refrains from further comment.

SKI's Evaluation

In the opinion of SKI the four research projects that have been launched in this area: "Identity and Security in Time and Space – Cultural-Theoretical Perspectives on the Existential Dimensions of the Nuclear Waste Issue", "Public Opinions and Attitudes to Disposal of Spent Nuclear Fuel" and "Nuclear Waste – from Energy Reserve to Disposal Problem" as well as "Like Night and Day despite the Same Nuclear Origin" have shed light on a large number of aspects relating to opinion and attitudes. Here, as in other areas, integration of the research results in the context of the findings of previous research would have added greatly to its value in demonstrating the collective knowledge that SKB has produced.

One of the results presented from the first project is that the time concept in relation to the repository can be difficult to grasp whereas the actual time taken to construct the facility is regarded as conceivable. This uncertainty and the difficulty of perceiving the chronology of the repository, anxiety about whether the repository can also be relied on to function in the future and great uncertainty about whether this will really be the case offer good reasons for further studies based on future scenarios. SKI considers that the results are of the utmost relevance and should justify future research activities. In this area, aspects such as changes in the nature of society, unexpected events and social development should be relevant.

7.2.4 Global Changes

SKB's Report

Chapter 33 discusses the establishment of the repository in Sweden and the links with global changes. The aim in this research area is to enhance knowledge about the relevant global factors and changes.

One project undertaken in this area of research is the study "National Nuclear Waste Policies in the European Union" which presented its final report in the spring of 2007. Another two projects started during 2006. In addition SKB considers that research undertaken in other fields is relevant in the area of global change.

The National Nuclear Waste Policies in the European Union project deals with two aspects of the management of spent nuclear fuel and nuclear waste, on the one hand Sweden's national responsibility for the waste produced in the country and on the other the rights it enjoys with respect to interim storage and disposal of spent nuclear fuel from other countries. At the multilateral level these are subject to the regulations in the non-proliferation treaty and the IAEA convention. There are no direct regulations about responsibility for spent nuclear fuel within the framework of the EU and the fact that this is essentially a national responsibility may even conflict with European legislation.

Two new projects in this area of research were launched in the autumn of 2006 and RD&D Programme 2007 presents plans to start another project in the area at the end of 2007.s

Comments by the Reviewing Bodies

The Waste Network considers that considerably more research is required about methods and programmes intended to predict future structural changes in society, etc.

Chalmers University of Technology considers it remarkable that currently no research programme has been defined that deals with global risks, safety and changes in the threats posed to spent nuclear fuel and disposal.

The Swedish Emergency Management Agency feels that a long-term perspective on global changes should be taken into account in future research ventures. This applies to new insights and threats in case of accidents or sabotage as well as the possibility of unlawful, unintentional intrusion into repositories, and also changes in the social system in terms of altered values, risk assessment and other knowledge and conditions.

In addition the research programme should be supplemented by research into ethics and conflict management.

The Municipality of Oskarshamn considers that more future-oriented research with a global focus is desirable. The Regional Council for Kalmar County is positive to SKB's social research and supports the wishes expressed by the Municipality of Oskarshamn for more future oriented research with a global focus and enhanced spin-off studies as well as models for the transfer of technology to create expanding innovation systems. In view of the complexity of the subject the Regional Council considers that there is every reason not to eliminate the possibility of continued social research and social studies after the cut-off period indicated in the programme.

SSI views the increase in the research on the theme of global change as positive. In its opinion the question of preserving information fits into this theme. SSI takes a positive view of the fact that SKB has initiated a project dealing with the preservation of information in connection with the report Preserving Knowledge for the Future – Phase 1. This is an important component in fulfilling SSI's requirements with respect to the risk of trespass, as presented in SSI's general advice. SSI looks forward to Phase 2 of the project.

The Municipality of Östhammar considers that it would be valuable to supplement the national social research with international research at an EU level. The municipality is convinced that international interest exists in research of this kind and that it should be possible to cofinance it through the EU.

SKI's Evaluation

In its response to RD&D Programme 2004, SKI indicated that the resources allocated for the field of global changes in the programme were far too restricted. In RD&D Programme 2007 another project has been completed and provides an overview of and insight into the issues that Sweden faces internationally with respect to the management of spent nuclear fuel and nuclear waste.

SKI wishes to stress how important it is for SKB to monitor closely international events that may affect the process of managing spent nuclear fuel in Sweden. This involves the management of spent nuclear fuel in other countries, events and decisions outside Sweden that may affect the situation in Sweden and also socio-economic developments in other countries that are relevant to the management of spent nuclear fuel in Sweden.

SKI considers that long-term monitoring of global changes should form part of SKB's continued research programme. This should include changes that may take place in the social system in terms of values and risk assessment as well as threats posed in the event of accidents, sabotage and intrusion into the repository.

7.3 SKI's Overall Evaluation of the Social Science Research

The research undertaken by SKB in the field of social science research contributes to an overall picture of the disposal process that will play an important role in making decisions when applications for repository licences are submitted and will have to be

dealt with by the authorities and others involved. The research that has been funded through the programme has comprised a broad social science area and resulted in interesting studies that have raised new questions and whose results have provided additional knowledge and insights into previous issues.

In order to take advantage of the important issues dealt with in the programme it is important to further clarify the link between SKB's social science research and other documents and processes (for example environmental impact statements) that form part of the preparation for SKB's application to construct a repository in 2010. SKI considers that continual research in the social science field is important and that continued social research after 2010 is desirable.

Demarcation of the Social Science Research Area
SKI lacks any clear link to the aggregate knowledge that exists as a result of the work undertaken by SKB during the pilot study stage and the studies and research conducted by other, such as Kasam. The question posed by SKI is how the research undertaken during SKB's earlier social science research programme relates to that which has now been completed.

Geographic Demarcation of the Area
SKI considers that the description of societal effects is far too tightly defined in terms of the geographical focus. The research has largely concentrated on the municipalities. In order to comply with the aims of SKB's research programme, to acquire general knowledge, it would be desirable for the research to cover a broader geographic context and not concentrate merely on information gathered in the municipalities.

Global Monitoring
The international dimension of the social science research needs to be enhanced. SKI considers that SKB should, on the basis of international experience, have attempted to transfer and compare relevant global factors and changes and assess their significance for Swedish circumstances.

Time Frame
The research concentrates mainly on values and socio-economic developments today or in the immediate future and no further than to the end of the construction period. By 2010 SKB intends to have a research programme that can shed the light needed on various social aspects. In view of the long time frame for the project SKI considers that studies based on futurological research would be desirable

Description of SKB's Research Programme and its Results
The description of the research that has taken place in SKB's research programme is accounted for very concisely. Further presentation of the results of this research, i.e. what conclusions have been made, how results agree with earlier research results in the same area, both within and outside SKB's programme, should have been supplied by SKB. SKB should also have attempted to assess the status of the programme, i.e. what has been come to light so far and in which areas further clarification is required.

SKB should also have shown how the results attained have affected SKB's future research plans for the programme and how this links in with the application process. More information and transparency about the way in which SKB's research programme

was initiated and implemented would be desirable. This could include, for instance, the process relating to invitations for funding applications, selection and the criteria for implementation of the programme.

Integrated Survey of the Research Results
A summary and conclusion about the social science research and studies undertaken up to now in SKB's programme that have direct relevance for the disposal programme would offer insight into the needs for continued research and the kind of funding applications that will be invited for future projects in SKB's social science research programme.

Extending the Research Topics
SKI considers that it would have been interesting if the framework of the programme had included discussion of human intrusion and related unforeseen changes in society and penetration of various alternative social developments.

8 The LILW Programme and Decommissioning

In this chapter SKI presents its evaluation of Part VI, i.e. Chapters 34-40 in RD&D Programme 2007.

8.1 Overview

This section corresponds to Chapter 34 in RD&D Programme 2007. The overview largely coincides with what is presented in SKB's plan of action for the LILW programme in Chapter 3 of RD&D Programme 2007.

SKB's Report

In this section of RD&D Programme 2007 SKB accounts for what is referred to as the LILW programme and decommissioning of the facilities covered by the programme according to the industry's plans. "LILW" stands for "low and intermediate level waste", and the facilities covered by SKB's programme are the existing and future repositories for low and intermediate level waste as well as the interim storage for long-lived waste in the BFA, (Rock storage for waste).

This section also contains SKB's report on the cost studies for decommissioning nuclear power stations undertaken by SKB at the behest of the power companies.

For the next three-year period SKB defines the following milestones:

- New safety reports for the repository for radioactive operational waste (SFR 1), presented to the authorities in 2008.
- Completion of the existing BFA on the Simpevarp peninsula for interim storage of core components.
- Licensing and manufacture of transport containers for intermediate level long-lived waste (should be ready no later than 2011).
- Initiation of preparations for the extension of SFR in 2008, with commissioning planned for 2020.

For the next six-year period SKB also defines the following milestones

- Start of operation of dry interim storage of core components in BFA, by the end of 2011 at the earliest.
- Submission of an application to extend SFR in 2013.

Finally SKB reports that the planning of a repository for long-lived low and intermediate level waste (SFL) will begin after submission of the application to extend SFR. It is reckoned that SFL can be commissioned in 2045. SKB states that it is possible to delay the construction of this repository as the current volumes of waste are still small.

Comments by the Reviewing Bodies

The Municipality of Oskarshamn does not refer to the LILW programme in the main section of its statement other than to refer to the statement in the municipality's conditions for a site investigation in 2002 that in permitting this investigation it was not taking a stance on the siting of SFL. It is also possible to determine that the extent of interim storage has now increased in Oskarshamn with the relicensing of BFA.

The Municipality of Östhammar and the local safety committee at the Forsmark nuclear power station are positive to SKB's improvement of its presentation of the LILW programme since RD&D Programme 2004. The committee draws attention to the opinions that have been expressed about decommissioning the Barsebäck power station prior to 2020. If this also entails early location of a final repository in the municipality of Östhammar, the committee feels that such plans should be presented as soon as possible.

SKI's Evaluation

SKI is able to determine that Chapter 3 about the plan of action for the LILW programme adds nothing in essence apart from what is presented in Part VI of the RD&D programme. The observations of SKI presented in Chapter 8 about SKB's planning therefore also cover its review of Chapter 3.

SKI has no particular opinions about this overview other than that it clearly demonstrates how important it is for SKB to allocate adequate resource to enable adherence to the announced timetable for the extension of SFR.

SKI will return to the issue of the timetabling of SFL in section 8.2.2.

8.2 Low and Intermediate Level Waste

This section corresponds to Chapter 35 of RD&D Programme 2007.

8.2.1 Origins of Waste – Waste Quantities and Types

This section corresponds to sections 35.1-2 in RD&D Programme 2007.

SKB's Report

In addition to dealing with the major flows of waste in the form of operating and decommissioning waste from the nuclear power plants, SKB also deals here briefly with other waste from Studsvik and what is called IKA waste (radioactive waste from non-nuclear applications). SKB maintains that waste that does not originate from nuclear power plants is not included in SKB's undertaking to its owners and therefore a separate contract has to be signed. SKB claims, however, to be positive about dealing with radioactive waste from non-nuclear applications – for reasonable compensation and if it can fit in with its regular operations. This statement is justified by a reference to the observation from Kasam (now the Swedish National Council for Nuclear Waste) in

connection with RD&D Programme 2004 on the necessity of creating a national system for the disposal of all radioactive waste in principle.

In section 35.2 SKB also reviews the status of the management of short-lived and long-lived nuclear waste. Here it points out that forecasts of the use of SFR have been estimated generously. The original forecast for 2010 was 90,000 m^3 which can be compared with the actual 31,000 m^3 at the end of 2006. On the other hand, the increased output and extended service lives of the nuclear power reactors will contribute to increasing quantities of waste, not least in respect of long-lived waste in the form of replaced core components.

In order to document long-lived waste SKB has developed a new documentation system, Draak, similar to the one used for waste for SFR.

SKB states that in its review of RD&D Programme 2004, SKI indicated that 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's comment on this is: "In the light of SKB's other activities it will be RD&D Programme 2010 which will focus on the LILW programme".

Comments by the Reviewing Bodies

SSI considers that SKB's facilities could in the future provide important resources for the management of other radioactive waste than that covered today by the RD&D programme, for example waste from fuel fabrication, Ågesta, Studsvik, hospitals, research and industry as well as some wastes that contain naturally radioactive substances. In order to facilitate planning it is therefore important for SKB to spell out what possibilities for disposal of this waste are available in SKB's programme. To enable costs to be estimated as well, it is, in SSI's opinion, important for the concept for the disposal of low and intermediate level waste to be dealt with further.
SSI points out that SKB's presentation of SFL remains very vague and that SKB offers no justification for its postponement of continued planning and research to the future.

SKI's Evaluation

SKI agrees with SSI that the programmes for the handling of different streams of radioactive waste should be coordinated to guarantee a satisfactory solution for the community. In purely legal terms, however, it is hardly possible to make demands of SKB's programme in this respect but this should be arranged indirectly through imposing requirements on the owners and producers of radioactive waste that does not derive from nuclear power plants. SKI would like to stress, however, that this kind of coordination is, for practical reasons, only possible for the final steps of waste management , i.e. disposal and the necessary conditioning for this purpose.

The production by SKB on its own initiative of a documentation system for long-lived low and intermediate level waste is positive and this will be monitored by the authority in the course of its supervisory procedures.

SKI considers it remarkable that SKB has, without notifying the authorities, failed to supply a more detailed description of the programme for long-lived waste as requested

by SKI in 2004. This is even more remarkable as this also formed part of the expectations listed in the Government's decision on RD&D Programme 2004.

8.2.2 Facilities for Low and Intermediate Level Waste

This section corresponds to section 35.3 in RD&D Programme 2007.

SKB's Report

SKB's existing and planned facilities for low and intermediate level waste comprise:

- The repository for radioactive operational waste (SFR 1).
- The repository for decommissioning waste (SFR 3).
- The facility for the dry interim storage of long-lived intermediate level waste that forms part of the BFA (Rock store for waste).
- Part of Clab for the interim storage of core components.
- The repository for long-lived low and intermediate level waste (SFL).

After the initial review of the history and status of SFR, which takes into account for instance volumes required for future disposal, SKB concludes that SFR 1 needs to be extended if no lack of volume is to arise after 2020. This extension, in two phases, will then according to SKB's plans take place so that both the new and existing sections can receive operational as well as decommissioning waste. The first phase will consist of space for decommissioning waste from the plants that have already been decommissioned and an additional rock cavern for intermediate level operational waste. The second phase is to provide space for both operational waste and decommissioning waste from plants that are currently in operation. Site investigations have begun during 2008 and an application for the extension (including extending the licence for the existing SFR 1) will be submitted to the authorities in 2013. SKB's considers that appraisal of the application will take two years and operations are expected to begin in 2020. The date on which phase 2 can begin to operate is expected to be around 2030 in view of the planned operational lives of the remaining nuclear power plants. SKB intends to draw up a combined application timetable for the extension and operation of the entire SFR (=SFR 1 + SFR 3).

Together with the nuclear power companies SKB has produced a proposal on the storage of core components in dry conditions. The previous method of storage in Clab is considered too expensive and to demand too much space. The proposal involves using a section of the existing interim storage for nuclear waste (BFA) at the Oskarshamn plant for this purpose. During interim storage it is intended to enclose the waste in metal boxes that could also be used for disposal. SKB points out, however, that a possibility of reconditioning exists as the acceptance criteria for disposal have still not been determined. A transport container for waste (ATB-1T) also has to be developed, and this is the determining factor in setting the date for the beginning of interim storage to 2011.

The repository for long-lived low and intermediate level waste (SFL) is planned by SKB to start operating in 2045 at the earliest, "in other words when the bulk of the waste is available for disposal". In section 38.2 SKB offers more detailed reasons for its choice of date for SFL. SKB considers that today there is no reason to begin

construction of SFL as the volumes of waste are still low. SKB therefore feels that early construction would result in an unjustifiably long operational life.

SFL is said by SKB to be intended for heavily neutron-irradiated waste, such as core components in the form of control rods, for instance, fuel boxes, core grids and core barrels. SKB mentions that SKI and SSI in their reviews of RD&D Programme 2004 considered that priority should be given to the design of SFL and SKI therefore urged SKB to provide a coherent account of the specifications that must apply to the construction of a repository in its next RD&D programme. SKB now state that its plans for SFL will be presented in RD&D Programme 2010. This presentation may include a strategy for the selection of a site and the depth of the repository. Currently SKB is planning to update the waste inventory and also to undertake a "conceptual safety assessment" of the facility after the application for the SFR extension has been completed.

Comments by the Reviewing Bodies

The National Board of Housing, Building and Planning approves of the extension of SFR to enable the disposal of decommissioning waste from Barsebäck. One question the board feels should be explored in this context is the siting of the repository under the Baltic. According to the board one alternative could well be to site the facility on land.

Milkas (Pettersson) considers overall that where the current plans for the interim storage of the major components that have been replaced, including core components, are concerned SKB has not had the capacity to resolve the problems. Dismantling is planned of the decommissioned reactors at Barsebäck, Studsvik and Ågesta. SKB's lack of resources to receive (some of) the decommissioning waste before 2045 is a totally unsatisfactory planning failure. Milkas concludes with the comment that the needs of society and of the authorities show that the completion of SFL should be brought forward to 2020-2025.

SSI takes a positive view of SKB's commencement on the work of extending SFR. At the same time SSI stresses the importance of the inclusion by SKB in its application of good grounds for its choice of the site for the repository and the method to be used. SSI also notes that the construction timetable has been postponed since the 1990s so that the main strategy adopted by the industry of dismantling and demolition without delay after shutdown of nuclear reactors cannot be applied for the Barsebäck plant. For this reason SSI considers that the timetable for the extension of SFR in phases should be reviewed further, for example in order to provide space for decommissioning waste if additional reactors are to be closed down earlier than currently forecast.

SSI maintains that the way in which SKB and the power companies have dealt with the issue of interim storage of core components is [yet another] example of the shortcomings in SKB's advance, long-term planning of the disposal of waste. SSI therefore feels that SKB and the owners of the reactors should account for the volumes of waste that can be anticipated, when they will arise, how the required interim storage can be provided and how all this is linked to the plans for the construction of SFL.

SSI maintains that SKB's presentation of SFR contains no real review of the reasons for delaying construction until the bulk of the waste is available. Step-by-step construction

that would enable deposition to start earlier should therefore be evaluated. SSI also points out that SKB has not provided the clarification of the design of the depository that should have been included in RD&D Programme 2007 according to the Government's decision on RD&D Programme 2004.

In conclusion SSI does not consider that SKB's presentation of SFL provides the comprehensive information required in the legislation and that therefore the RD&D programme should be supplemented in this respect.

SKI's Evaluation

SKI's assessment is that SKB's description of the plans for SFR is adequate from a technical point of view. SKI expects, however, more coherent and better supported reasons for the timetable for the extension of SFR in RD&D Programme 2010. This applies not only in view of the ongoing discussion of available storage volumes for decommissioning waste from the Barsebäck plant (see below section 8.5.2) but also for waste from the operation and decommissioning of other nuclear power plants. Like SSI, SKI also considers that the question of siting SFR 3 at the existing SFR 1 is something that has to be justified in an extension application. For this reason it is important to emphasise that the site survey now under way for SFR 3 should be just as impartial as for a separate repository.

SKI considers that using BFA for interim storage of core components is an acceptable solution and a good alternative to the construction of separate interim storage facilities. This method should also, in SKI's opinion, provide the desired flexibility when it comes to determining the date for the construction of a repository for long-lived low and intermediate level waste. On the other hand, SKI considers it less appropriate for BFA to be commissioned for the reception of core components before even preliminary acceptance criteria have been established for storage and disposal.

As has also been pointed out in section 8.2.1, SKI considers it remarkable that SKB has not provided the account of the management of long-lived low and intermediate level waste expected by the authorities and the Government in RD&D Programme 2007. This applies both to the reasons for the timetable and the more detailed contents of a programme to develop a disposal solution that can be verified as far as possible through analyses of long term safety. SKI therefore concurs with SSI in its opinion on the need for an account of waste production at various times and how this should lead to the optimal choice of a date for the commissioning of SFL. It is equally surprising that SKB fails to mention waste other than core components for which this repository is intended. SKI would therefore like to point out that about 2,000 m^3 of waste from Studsvik has long been waiting for disposal in SFL

8.3 Safety Reports

This section corresponds to Chapter 36 in RD&D Programme 2007.

8.3.1 Safety and Radiation Protection Regulations

This section corresponds to section 36.1 in RD&D Programme 2007.

SKB's Report

SKB provides a very concise account of the regulations that apply to the organisation of safety assessments.

SKI's Evaluation

Here SKB's presentation is far too brief to justify any detailed evaluation. In RD&D Programme 2010, the authority expects a more thorough review of how current regulations are applied. SKB is recommended, however, to consult the Swedish Radiation Safety Authority on how to present such a review. SKI would like to point out that since the completion of RD&D Programme 2007 consultation of this kind has taken place in respect of the nuclear fuel programme. This has led to the clarification of a number of issues that also apply to the disposal of low and intermediate level waste. This concerns in particular the form and content of the "preliminary safety report" that should accompany an application for the construction or extension of a repository. SKI would also like to point out that after a licence has been granted the preliminary safety report, as prescribed in regulations, has to be reviewed and approved by SKI prior to start of construction.

8.3.2 Safety Reports for SFR 1 and the Extended SFR

This section corresponds to sections 36.3-4 in RD&D Programme 2007. (Neither SKI nor the bodies consulted have any opinions on section 36.2, SKB's safety strategy.)

SKB's Report

Here SKB deals with the ongoing update of the safety assessment for SFR 1 that will be submitted to the authorities during 2008. According to SKB this work focuses on drawing up a better-founded nuclide inventory for disposal. SKB also states that in impending updates of safety assessment for SFR the bulk of the calculations will be made using probabilistic methods.

SKB plans a safety assessment for the preliminary safety reports for stage 1 of the extended SFR that includes both the new and old sections of the repository. SKB claims that applying for a joint licence for the existing and extended repository will enable optimal use through the emplacement of waste in different areas.

SKI's Evaluation

SKB's presentation is very short and contains virtually no planning of the research and development that may be necessary for the safety assessment of the repository for the period after closure. SKI considers the use of probabilistic methods to be valuable but would like to point out that these must, nevertheless, be supported by deterministic calculations.

8.3.3 Preliminary Safety Report (PSAR) for SFL

This section corresponds to section 36.5 in RD&D Programme 2007.

SKB's Report

Here SKB mentions that assessments of the possibilities for the disposal of new types of waste have been carried out on the basis of the safety assessment made for SFL in 1999 and the safety assessment for SFR. The assessment of new types of waste for SFL depends therefore, according to SKB, on reconditioning being possible.
SKB plans to undertake an "update of the safety assessment for the SFL facility" after the application for the extension of SFR (in Chapter 3 of the RD&D programme the date for this is given as 2014). SKB intends to present the detailed planning for this in "future RD&D programmes".

Comments by the Reviewing Bodies

The Municipality of Oskarshamn's expert Pereira points out that the long-term safety of SFL is not a trivial issue and that hitherto only a preliminary safety assessment has been made of SFL. SKB should therefore make plans for a new safety assessment so that it can be undertaken during the next programme even if there are no site-specific data.
SSI considers that the lack of a credible disposal concept for SFL and well-supported guidelines for conditioning of the waste may lead to future radiation protection problems, for instance in connection with reconditioning. The repository may also have to be adapted to existing waste in a way that can impair its function. In addition, SSI maintains that a credible disposal concept is an important basis for characterisation of the waste and that shortcomings in this respect can lead to uncertainties in safety assessments.

SKI's Evaluation

One important issue, which is also raised by SSI, relates to the need to undertake a renewed assessment of SFL without undue delay to enable as far as possible determination of preliminary acceptance criteria for conditioning the waste in preparation for storage and disposal. This should preferably have been completed before waste is removed from the nuclear power plants for interim storage in BFA. Now the reverse order will be adopted with the commissioning of BFA in 2011 and no evaluation of SFL before 2014. Reconditioning is, of course, a possibility with the principles now applied by SKB. However, in SKI's opinion, this can only result not only in unnecessary radiation exposure at a later stage but also in less appropriate solutions from a radiation safety point of view for the transport and storage of the waste.

8.4 Research

This section corresponds to Chapter 37 in RD&D Programme 2007.

SKB's Report

SKB accounts here mainly for findings since RD&D Programme 2004, which include

- A detailed study of dismantling and demolition for Oskarshamn 3,
- Chemical modelling of how concrete and bentonite degrade,

- Analysis of (so-called) correlation factors to enable estimation of the amount of radionuclides in the waste that are difficult to measure,
- Estimates of the uncertainties of correlation factors,
- A study of uncertainties in the sorption of radionuclides in concrete and bentonite etc.,
- Measurements of the nickel isotopes Ni-59 and Ni 63 in ion exchange resins,
- Measurement of C-14 in ion exchange resins,
- Development of a model for estimating the quantities of I-129, Mo-93, Tc-99 and Cs-135 in operational waste,
- The impact of permafrost on concrete, bentonite etc.
- Estimates of the uncertainties in the hydrological model for SFR,
- A geochemical model for the multi-barrier system in the SFR silo,
- Studies relating to the complex formation of radionuclides with organic degradation products, for instance from cellulose, and models for their impact on the emission of radionuclides from SFR.

Where the planned research programme is concerned SKB only mentions the ongoing rock studies at SFR 1. SKB also reports that no further research apart from the ongoing studies on concrete, complex formations and correlation factors has been decided on at the moment.

Comments by the Reviewing Bodies

Chalmers University of Technology raises the question of using the correlation factors to estimate the quantity of radionuclides difficult to measure , above all in operational waste. The university points out the uncertainty of this method and suggest possibilities that even today enable experimental studies to reduce the uncertainties in these correlation factors or perhaps even to eliminate them.

The municipality of Oskarshamn's consultant Pereira considers that the ongoing research in the LILW programme could be dealt with in greater detail.

SSI points out that the research undertaken is the result of demands from the authorities for supplementation of the safety reports for SFR. SSI considers it positive that SKB is dealing with the inventory issue but would like to see a strategy from SKB for continued research in the area linked to operation and the extension of SFR.

SKI's Evaluation

Like SSI, SKI considers that the measures taken by SKB to establish a nuclide inventory for SFR are praiseworthy. In particular the studies of C-14 and nickel isotopes have provided important information and a basis for decisions relating to the control of disposal in SFR 1. SKI concurs in the opinion of Chalmers University of Technology that the use of correlation factors should preferable be replaced by other methods of estimating the nuclide content of the waste. In addition SKI would like to emphasise the importance of producing models for the analysis of the impact of complex formation on long-term safety and also their use in deciding on continued research in the field as well as operation of the repository.

In the opinion of SKI it is clear from SKB's presentation that limited resources, relatively speaking, are currently being allocated by SKB for research in the LILW programme. This is understandable given that attention at the moment must be focused on the nuclear fuel programme. But SKB's tasks also include pursuing issues in the LILW programme so that at least the knowledge and the material required for current decisions are available. This applies not least to the material required for the management of long-lived low and intermediate level waste as well as decommissioning questions. The evident lack of programmes in this area may therefore have added to the lack of clarity about the material on which to make decisions affecting the timetables and choice of routines for dealing with long-lived low and intermediate level waste.

8.5 Allocation of Responsibilities and Strategies for Decommissioning

This section corresponds to Chapters 38 and 39 in RD&D Programme 2007.

8.5.1 Division of Responsibilities and SKB's Strategy for Decommissioning

This section corresponds to Chapters 39 and section 38.1 in RD&D Programme 2007

SKB's Report

SKB maintains in Chapter 39 on the allocation of responsibilities for decommissioning that here it wants to provide the clarification of accountability requested by the authorities in their review of RD&D Programme 2004. SKB states that the licensees are responsible for planning, licensing issues and the physical decommissioning process. SKB's responsibility is to take care of the radioactive waste from decommissioning, including transport to the repository and deposition. This also means that it is SKB's responsibility to construct the repository and in consultation with the producers of the waste to ascertain that waste is dealt with and packaged in the appropriate manner for disposal.

SKB is also responsible for carrying out the calculations of the general costs of decommissioning nuclear power stations. A special decommissioning group provides SKB with opinions about the technology and strategic choices on which its decommissioning studies are based. These will be used for unit-specific decommissioning studies as the time for decommissioning nuclear power plants approaches.

Chapter 38 begins with more or less the same statements from SKB as in Chapter 39. SKB's section on its main strategy (section 38.1) is in its turn basically a repetition of what has already been described in more detail in Chapter 35, but this time the focus is on the completion of the different facilities in the programme. SKB stresses the importance of the licensees' own planning when it comes to decommissioning of nuclear power plants. SKB is conducting research at the behest of its owners and provides advice on strategy issues. However, SKB makes no demands as to how or when the owners are to decommission their reactor units.

SKB says that its strategy and the strategy of the utilities is that dismantling and demolition will begin as soon as a plant has been finally shut down and the resulting waste can be sent to an approved repository. Extension of SFR for this purpose will be complete by 2020 so this strategy cannot be adopted for the Barsebäck plant.

SKI's Evaluation

SKI would like to begin with a more general comment and state that SKB should have been able to offer a more coherent picture of the allocation of responsibilities in one and the same place. This is now accounted for in both Chapters 38 and 39.
SKI's opinion is that the main strategy of immediate dismantling after shut down is the only viable one, something on which there is also great agreement internationally. The strategy of SKB and the nuclear power companies contains, however, a proviso that it must be possible to dispose of decommissioning waste directly. There must therefore exist cogent reasons for delaying this final disposal solution, as is the case, for example, with Barsebäck. SKI will revert to its assessment of the application of the main strategy in this case in the next section (8.5.2).

8.5.2 Timetables for the Decommissioning of the Barsebäck Plant

This section corresponds to sections 38.2 and 38.3 in RD&D Programme 2007.

SKB's Report

SKB begins with a retrospective account of the closure of Barsebäck 1 in 1999 and Barsebäck 2 in 2005. SKB also mentions that in reviewing RD&D Programme 2004, the authorities stressed that SKB should attach great importance to the decommissioning issues in RD&D Programme 2007. The government decision on 2004 RD&D Programme 2004 also makes it clear that a study should be made of the shortest time required to enable commencement of a licensing process for the disposal of decommissioning waste. (The study should also comprise the date for SFL, see section 8.2.2.)

SKB states that the preliminary timetable for the extension of SFR contains no margins to enable operations to start before 2020. In SKB's opinion the relicensing of SFR 1 to receive decommissioning waste offers no solution either. SKB therefore asserts that the space now reserved for the operational waste from other owners must be utilised. This procedure could in its turn lead to undesirable effects on the operation of units at the other nuclear power stations if the commissioning of the extended repository is delayed, in SKB's opinion. Nor would a scenario involving the creation of an interim storage facility for decommissioning waste from Barsebäck lead to the saving of more than about one year. SKB bases this conclusion on a study attached by Barsebäck to its application for service and maintenance operation as laid down in the Environmental Code (Soldéus, 2005).

SKB's overall assessment is that most rapid alternative for dealing with decommissioning waste is to adopt SKB's main alternative. This would allow the final deposition of short-lived decommissioning waste to begin in 2020 and the interim storage of long-lived waste in BFA to begin at the end of 2011.

In section 38.3.1. SKB includes an account that is (evidently) based on Barsebäck's own strategy for the decommissioning of its plant. Service and maintenance operation will continue until 2017 and will then be followed by a phase involving planning and preparatory work before decommissioning, referred to as re-establishment operation. Barsebäck points out here that the Government is financing service and maintenance operation of Barsebäck 1 until 2015 and of Barsebäck 2 until 2017. Then Barsebäck will use the funding available from the Nuclear Waste Fund for further service and maintenance operation, re-establishment and decommissioning. It is also pointed out that the environmental permit for service and maintenance operation has to be reviewed in a new hearing before the Environmental Court for the period after 2012 and that also that an approval by the Swedish Radiation Safety Authority will be needed to begin dismantling and demolition. The final objective of the decommissioning is clearance with some buildings remaining ["brown field"] or, alternatively, full restoration of the site ["green field"]. Decommissioning of Barsebäck 1 is timetabled for 2020-2026 and Barsebäck 2 for 2020-2028.

In a special report (SKB, 2008) on the management of decommissioning waste in SFR submitted to the authorities in April 2008, SKB provides a more detailed account of the possibilities of offering an earlier date for reception of decommissioning waste in SFR 1 than presented above. This report was produced by SKB as a supplement to both RD&D Programme 2007 and also the seminar on decommissioning issues arranged by the Swedish National Council for Nuclear Waste on 11 December 2007. In this report SKB offers support, by and large, for the arguments presented in the section of RD&D Programme 2007 dealt with here.

Comments by the Reviewing Bodies

The Municipality of Kävlinge begins by pointing out that it is the municipalities that bear the ultimate responsibility for planning issues according to the Swedish Planning and Building Act. This is why companies and authorities have to consult the municipality when operations are to be phased out on property in an area subject to its local planning decisions. The municipality does not share SKB's opinion that decommissioning the Barsebäck plant has to wait for the extension of SFR. In this context the municipality questions the current division into operational and decommissioning waste [for disposal in SFR]. The municipality claims that relicensing BFA as an interim storage facility for core components would enable the effective decommissioning and dismantling of major elements of the Barsebäck plant. Review by the authorities is a time-consuming process and it would be advisable to work in parallel to reduce lead times before the decisions.

With SKB's current plan the period between shut down and a completely restored site would be 23 years, which is an unreasonably long time according to the Municipality of Kävlinge. One argument for rapid dismantling and demolition presented by the municipality is that the available expertise will disappear very quickly. The municipality expects a dialogue with the operator about the plant before the environmental assessment for continued service and maintenance operation is undertaken in 2012 and the environmental assessment of the application for a permit to start dismantling. In conclusion the Municipality of Kävlinge wants to point out to SKI

that the issue of the decommissioning and dismantling/demolition of the power station in the municipality is a test case for future decisions that affect other municipalities.

The local safety committee at the Oskarshamn nuclear power plant views SKB's improvement of its account of the LILW programme since RD&D Programme 2004 positively. The committee also states that SKB and the licensees have a strategy that involves dismantling and demolition of a plant as soon as it has been finally shut down. At the same time it is regarded as unfortunate that the dismantling and demolition of Barsebäck must be postponed until 2020 to wait for the extension of SFR. The committee also point out that the possibilities open to the authorities of affecting the timetable are restricted. The lack of any national policy for decommissioning and dismantling is a shortcoming. There are no fixed time limits for decommissioning and storage capacity for decommissioning waste must be available before dismantling and demolition of a nuclear power plant can begin. The committee also stresses the issue of expertise as very important and that therefore the disappearance of qualified personnel and measures to maintain qualifications are also significant factors when planning the dismantling of nuclear facilities. The committee concludes by pointing out that there will be more interim storage at Oskarshamn as a result of the government decision that BFA is also to accept core components from other Swedish nuclear power stations.

SSI does not feel that SKB has provided sufficient material to support its stance on the disposal of decommissioning waste in the existing SFR 1. With regard to the recently submitted report on decommissioning waste SSI would particularly like to see the material on which the estimates of volumes have been based and an account of when during decommissioning the different forms of waste are expected to be generated.

In addition SSI points out that the RD&D report does not contain a multifaceted and comprehensive programme for the decommissioning of nuclear power plants. SSI therefore proposes that the government should request supplementation of RD&D Programme 2007 by a coherent account of and the reasoning behind the strategy for the management of all short-lived low and intermediate level waste from the operation and decommissioning of nuclear power plants as well as what flexibility is available for changes in the current plans.

SKI's Evaluation

SKI considers that SKB's arguments for the timetable for the decommissioning of the Barsebäck plant appear to be relatively well supported. The RD&D programme itself lacks, however, material to show in quantitative terms the possibilities of beginning disposal of decommissioning waste in the existing SFR at various times and the problems that would ensue. At the end of April SKI received the report on the management of decommissioning waste referred to above. However, lack of time has prevented SKI from studying this material in more detail. SKI can, nevertheless, agree with SSI that there is still a shortage of material describing when and at what rate various forms of waste are generated during decommissioning. Only on the basis of such material is it possible, in SKI's opinion, to make a final assessment of how reasonable SKB's assertions are. SKI therefore recommends the Government to request supplementation of the programme in this respect.

SKI would also, like the local safety board at the Oskarshamn nuclear power plant, like to point out that the authorities and the government have hardly any genuine possibilities of affecting the time at which nuclear facilities are dismantled as long as they comply with the current requirements concerning safety and radiation protection. What the authorities can do is to act to ensure that the material on which the industry bases its decisions is penetrated as transparently as possibility. There then arises the more or less political and legal question of whether the legislation should be amended to provide society with judicial instruments to influence when dismantling and demolition occurs. With this statement SKI would also like to agree that it is regrettable that the Municipality of Kävlinge has been placed in an indeterminate position with no opportunity to influence the timing of the decommissioning of the Barsebäck plant.

8.5.3 The Licensees' Decommissioning Strategies

This section corresponds to section 38.3 in RD&D Programme 2007. (Section 38.3.1 is dealt with however in section 8.5.2.)

SKB's Report

SKB begins by referring to the opinion expressed by SSI in its response to the 2004 RD&D programme that the report needed to be supplemented with the planning and the measures that the individual power stations are responsible for with regard to the decommissioning of their plant. It is made clear that SKB's intention has been to clarify its presentation of RD&D Programme 2007 in this respect, as for instance in section 38.3 dealt with here.

SKB presentation is concise and does not add much more information that can be found elsewhere in section VI of RD&D Programme 2007. The report is therefore a general one and applies with a few specific exceptions to all the nuclear power plants and the licensees. The following points are nevertheless of some interest:

- The aim in decommissioning is clearance of the site subject to no restrictions with regard to use of the land or buildings.
- The power companies' joint objective is said to be use of the site for future energy production after decommissioning.
- The current plans are for the Forsmark and Ringhals plants to have an operational life of 50 years and OKG 60 years.
- Dismantling a unit will not commence before adjacent units with shared building and/or systems have been shut down.
- Dismantling is assumed to take place after relatively thorough decontamination of the plant's process system.
- A dismantling and demolition period of about five years means that clearance can be expected about seven years after shut down. This applies provided that there are no adjoining units in operation.

Comments by the Reviewing Bodies

SSI points out that in connection with its review of RD&D Programme 2004 the authority stressed the need to extend the report with regard to dismantling and demolition issues so that it also included how reactor owners intended to undertake

decommissioning. SSI maintains now that this has obviously not been complied with by SKB or the reactor owners. SSI therefore considers that the report does not meet the demands laid down in section 12 of the Nuclear Activities Act (1984:3) so that it must therefore be supplemented. The report must show clearly what measures the reactor owners intend to take in order to comply with section 10 of the Act, most appropriately in the form of the decommissioning plans stipulated in SKI's and SSI's regulations. SSI also considers that each individual nuclear power station should submit a supplementary report for the plants that in the long run they will responsible for decommissioning.

SKI's Evaluation

In their opinions on RD&D Programme 2004, the authorities stated that the division of responsibilities for decommissioning needed clarification in order to procure a better presentation of those aspects of the RD&D programme for which SKB had not taken over responsibility from its owners, in other words they endorsed SSI's comment on RD&D Programme 2004. In SKI's opinion SKB's account of the strategies of the nuclear power companies in general terms is far from adequate for this purpose. On the other hand SKI considers that the decommissioning plans referred to by SSI should contain the information required. Therefore SKI's judgement is that the supplementation requested by SSI can in itself be justified in the form of a preliminary report for RD&D Programme 2010 but that it is enough for SKB to offer a summary of the relevant material on the basis of the nuclear power companies' decommissioning plans. However, in connection with RD&D Programme 2010, SKI expects more comprehensive material of this kind, for instance in the form of the unit-specific decommissioning studies that SKB and the nuclear power companies intend to produce, see below in section 8.7.

8.5.4 The Ågesta Reactor

There is no corresponding section in RD&D Programme 2007.

SKB's Report

On the subject of the decommissioning of the Ågesta reactor SKB states that it may also "dispose of radioactive waste" from the Ågesta reactor and that "a special agreement will be signed for the management of waste from the R2 reactor at Studsvik and the Ågesta reactor".

Comments by the Reviewing Bodies

SSI points out that the Ågesta reactor is also covered by the stipulations in the Nuclear Activities Act requiring decommissioning measures and the establishment of a programme for research and development in sections 10 and 12. SKB's presentation makes it seem as if waste from Ågesta is not included in SKB's tasks. SSI considers therefore that the Government should request the licensee for the Ågesta reactor, Vattenfall AB, to account for a programme of the same type as those required for other nuclear power reactors.

SKI's Evaluation

SKI agrees with SSI that the power and heating reactor at Ågesta is subject to the requirement in the Nuclear Activities Act of a programme for research and development. SKI therefore considers, like SSI, that RD&D Programme 2007 should be supplemented with an account of how Vattenfall AB as licensee for the Ågesta reactor intends to fulfil its obligations under section 12 of the Act.

8.6 Technology for Decommissioning

This section corresponds to Chapter 40 in RD&D Programme 2007.

SKB's Report

In section 40.1 SKB states that since the last RD&D programme a decommissioning study has been undertaken for Oskarshamn 3. The study contains accounts of different techniques for dismantling, waste quantities and activity contents. Timetables and calculations of costs are also included. It is intended to use this study as a reference for corresponding decommissioning studies for all of the BWR units. A corresponding study for PWR units based on Ringhals 2 will also be undertaken in the programme. The plant and unit-specific decommissioning studies will be carried out by SKB together with the nuclear power companies and the material in the reference studies will be adapted to the specific circumstances that apply for each nuclear power unit. The aim is that this will provide a more reliable and more detailed basis for estimates of the volumes of waste and of activity from each of the nuclear power stations. SKB states that the unit-specific studies are needed to plan the extension of SFR, for which an application will be submitted in 2013.

In section 40.2 SKB describes the conditions for and the content of the reference study for Oskarshamn 3, without, however, any quantitative results about, for example, quantities of waste or the time needed for different aspects.

Comments by the Reviewing Bodies

No specific opinions have been expressed on this section of RD&D Programme 2007. There is, however, a manifest link between the unit-specific decommissioning studies and the statement made by SSI in its response that each company should submit individual supplementary accounts of their decommissioning plans for the plants that in the long run they are responsible for decommissioning, see section 8.5.3.

SKI's Evaluation

As it did in connection with RD&D Programme 2004, SKI views completion of the unit-specific studies as important, and not merely in view of the cost estimates but also to provide a basis for planning and justification for the system of managing decommissioning waste. In SKI's opinion it is also important for these studies to be produced as soon as possible so that they can provide a basis for or quite simply be included in RD&D Programme 2010 (cf. SKI's assessment in section 8.5.3).

SKI would also like to stress the importance of the authority being provided with an opportunity to review the reference studies in some way and express its opinions before they are used as the basis for decommissioning studies for other nuclear power units. SKB should, for example, ascertain to what extent these studies can be applied to other units and what uncertainties can be linked to this kind of application. SKI has no particular opinions on section 40.2 of RD&D Programme 2007 (Reference Study). The division of decommissioning into various phases and the technological solutions accounted for by SKB are uncontroversial and fit in well, in SKI's opinion, with national and international practices. SKI will delay making any more specific comments until a more detailed review of the reference study itself has been made as referred to above.

8.7 SKI's Overall Evaluation of Part VI – the LILW Programme and Decommissioning

8.7.1 General Comments on SKB's Report

In the section under review SKI can discern that SKB intends to offer a more ambitious description of the LILW programme than in previous RD&D programmes. However, considerable improvement of the presentation is required before RD&D Programme 2010 which, according to SKB's plans, is to focus on the LILW programme. This applies both to its contents and its organisation, which needs to distinguish more clearly between accounting for the characteristics of the action plan and the presentation of a research and development programme.

The bulk of part VI is in other words organised more as an account of the current status of SKB's facilities in the LILW programme and what measures SKB plans to adopt concerning extension, applications and other reporting requirements and the timetables for doing so. What is lacking in this particular account is, however, clear reasons for and analysis of alternatives to SKB's strategy with regard to these measures. Here it would also be beneficial to have a presentation based on the timetable and milestones that can be found in the action plan for the LILW programme in Chapter 3 of RD&D Programme 2007.

SKI further considers that SKB's presentation of its plans and programme in connection with decommissioning also needs to be structured more effectively on the basis of the division of responsibilities that exists between the nuclear power companies and SKB. In RD&D Programme 2007 SKB distinguishes, for example, between the licensees' strategies and its own. These must of course be accounted in one context and there can, as it were, only be one strategy. Here responsibility lies with the nuclear power companies as SKB's plans must be based on the plans of the companies themselves. The section on the strategies of the licensees is, moreover, not complete as only the strategy for the Barsebäck plant is accounted for.

Finally SKI would like to remind SKB that in connection with RD&D Programme 2004, it already announced that RD&D Programme 2010 was to focus on the LILW programme. As SKI considers that RD&D Programme 2007 needs supplementing with regard to the LILW programme, the short time that remains before the following RD&D programme is to be submitted has to be taken into account. If there is to be any point in

supplementing the report in the sense that SKB will be able to benefit from the comments of the authorities on the programme overall before completion of RD&D Programme 2010, the time that elapses between the submission of the additional material, the review by the authorities and any decision by the government that this may call for, should be kept as short as possible. One suggestion could be that the additional material needs to be submitted to the Swedish Radiation Safety Authority and the Swedish National Council for Nuclear Waste no later than 31 March 2009. Review, including the consultation round should then be completed by 30 September 2009 and the Government should be able to make decision relatively soon afterwards. However, even this timetable presupposes that SKB begins to work with the supplementary material and RD&D programme 2010 immediately after submission of the opinion on RD&D Programme 2007, without necessarily waiting for a government decision.

8.7.2 Specific Comments

Final Disposal of Long-lived Low and Intermediate Level Waste - SFL

With a vague reference to lack of resources SKB has failed to respond to the expectations of the authorities and the Government in its report of the planning of SFL in RD&D Programme 2007. Irrespective of whether it will take one, two or three decades before the construction of this facility, in SKI's opinion, a credible design is required already today on which to base the criteria for the selection of treatment methods for the waste it is intended to dispose of in SFL. SKI therefore considers that SKB should supplement RD&D Programme 2007 with regard to its plans and programme for SFL. The supplementary material should be organised so that it provides the authorities with a basis for their appraisal of whether SKB's presentation of the programme for SFL in RD&D Programme 2010 is adequate in its coverage of the following respects:

- A quantitative estimate of when the waste it is intended to deposit in SFL will be generated. This estimate is required to justify and assess the reasonableness of SKB's timetable for SFL, including identified possibilities of gradual extension and/or the need for interim storage of the waste.
- The production of alternative designs for the repository, including the construction requirements and safety functions that will be applied.
- The focus of future safety assessments of SFL, for instance the intention to enable the development and verification of acceptance criteria for waste intended for disposal in SFL.
- The contents of research and development programmes to support future safety assessments of SFL.

Final Disposal of Short-lived Low and Intermediate Level Waste – SFR

SKI is of the opinion that SKB needs to offer clearer justification of its plans for the extension and operation of SFR. This should, of course, be in the context of RD&D Programme 2010. So that the authority can be sure well in advance that these questions will be dealt with soundly, SKI considers, however, that RD&D Programme 2007 should be supplemented on this point. The supplementary material should consequently deal with how SKB will account for these matters in RD&D Programme 2010,

including a preliminary but more detailed presentation of the management of operational and decommissioning waste in SFR. SKB should be able to base this on its report on the management of decommissioning waste from the Barsebäck plant dated 18 April 2008 (SKB, 2008).

Planning the Decommissioning of Nuclear Power Plants

SKI can see that SKB has attempted to account for decommissioning issues, including strategies, timetable and programmes for the management of decommissioning waste, in greater detail since the previous RD&D programme. SKB has also attempted to offer greater clarity about the division of responsibilities between the nuclear power companies and SKB where decommissioning is concerned. In SKI's opinion, however, this section of the LILW programme has not yet been given an appropriate structure or sufficiently detailed contents. SKI therefore looks forward to RD&D Programme 2010, which, according to SKB's plans, is to focus, among other things, on those aspects of SKB's programme that concern management of decommissioning waste.

It is clear from SKB's presentation that the nuclear power companies still have the responsibility for jointly or separately accounting for their own plans and strategies for decommissioning nuclear power stations. SKI does not consider SKB's presentation of the power companies' decommissioning strategies in general terms adequately enables the authorities to assess how reasonable the timetables and measures planned are, irrespective of whether responsibility for them rests with SKB or the power companies. SKI therefore considers that SKB should submit a supplement to RD&D Programme 2007 in the form of a survey of the decommissioning plans produced by the power companies pursuant to SKI's and SSI's regulations. This supplementary material must provide a basis for the assessment by Swedish Radiation Safety Authority of how SKB and the power companies should proceed with this issue in connection with RD&D Programme 2010. In SKI's opinion the reasons given by SKB for the timetable for decommissioning the Barsebäck plant are relatively well-supported. However, some material is still missing that would in quantitative terms display the possibilities and problems linked to the deposit of decommissioning waste in the existing SFR at various points in time. This applies in particular to a specification of when and at what rate different forms of waste will be generated during decommissioning. SKI recommends the government to request supplementation of the RD&D programme on this point. Here as well, SKB should be able to base this on its report on decommissioning waste from Barsebäck dated 18 April 2008. SKI also considers that RD&D Programme 2007 should be supplemented with a report of how Vattenfall AB, as licensee for the Ågesta reactor, intends to discharge its obligations under section 12 of the Nuclear Activities Act.

Research Programme

The research for the LILW programme accounted for by SKB comprises on the whole only research already taking place relating to SFR 1. This state of affairs is in SKI's opinion obviously unsatisfactory. In future RD&D programmes, therefore, SKB should account in a structured and systematic way for conceivable future research needs for the entire LILW programme and with reasons for when SKB intends to meet them on the basis of its action plan. The most conspicuous shortcomings of this nature concern

research and development measures for SFL (see above). SKI therefore has great expectations of RD&D Programme 2010 in this respect. The lack of continuous measures in this area means, however, that SKI needs to carry on some form of dialogue with SKB on these issues well before the submission of RD&D Programme 2010. This emphasises the significance of what has been said above about some form of supplementation of RD&D Programme 2007 with regard to SFL.

References

Chapter 2

SKI, 2007. Statens ansvar för slutförvaring av använt kärnbränsle. SKI Rapport 2007:01, SSI Report 2007:01. Swedish Nuclear Power Inspectorate, Stockholm.

SKI 2007/1155. Miljökonsekvensbeskrivning till SKB:s ansökan enligt lagen (1984:3) kärnteknisk verksamhet om att uppföra, inneha och driva ett slutförvar för använt kärnbränsle. 2008-02-27. Swedish Nuclear Power Inspectorate, Stockholm.

Toverud Ö., Strömberg B., 2007. The KBS-3 EBS Workshops: An Example of Regulator-implementer Pre-licensing Interaction in the Swedish Programme in: EBS in the Safety Case: Design confirmation and Demonstration, Workshop proceedings Tokyo, Japan 12-15 September 2006. OECD 2007, NEA No. 6257, Paris.

Chapter 3

SKB, 2004. RD&D Programme 2004. Programme for research, development and demonstration of methods for the management and disposal of nuclear waste, include social science research. SKB (Swedish Nuclear Fuel and Waste Management Co)/Svensk Kärnbränslehantering AB.

SKB, 2006. Ansökansplan för inkapslingsanläggningen och slutförvaret för använt kärnbränsle. SKB R-06-50, Svensk Kärnbränslehantering AB.

SKI, 2002. The Swedish Nuclear Power Inspectorate's Review Statement and Evaluation of the Swedish Nuclear Fuel and Waste Management Co's RD&D Programme 2001. SKI Report 02:33.

SKI, 2005. The Swedish Nuclear Power Inspectorate's Review Statement and Evaluation of the Swedish Nuclear Fuel and Waste Management Co's RD&D Programme 2004. SKI Rapport 2005:65. Swedish Nuclear Power Inspectorate, Stockholm.

Chapter 4

Ask D., Cornet F., Brunet C., Fontbonne F., 2007. Stress measurements with hydraulic methods in boreholes KFM07A, KFM07C, KFM08A, KFM09A and KFM09B. Forsmark site investigation. P-07-206. Svensk Kärnbränslehantering AB, Stockholm.

Dverstorp B., 2007. SSI:s granskning av SKB:s storregionala grundvattenmodellering för östra Småland (SKB Report 06-64), SSI report 2007:11, Swedish Radiation Protection Authority, Stockholm.

Ericsson L.O., Holmén J., Rhén I., Blomqvist N., 2006. Storregional grundvattenmodellering – fördjupad analys av flödesförhållanden i östra Småland.

Jämförelse av olika konceptuella beskrivningar. SKB R-06-64. Svensk Kärnbränslehantering AB, Stockholm.

Geier J., 2006. Review of supraregional modeling of groundwater flow in eastern Småland SKB R-06-04. SKI-INSITE-TRD-06-04. Swedish Nuclear Power Inspectorate, Stockholm.

Martin D., 2007. Quantifying in situ stress magnitudes and orientations for Forsmark. Forsmark stage 2.2. SKB R-07-26. Svensk Kärnbränslehantering AB, Stockholm.

SKB, 2000. Vilka krav ställer djupförvaret på berget? Geovetenskapliga lämplighetsindikatorer och kriterier för lokalisering och platsutvärdering. SKB R-00-15. Svensk Kärnbränslehantering AB, Stockholm.
.
SKB, 2004. Platsundersökningar Forsmark. Program för fortsatta undersökningar av geosfär och biosfär. SKB R-04-75. Svensk Kärnbränslehantering AB, Stockholm.

SKI, 2002. Statens kärnkraftsinspektionens föreskrifter om säkerhet vid slutförvaring av kärnämne och kärnavfall. Allmänna råd om tillämpning av Statens kärnkraftsinspektionens föreskrifter enligt ovan. SKIFS 2002:1. Swedish Nuclear Power Inspectorate, Stockholm.

SKI, 2005. Statens kärnkraftinspektions föreskrifter om fysiskt skydd av kärntekniska anläggningar. Allmänna råd om tillämpning av Statens kärnkraftinspektions föreskrifter enligt ovan. SKIFS 2005:1. Swedish Nuclear Power Inspectorate, Stockholm.

SKI, 2008. Myndigheternas granskning av SKB:s preliminära säkerhetsbedömningar för Forsmark och Laxemar. SKI Rapport 2008:03, SSI Rapport 2008:01. Swedish Nuclear Power Inspectorate, Stockholm.

Chapter 5

Backers T., Stephansson O., 2008. Modelling of Fracture Initiation, Propagation and Creeep of a KBS-3V and KBS-3H Repository in Sparsely Fractured Rock with Application to the Design at Forsmark Candidate Site. SKI Report 2008:25. Swedish Nuclear Power Inspectorate, Stockholm.

SKB, 2002. Äspö Hard Rock Laboratory, Prototype Repository, Installation of buffer, canisters, backfill and instruments in Section 1. SKB IPR-02-23. Svensk Kärnbränslehantering AB, Stockholm.

SKB, 2006a. Äspö Hard Rock laboratory, Prototype Repository, Statistical evaluation of buffer density. SKB IPR-06-15. Svensk Kärnbränslehantering AB, Stockholm.

SKB, 2006b. Kapsel för använt kärnbränsle, konstruktionsförutsättningar. SKB R-06-02. Svensk Kärnbränslehantering AB, Stockholm.

SKB, 2006c. Kapsel för använt kärnbränsle. Tillverkning och förslutning. SKB R-06-01. Svensk Kärnbränslehantering AB, Stockholm.

SKI, 2002. Statens kärnkraftinspektions föreskrifter om säkerhet vid slutförvaring av kärnämne och kärnavfall. Allmänna råd om tillämpning av Statens kärnkraftinspektions föreskrifter enligt ovan. SKIFS 2002:1. Swedish Nuclear Power Inspectorate, Stockholm.

Werme L., 1998. Design premises for canister for spent nuclear fuel. SKB TR-98-08. Svensk Kärnbränslehantering AB, Stockholm.

Chapter 6

Andersson D M., 1984. Smectite alteration. SKB TR-84-11. Svensk Kärnbränslehantering AB, Stockholm.

Apted M., Bennet D.G., Saario T., 2008. A Review of Evidence for Corrosion of Coppper by Water. SKI-BRITE TRD-08-01. Swedish Nuclear Power Inspectorate, Stockholm.

Backers T., Stephansson O., 2008. Modelling of Fracture Initiation, Propagation and Creeep of a KBS-3V and KBS-3H Repository in Sparsely Fractured Rock with Application to the Design at Forsmark Candidate Site. SKI Report 2008:25. Swedish Nuclear Power Inspectorate, Stockholm.

Bäckblom G., Munier R., 2002. Effect of earthquakes on the deep repository for spent fuel in Sweden based on case studies and preliminary model results. SKB TR-02-24. Svensk Kärnbränslehantering AB, Stockholm.

Börgesson L., Hernelind J., 2006. Earthquake induced rock shear through a deposition hole. Influence of shear plane inclination and location as well as buffer properties on the damage caused to the canister. SKB TR-06-43. Svensk Kärnbränslehantering AB, Stockholm.

Dverstorp B., 2007. SSI:s granskning av SKB:s storregionala grundvattenmodellering för östra Småland (SKB Report 06-64). SSI report 2007:11. Swedish Radiation Protection Authority, Stockholm.

Ericsson L.O., Holmén J., Rhén I., Blomquist N., 2006. Storregional grundvattenmodellering - fördjupad analys av flödesförhållanden i östra Småland. Jämförelse av olika konceptuella beskrivningar. SKB R-06-64. Svensk Kärnbränslehantering AB, Stockholm.

Follin S., Svensson U., 2003. On the role of mesh discretisation and salinity for the occurrence of local flow cells. Results from a regional-scale groundwater flow model of östra Götaland. SKB R-03-23. Svensk Kärnbränslehantering AB, Stockholm.

Follin S., Johansson P-.O., Levén J., Hartley D.H., McCarthy R., Roberts D., 2007. Updated strategy and test of new concepts for groundwater modelling in Forsmark in preparation of site descriptive modelling stage 2.2. SKB R-07-20. Svensk Kärnbränslehantering AB, Stockholm.

Geier J., 2006. Review of supraregional modeling of groundwater flow in eastern Småland SKB R-06-64. SKI-INSITE TRD-06-04. Swedish Nuclear Power Inspectorate, Stockholm.

Grundfelt B., Wiborgh M., 2006. Djupa borrhål – Status och analys av konsekvenserna vid användning i Sverige. SKB R-06-58. Svensk Kärnbränslehantering AB, Stockholm.

Hallberg R., 2008. Review of the SR-Can project regarding microbial processes. Paper in SKI Report 2008:16, SSI Report 2008:06. Swedish Nuclear Power Inspectorate, Stockholm.

Hartley L., Hoch A., Jackson P., Joyce S., Mc Carthy R., Rodwell W., Swift B., Marsic N., 2006a. Groundwater flow and transport modelling during the temperate period for the SR-Can assessment Forsmark area - version 1.2. SKB R-06-98. Svensk Kärnbränslehantering AB, Stockholm.

Hartley L., Hoch A., Jackson P., Joyce S., Mc Carthy R., Rodwell W., Swift B., Marsic N., 2006b. Groundwater flow and transport modelling during the temperate period for the SR-Can assessment. Laxemar subarea - version 1.2. SKB R-06-99. Svensk Kärnbränslehantering AB, Stockholm.

Hicks T.W., 2007. Review of Quality Assurance in SKB´s Repository Research Experiments. SKI Report 2007:11. Swedish Nuclear Power Inspectorate, Stockholm.

Holmlund P., 2008. Review of the climate and climate-related issues in the safety assessment in SR-Can. Paper in SKI Report 2008:16, SSI Report 2008:06. Swedish Nuclear Power Inspectorate, Stockholm.

Hora S., Jensen M., 2005. Expert panel elicitation of seismicity following glaciation in Sweden. SSI Report 2005:20. Swedish Radiation Protection Authority, Stockholm.

IPCC, 2007. IPCC 4th assessment report. http://www.ipcc.ch

Kasam, 2007. Kunskapsläget på kärnavfallsområdet 2007 – nu levandes ansvar, framtida generationers frihet. SOU 2007:38. Swedish National Council for Nuclear Waster, Stockholm.

Marsal F., De Windt L., Pellegrini D., 2008. Modelling of long term geochemical evolution of the bentonite buffer of a KBS-3 repository, In: Modelling of long term geochemical evolution and study of mechanical perturbation of bentonite buffer of a KBS-3 repository. SKI Report 2008:24, SSI Report 2008:07. Swedish Radiation Protection Authority, Stockholm, 2008.

Martin D., 2005. Preliminary assessment of potential underground stability (wedge and spalling) at Forsmark, Simpevarp and Laxemar sites. SKB R-05-71. Svensk Kärnbränslehantering AB, Stockholm.

Martin D., 2007. Quantifying in situ stress magnitudes and orientations for Forsmark. Forsmark stage 2.2. SKB R-07-26. Svensk Kärnbränslehantering AB, Stockholm.

Muurinen A., Carlsson T., 2007. Development of methods for on-line measurements of chemical conditions in compacted bentonite. Physics and Chemistry of the Earth, 32: 241-246.

Ochs M., Talerico C., 2004. Data and uncertainty assessment. Migration parameters for the bentonite buffer in the KBS-3 concept. SKB TR-04-18. Svensk Kärnbränslehantering AB, Stockholm.

Rutqvist J., Tsang C-F., 2008. Review of SKB's Work on Coupled THM Processes Within SR-Can. External review contribution in support of SKI's and SSI's review of SR-Can. SKI Report 2008:08. Swedish Nuclear Power Inspectorate, Stockholm.

Savage D., 2005. The Effects of High Salinity Groundwater on the Performance of Clay Barriers. SKI Report 2005:54. Swedish Nuclear Power Inspectorate, Stockholm.

SKB, 2003. Grundvattnets regionala flödesmönster och sammansättning – betydelse för lokalisering av djupförvaret. SKB R-03-01. Svensk Kärnbränslehantering AB, Stockholm.

SKB, 2004. Interim main report of the safety assessment SR-Can. SKB TR-04-11. Svensk Kärnbränslehantering AB, Stockholm.

SKB, 2006a. Kapsel för använt kärnbränsle. Tillverkning och förslutning. SKB R-06-01. Svensk Kärnbränslehantering AB, Stockholm.

SKB, 2006b. Long-term safety for KBS-3 repositories at Forsmark and Laxemar – a first evaluation. Main report of the SR-Can project. SKB TR-06-09. Svensk Kärnbränslehantering AB, Stockholm.

SKB, 2006c. Data report for the safety assessment SR-Can. SKB TR-06-25. Svensk Kärnbränslehantering AB, Stockholm.

SKB, 2007. Boreholes KFM01D, KFM08C, KFM09B Characterisation of pore water. Part 1 Diffusion experiments and pore-water data. SKB P-07-119. Svensk Kärnbränslehantering AB, Stockholm.

SKI, 2002. Statens kärnkraftinspektions föreskrifter om säkerhet vid slutförvaring av kärnämne och kärnavfall. Allmänna råd om tillämpningen av statens kärnkraftinspektions föreskrifter enligt ovan. SKIFS 2002:1. Swedish Nuclear Power Inspectorate, Stockholm.

SKI 2007/598. SSI/SKI-gemensamt brev till SKB inom samrådet för platsundersökningsskedet. 2007-10-22. Swedish Nuclear Power Inspectorate, Stockholm.

SKI, 2008. SKI:s och SSI:s gemensamma granskning av SKB:s säkerhetsrapport SR-Can, SKI Report 2008:19, SSI Report 2008:04. Swedish Nuclear Power Inspectorate, Stockholm.

SSI FS 1998:1. Föreskrifter om skydd av människors hälsa och miljön vid utsläpp av radioaktiva ämnen från vissa kärntekninska anläggningar. Swedish Radiation Protection Authority, Stockholm.

SSI FS 2005:1. Föreskrifter och allmänna råd om hantering av aska som är kontaminerad med cesium-137. Swedish Radiation Protection Authority, Stockholm.

SSI FS 2005:5. Allmänna råd om tillämpning av föreskrifterna (SSI FS 1998:1) om skydd av människors hälsa och miljön vid utsläpp av radioaktiva ämnen från vissa kärntekninska anläggningar. Swedish Radiation Protection Authority, Stockholm.

Stenhouse M., Jégou C., Brown P., Meinrath G., Nitsche H., Ekberg C., 2008. Review of SR-Can: Evaluation of SKB's handling of spent fuel performance, radionuclide chemistry and geosphere transport parameters. External review contribution in support of SKI's and SSI's review of SR-Can. SKI Report 2008:17. Swedish Nuclear Power Inspectorate, Stockholm.

Szakálos P., Hultquist G., Wikmark G., 2007. Corrosion of copper by water. Electrochem Solid-State Letters, Vol. 10 No. 11, C63-C67.

Waber H.N., Smellie J.A.T., 2007. Boreholes KFM01D, KFM08C, KFM09B Characterisation of pore water. Part 1 Diffusion experiments and pore-water data. SKB P-07-119. Svensk Kärnbränslehantering AB, Stockholm.

Öhman J., Niemi A., Tsang C.-F., 2005. A regional-scale particle-tracking method for nonstationary fractured media. Water Resources Research, Vol. 41, W03016, doi:10-1029/2004/WR003498.

Chapter 8

SKB, 2008. Omhändertagande av rivningsavfall i SFR. Internal company report 18 April 2008. Svensk Kärnbränslehantering AB, Stockholm.

Soldéus U., 2005. Miljökonsekvensbeskrivning Barsebäcksverket. Barsebäck Report 1876391/2.0, Barsebäcks Kraft AB.

www.ski.se

STATENS KÄRNKRAFTINSPEKTION
Swedish Nuclear Power Inspectorate

POST/POSTAL ADDRESS SE-106 58 Stockholm
BESÖK/OFFICE Klarabergsviadukten 90
TELEFON/TELEPHONE +46 (0)8 698 84 00
TELEFAX +46 (0)8 661 90 86
E-POST/E-MAIL ski@ski.se
WEBBPLATS/WEB SITE www.ski.se