Record of SSM BRITE (Barrier Review, Integration, Tracking and Evaluation) Review Group Meetings 4, 5 and 7 November 2009

1 Background

The Swedish Radiation Safety Authority (SSM) has responsibility for conducting a formal review of a Licence Application for the construction of a spent nuclear fuel repository, which is being developed by the Swedish Nuclear Fuel and Waste Management Company (SKB).

To inform its review of SKB's plans and the associated Licence Application, SSM is taking advice from a range of experts, including the Barrier Review, Integration, Tracking and Evaluation group, BRITE[1].

The BRITE Group met with SSM and SKB during 4 - 7 November 2009. This document records keys points from the meetings with SSM on 4, 5 and 7 November 2009. On 6 November 2009 the BRITE group met with SSM and SKB. A record of the meeting on 6 November 2009 is being prepared by SKB.

The agenda for the meetings on 4, 5 and 7 November 2009 are attached as Appendix 1.

[1] The BRITE group comprises Mick Apted (Monitor Scientific LLC), David Bennett (TerraSalus Limited), Timo Saario (VTT Materials and Building), Göran Sällfors (Chalmers University of Technology), Peter Segle (Inspecta), David Savage (Quintessa Limited).

2 Meeting of BRITE and SSM on 4 November 2009

2.1 Attendance

Jinsong Liu (JL)	SSM	
Bo Strömberg (BS)	SSM	
Jan Linder (JLin)	SSM	
Lena Sonnerfelt (LS)	SSM	
Öivind Toverud (OT)	SSM	
Patrik Borg (PB)	SSM	
David Savage (DS)	BRITE	Quintessa
David Bennett (DB)	BRITE	TerraSalus Limited
Mick Apted (MA)	BRITE	Monitor Scientific
Peter Segle (PS)	BRITE	Inspecta
Timo Saario (TS)	BRITE	VTT Materials and Building
Göran Sällfors (GS)	BRITE	Chalmers University of Technology
Randy Arthur (RA)	Contractor	Monitor Scientific
Håkan Wennerstrom (HW)	Contractor	Lund University

2.2 Introduction (DS/JL)

- DS welcomed the participants and presented the agenda (Appendix 1).
- One of the main areas of BRITE's work during 2009 has been on buffer erosion. JL explained that the focus of SSM's buffer erosion project is primarily to build up competence with which to assess the issue of buffer erosion in the forthcoming Licence Application, rather than to make a formal review of SKB's reports at this stage.
- JL also noted that the BRITE group is expected to continue working on various issues, including buffer erosion during 2010 in the lead up to the Licence Application review (see Section 3.4).

2.3 Buffer Erosion

2.3.1 Chemical aspects of buffer erosion

Based on an examination of several draft documents provided by SKB and its contractors, RA, HW and DB gave presentations on different aspects of buffer erosion, but focussing mainly on chemical processes (Appendices 2, 3 and 4).

The main conclusions from these presentations are summarised in the following slides:

Conclusions: Comments on the Clay Tech model

- Useful framework for thinking about sol-gel stability.
- Theory is unclear:
  - Poorly defined terms and questionable assumptions (e.g., activities, free-ion concentrations, total analytical concentrations, stoichiometric versus effective ionic strength).
- Theory is incomplete:
  - Apparently does not consider effects of sol concentration on critical ionic strength.
- Experimental results are unconvincing:
  - Na^+ & Ca^{2+} concentrations are calculated, not measured, values - pH not determined.
  - Gels defined by turbidimetric measurements have the water ratios of sols based on rheological measurements.
  - Gel-formation is attributed to face (-)/edge (+) interactions, but there is conflicting evidence as to whether edges have positive charges at pH > 6.5.
- Approach has still only been applied to relatively simple Na/Ca systems.
- Uncertain whether this approach can be made sufficiently robust for use in a safety case.
- Equilibrium constraints on $X_{Ca(clay)} \geq 0.9$ for montmorillonites in contact with glacial meltwaters should be further evaluated.

Arthur_porewater chem_091104.ppt 11

Reflections on the contents of reports provided by SKB

(report received 28/10 not included)

- Na-montmorillonite or bentonite erode when exposed to pure water
- Ca-montmorillonite or betonite stays intact when exposed to pure water of solutions of $CaCl_2$ or gypsum.
- Na-montmorillonite or betonite does not erode when in contact with more concentrated NaCl-solutions. No real consensus on value of critical concentration.
- Presence of Ca^{2+} ions in NaCl-solutions narrows conditions under which erosion occurs. The reports don't give a satisfactory account of this effect.
- Role of interaction edge-side isn't fully investigated.

Conclusions

- Based on the information available at this stage, bentonite erosion by dilute groundwaters cannot be ruled out
- The Neretnieks *et al*. (2009) conceptual model seems reasonable in most respects, but not all aspects are sufficiently supported by experimental evidence
- The reports examined do not present convincing evidence that the accessory minerals in commercial bentonite will form effective filters, as postulated by Neretnieks *et al*. (2009)
- The conceptual model is a significant simplification of the repository situation

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Conclusions

- The calculated rates of bentonite erosion presented by Neretnieks *et al*. are highly uncertain
- There remain some apparently significant gaps in data and knowledge
- Neretnieks *et al*. (2009) suggest that it might be appropriate to add specially chosen particles to the buffer material that would increase confidence that smectite eroding from the bentonite would be filtered
- It is not clear that this would be practicable or effective
- Neretnieks *et al*. (2009) make no comment about other risk management possibilities (e.g., a supercontainer envelope or deposition hole liner)

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Discussion around the presentations included:

- It was noted that there are considerable differences in the terminology being used by SKB and its contractors (e.g., Clay Technology and KTH) to describe the various clay gels and sols that can form during buffer erosion. This inconsistency in the use of terminology results in confusion and poor communication of research results.

- It was noted that the buffer erosion experiments performed by SKB and its contractors had all been conducted at 1 bar pressure, but that pressures in the repository system will be much higher (between hydrostatic pressure at repository depth and hydrostatic pressure plus the bentonite swelling pressure in the deposition hole). The group considered that working at 1 bar pressure was probably OK, as long as the buffer material in the experiments was fully water saturated.

- It was noted that the 'slot' experiments, performed to simulate the erosion of the buffer where a fracture intersects a waste deposition hole, would have given very different results for more realistic fracture apertures of 0.1 mm or less. It was also noted that SKB's experiments had not covered several aspects of real fractures (e.g., heterogeneity, asperities).

- It was noted that significant buffer erosion could compromise several buffer safety functions in addition to the increased inward transport of corroding species for corrosion of copper canister. For example microbial activity could be enhanced by buffer mass loss, and the colloid filtration safety function of the buffer could be lost. After the breach of canister, the release of hydrogen gas (produced by corrosion of the iron-insert) can be much faster and the rule of hydrogen as an inhibitor to alpha-radiolysis might be attenuated. This may possibly results in much higher dissolution rates of the spent fuel.

- There was agreement that further information is needed to properly understand the role of dissolved Ca in preventing erosion of Na-rich clays.

- It was noted that there is no convincing experimental evidence for the formation of 'filter cakes' during erosion of the bentonite buffer. The artificial fracture tests of Jansson *et al.* (2009) do show a dark, feldspar-rich layer in the clay, but the layer formed appears discontinuous.

- The group discussed the buffer erosion rates presented by KTH. The BRITE group considered that KTH's results for the lowest water flow velocities may not be valid because the model may not have converged due to discretization problems. The group also suggested that the long fracture penetration distances calculated may be longer than is realistic. In addition, KTH's results for the highest water flow velocities may not be

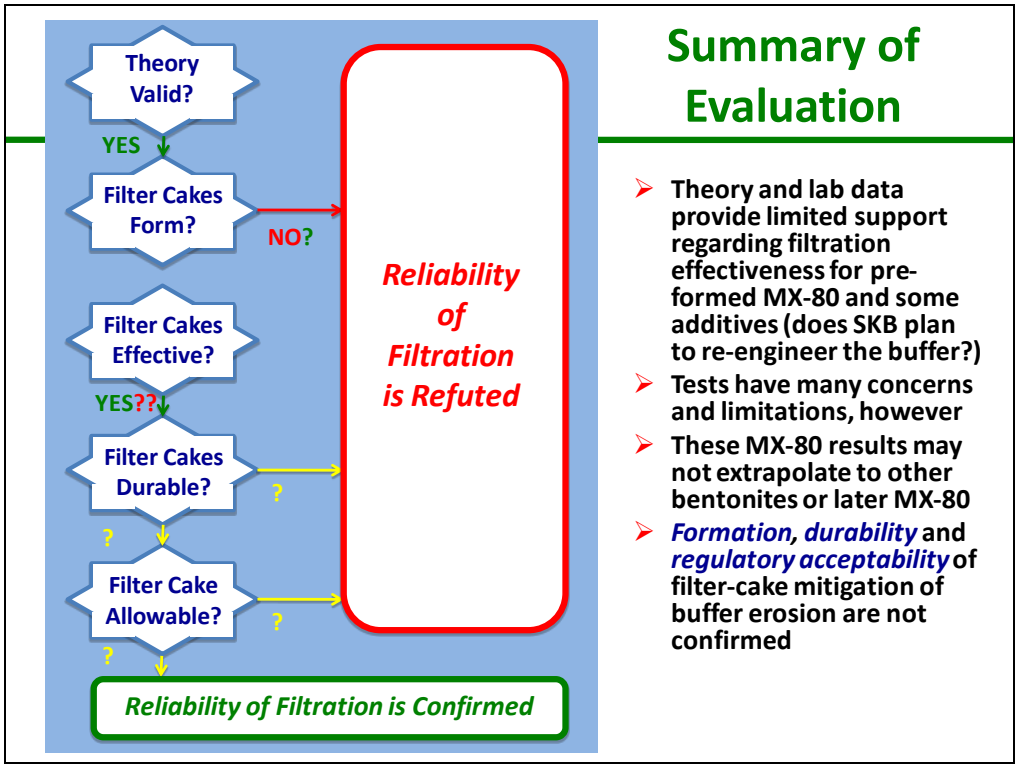
relevant because these flows seem unrealistically high for fractures of the widths expected to be encountered in the repository system.

- It was also noted that eventually site-specific information will be needed on likely glacial water compositions at Forsmark.

The group's comments and evaluations of SKB's reports will be fully documented and developed into a SSM technical report, as described below.

2.3.2 Filtration by formation of filter cake

MA gave a presentation on some of the physical aspects of buffer erosion, but focussing mainly on filtration (Appendix 5). SKB (Neretnieks,et al., 2009) considers that formation of filter cake by the accessory minerals in the bentonite might potentially be a mechanism to filtrate the bentonite colloid and prevent further erosion of the bentonite buffer. MA had followed a decision tree approach in an attempt to evaluate the current status of thinking on bentonite colloid filtration. The conclusions from this analysis are summarised on the following slide:



Discussion points around the presentation included:

- SKB and contractors have not shown by experiment the formation of a filter cake. They have assumed that filter cakes form and then tested their possible effectiveness.

- The reports examined do not give clear statements as to where in a disposal system such filter cakes could form.

- SKB and contractors have not addressed whether a filter cake could persist for long periods or discussed whether safety functions can be specified for degraded barriers. This latter point may be more of an issue for SSM to consider.

- It is unclear how water can flow from the buffer out through a filter as simulated in SKB's experiments, and it is not clear, therefore, that the filtration experiments are reasonable representation of the situation in the repository.

- A significant proportion of the accessory minerals in MX-80 were lost during preparation of the filter cakes used in the filtration experiments. This 'lost material' was not characterised, but would be present in the real situation. Therefore, how representative are the filtration experiments?

- It is also unclear if the experiments are relevant for a filter cake that formed close to a deposition hole. Close to a deposition hole such a filter would experience pressure from the swelling gel.

- If a filter cake does form, it is not clear what the effects of changing flow patterns would be. Does the flow go around the filter? Do further filter cakes form? The pattern of flow and its evolution in fractures could be rather complex.

- The effects of including additives within the buffer material (such as kaolin) to promote filtration and stop buffer erosion are unclear. Quite significant amounts of additives may be needed if this strategy was to be adopted. For example, mixtures with 50% and 20% of kaolin halted erosion but a mixture with 10% kaolin did not. If the buffer material were to be changed in this way, the effects on, for example, buffer ring preparation and buffer properties are unknown.

- Does kaolinite, a possible buffer additive, form colloids that could carry radionuclides?

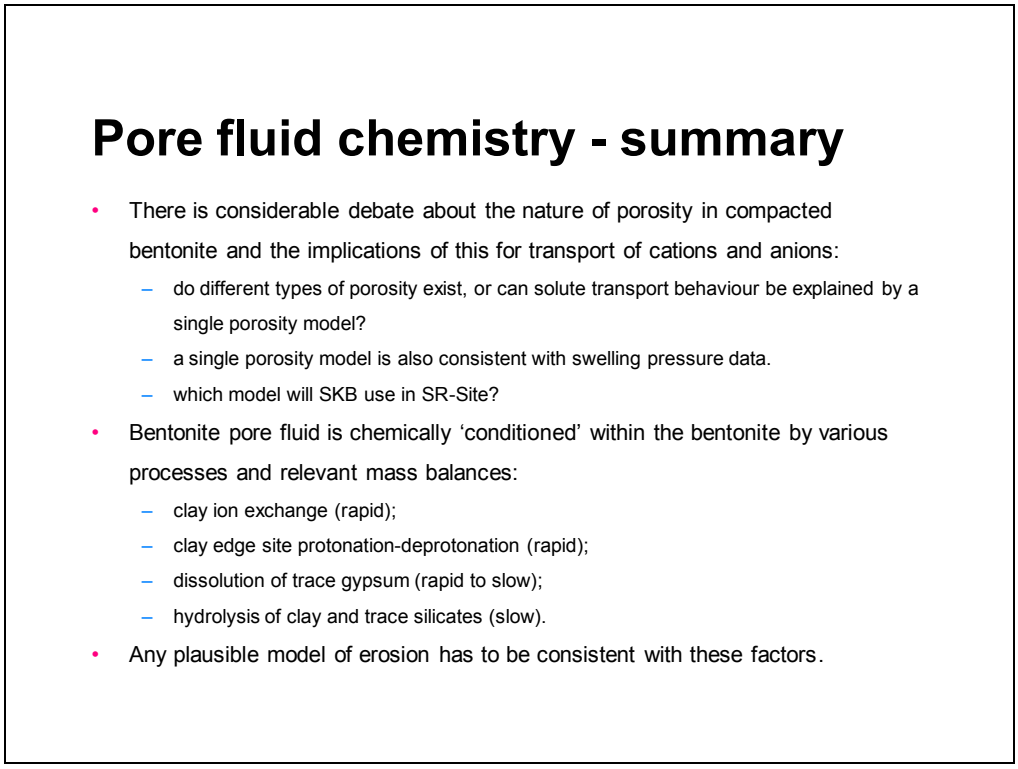
- The persistence of filter cakes could be affected by shearing on fractures, and during glacial unloading such shearing events might be quite likely to occur at the same time that dilute glacial waters could be present.

- Can tests on MX-80 be extrapolated to other bentonites?

The group's comments and evaluations of SKB's reports will be fully documented and developed into a SSM technical report, as described below.

2.3.3 Effects of pore fluid chemistry on buffer erosion

DS gave a presentation on bentonite pore fluid chemistry and its relationship to buffer erosion (Appendix 6). The main conclusions from this presentation are summarised in the following slide:



Discussion points around the presentation included:

- The multiple porosity model of clay microstructure proposed by Bradbury and Bayens has been adopted by several waste management organisations, but simpler, single porosity models can be used to explain the available experimental evidence.
- SKB and contractors have used different, inconsistent models to consider different aspects of bentonite behaviour.
- Any plausible model of erosion ought to be consistent with a single unifying conceptual model of the clay and the processes occurring in clays.

2.3.4 Physical buffer erosion

GS gave a presentation on physical erosion of bentonite (Appendix 7). Discussion points around the presentation included:

- Real fractures will be ~10 times narrower than considered in SKB and contractors' experiments, and the clay penetration distances will be correspondingly smaller.

- It is very difficult to measure the shear strengths of sols with high water ratios.

- There are clear differences of opinion between SKB and its contractors. KTH considers larger fracture apertures, finds that the effect of friction on clay swelling into fractures at the fracture walls is relatively minor, and calculates large clay penetration distances. Clay Technology, on the other hand, considers narrower fractures, finds that wall friction resists the swelling of the clay more effectively, and expects only smaller clay penetration distances. Evidence from grouting studies might suggest that the very large penetration distances calculated by KTH are not realistic.

- It was noted that all of KTH's buffer erosion calculations simply assume that the bentonite swells into the fracture and that this is not prevented by chemical effects at the bentonite swelling front. The BRITE group considers that chemical effects should be considered as well as physical erosion effects in order to better gauge the significance of buffer erosion in the repository system.

- There was discussion of whether natural fractures tend to clog (e.g., at asperities) and it was though that some useful evidence might be available from the colloid migration tests performed at Grimsel, and/or from experience with oil fields.

2.3.5 Outline Table of Contents for SSM Report on Buffer Erosion

It was agreed that each person evaluating the buffer erosion documents should aim to develop a few pages of text summarising their comments in accordance with the following outline table of contents:

- Introduction (RA)
  - Purpose (Aims and Objectives, Scope)
  - Terminology
  - Historical Perspective

- Chemical Aspects of Buffer Erosion
  - Chemical constraints on erosion rates (RA)
  - Clay formation and stability (HW)
  - Experimental work and consistency with the conceptual model (DB)

- Physical Aspects of Buffer Erosion
  - Strengths and weaknesses of physical and conceptual erosion models (GS)
  - Bentonite rheology (GS)
  - Transport of bentonite by water (GS)

- Effects of Porewater Chemistry
  - Models for the porosity of bentonite (DS)
  - Composition of bentonites and processes (DS)
  - Ion exchange (RA)

- Filtration (MA)
  - Theortical models for filtration
  - Filtercake formation
  - Effectiveness of filtercakes
    - Chalmers experiments
    - Clay Technology experiments
  - Persistence and reliability of filter cakes in a disposal system

- Summary (RA)
  - Status of knowledge
  - Key uncertainties
  - Need for further studies

2.4 KBS-3H

JL noted that the BRITE report on the KBS-3H design had recently been published as an SSM report (SSM Report 2009:35).

SKB's Licence Application is expected to be for the KBS-3V design, and SKB is not expected to respond to the BRITE KBS-3H report. Nevertheless, it was agreed that JL should send a copy of the BRITE report on the KBS-3H design to Margit Snellman at POSIVA who is leading a team of staff working on the assessment of that design.

It was noted that STUK had also commissioned a similar review of the KBS-3H assessment. MA agreed to request that copies of the STUK-sponsored report can be communicated to BRITE through SSM.

2.5 Backfill

Over that last several years, BRITE has been actively tracking SKB's research and development work aimed at designing and being able to implement a reliable backfill for the KBS-3 tunnels. SKB has provided BRITE with detailed presentations on its backfilling work at each of BRITE's last four meetings.

In the spring of 2009, noting that SKB has changed its concept for backfilling several times, and having visited SKB's most recent backfilling trials at Äspö, BRITE and SSM expressed strong concerns on SKB's ability to backfill the repository tunnels.

SSM raised these concerns with SKB at a formal exchange meeting with the municipalities (the Swedish National Council for Nuclear Waste's meeting with the Östhammar municipality, 2009-05-11), and again at a later meeting with SKB (expert meeting of buffer and backfill production [*lerlinje*], 2009-05-28).

In consideration of that the backfill materials and design details have been changed many times by SKB due to difficulties to fulfil the safety function requirements, and full-scale tests of the implementation of the backfill have not yet been performed, SKB needs to instil a sufficient level of confidence within SSM in its ability to backfill the tunnels in a way that will perform well enough.

In response, SKB has recently provided a list of new reports describing its work on the backfill (SSM 2009/1070, 2009-10-27). JL has made a proposal within SSM for BRITE to look at SKB's backfill reports during 2010 and to consider SKB's progress, particularly on the issue of implementation.

It was decided that SSM should ask SKB for information on what claims it will make about its ability to install the backfill in the Licence Application and what performance requirements the backfill will need to fulfil.

3 Meeting of BRITE and SSM on 5 November 2009

3.1 Attendance

Jinsong Liu (JL)	SSM	
Björn Dverstorp (BS)	SSM	
Jan Linder (JLin)	SSM	
Lena Sonnerfelt (LS)	SSM	
David Savage (DS)	BRITE	Quintessa
David Bennett (DB)	BRITE	TerraSalus Limited
Mick Apted (MA)	BRITE	Monitor Scientific
Peter Segle (PS)	BRITE	Inspecta
Timo Saario (TS)	BRITE	VTT Materials and Building
Göran Sällfors (GS)	BRITE	Chalmers University of Technology
Randy Arthur (RA)	Contractor	Monitor Scientific
Håkan Wennerstrom (HW)	Contractor	Lund University

3.2 Canister Issues

3.2.1 Cast-Iron Insert

PS gave a presentation on various issues related to the cast-iron insert (Appendix 8). Key points included:

- PS has been looking broadly across the available published information and has begun developing a plan for the review of insert-related issues in the Licence Application Review.
- Current thinking is that three areas will be looked at to come to an overall damage tolerance assessment. These areas are materials characterisation, loading characterisation, and defect characterisation.
- The assessment of defects will consider both 'local' insert collapse and 'global' insert collapse. These collapse modes depend on the applied load (e.g., from even and uneven swelling of the bentonite), creep of copper, and the potential for cracking of the insert. Local collapse of the insert would not compromise containment, but global collapse would.
- SKB reports TR-06-43 and R-06-87 address the effects of earthquake-induced rock shear on the copper canister and insert and, particularly, on plastic deformation of the copper lid.
- The review will also look at SKB's testing of the materials (e.g., by ultrasonic methods).

- PS noted that several claims made by SKB in SR-Can (e.g., about fracturing of copper) are not yet supported by published information (e.g., results presented to BRITE in 2008 that have not yet been published).

Discussion around the presentation included:

- PS should prepare as complete a list as possible of relevant reports, including those that may be expected from SKB before the Licence Application.

- BS noted that a Design Basis report for the EBS is expected from SKB soon. This report may sit above, and be supplied before, the Production Line reports.

- BRITE will need to review the EBS Design Basis report and the Production Line reports when they become available.

3.2.2 Copper Canister

TS gave a presentation on sulphide-induced Stress Corrosion Cracking (SCC) in copper (Appendix 9). Key points included:

- Some Japanese observations in 2007 identified localised SCC of copper when placed in sea water with sulphide concentrations of 70 mg/l.

- In the repository, groundwaters will typically have sulphide concentrations of approximately 1 to 3 mg/l.

- Higher sulphide concentrations could be produced by the action of Sulphate Reducing Bacteria (SRB).

- VTT is now running a project to determine the sulphide concentrations that SRB could create, to look at the diffusion of sulphide towards the canister, and to identify the minimum sulphide level that could cause SCC.

- Preliminary results suggest that SRB can produce up to 400 to 450 mg/l by consuming organic materials (these figures do not allow for any precipitation of sulphide). The total amount of sulphide that can be produced will depend on the size of the SRB population that can be supported.

- The rate of sulphide diffusion sulphide towards the canister depends on the properties of the bentonite (e.g., density) and would, thus, be influenced by any buffer erosion.

- SCC has been observed to cause crack growth in copper when placed under an applied stress density of 10 MPa/m^2 in sulphide-doped Finnish saline groundwaters with a dissolved sulphide concentration of ~80 mg/l.

- The aim of further experiments is to see if SCC occurs at even lower dissolved sulphide concentrations.

Discussion around the presentation included:

- The need to consider the influence of Fe^{2+} in the waters, which would probably lead to FeS precipitation and, therefore, lower dissolved sulphide concentrations.

- The activity of SRB in the bentonite will depend on density and would, therefore, be influenced by buffer erosion.

3.3 Licence Application Review Planning

BS has requested SSM's expert contractors to provide their views on which are key issues to consider during the Licence Application review. The responses from the experts will feed into SSM's development of a review plan.

BS noted that the INSITE (geosphere) and OVERSITE (biosphere) groups have now had their final meetings. SSM is now considering holding workshops to discuss the following topics:

1) The buffer erosion/copper-corrosion scenario and implications.
2) The earthquake-shear scenario and implications.
3) Consequence analyses.

BD gave a presentation on SSM's planning for the review of SKB's Licence Application (Appendix 10).

General points included:

- SSM/SKB are following a staged licensing process.

- SSM has developed a preliminary structure for the staff to be involved in the Licence Application review (see Appendix 10). Some external experts will be integrated in SSM's project group and will help in writing review output documents, while others will contribute only to the more technical review tasks.

- The overall budget for the review is on the order of ~1.5 to 2 M Euro / year (inclusive of SSM's costs) and these funds will be drawn from the Swedish nuclear waste fund.

- The review is expected to take at least 2 years.

- SSM is planning to undertake independent modelling studies to reproduce at least part of SKB's analyses, and to explore the effects of using some alternative models.

- SSM is planning to let 3-year framework contracts to organisations with key experience and understanding of the KBS-3 system, starting in 2010. This will involve competitive bidding for services in areas of relevant technical and scientific disciplines. Key criteria will include significant experience in the Swedish regulatory support programme and independence from SKB.

- Participation in SSM's project group could be by employment on a project basis.

- The Licence Application is expected to be approximately 10,000 pages long (including the Environmental Impact Statement and the ~700 page top level Safety Report).

- The Licence Application is currently expected in January 2011.

Elements of SSM's planning include:

- A Project QA plan (this is already under development).

- A Review Plan which will be available in draft form by the Autumn of 2010 for review and comment.

- SSM is seeking input from its technical experts to help develop the details of the review guidance.

- Requests for Complementary Information (RCI) from SKB will be made as needed.

- A Safety Integration Review (SIR) group, which will help SSM to decide on resolution status of issues.

- A web-based collaborative workspace.

- Broad national and international consultation and peer reviews.

- A web-based consultation facility.

- Public meetings after key review milestones.

3.4 BRITE Forward Planning

JL led a discussion of BRITE's possible activities during 2010. A potential list of activities is given below:

- Buffer erosion study
  - Further competence build-up through research on buffer erosion, with an emphasis on follow-up and evaluation of SKB's approaches
  - Modelling of buffer erosion and canister corrosion.
  - Attendance of SSM's planned buffer erosion/copper-corrosion workshop.
- Backfill study
  - Review of SKB's recent backfill reports and experimental / trial emplacement results.
- Meetings with SKB in May and September.
  - The May meeting could focus on the backfill issue.
- Licence Application Review Planning
  - Update the BRITE TIL and transform it into review plan issues and questions
- Canister study
  - Including review of SKB's damage tolerance assessment work.
- Copper corrosion study
  - Including review of new experiments and analyses, and consideration of stress corrosion cracking.

4 Meeting of BRITE and SSM on 7 November 2009

4.1 Attendance

Jinsong Liu (JL)	SSM	
David Savage (DS)	BRITE	Quintessa
David Bennett (DB)	BRITE	TerraSalus Limited
Mick Apted (MA)	BRITE	Monitor Scientific
Timo Saario (TS)	BRITE	VTT Materials and Building
Göran Sällfors (GS)	BRITE	Chalmers University of Technology
Håkan Wennerström	Contractor	Lund University
Randy Arthur (RA)	Contractor	Monitor Scientific

4.2 BRITE - SSM Discussion on Buffer Erosion

On 6 November, the BRITE group and several SSM staff had met with SKB in an expert meeting on buffer erosion to hear the latest information from SKB on its buffer erosion project and on its plans for assessing the effects of buffer erosion in the Licence Application. Minutes of the meeting on 6 November has been compiled by SKB.

On 7 November 2009, BRITE met with JL to discuss and evaluate SKB's findings and proposals. The discussions identified the following points:

- SKB and its contractors are continuing to use inconsistent terminology (e.g., with respect to gels, sols and the critical coagulation concentration, CCC). SKB is still using the term CCC, but this is not the normal definition of CCC.

- SKB's new 'CCC' is rather simple (based only on the concentrations of Ca and Na), and it is not clear how the new value of 2-4 meq/l relates to the sol formation zone (SFZ). BRITE considers that more research would be needed to understand the effect of other ions (K, Mg, etc) on buffer erosion. Similarly the effects of pH and CO_2 concentrations on CCC, sol formation and erosion should be addressed.

- When will bentonite erosion occur? Different views are held by KTH, by Clay Technology and by SKB. SKB seems to be following Clay Technology's belief that erosion will not continue in waters above the 'CCC'. KTH is arguing, however, that erosion will occur and continue as long as there is a swelling pressure. BRITE is not convinced about whether SKB's new CCC criterion is adequate. BRITE is also not convinced that erosion will occur only in dilute glacial waters.

- The KTH model:
  - The KTH model is based only on Na-smectite data (this might be OK if it can be shown to be truly conservative).
  - The KTH model of erosion at the 'gel/sol interface' is made unclear by KTH's use of terminology.
  - The KTH model does not implement the 'CCC' criterion at the eroding interface. However SKB's proposed approach does take the CCC into account.
  - The KTH model does not include wall friction. BRITE considers that there will be friction between the clay and the fracture walls, and that the strength of the friction forces will gradually diminish as the bentonite moves out into the fracture and becomes more disperse.
  - The KTH table of calculated buffer erosion rates contains several unrealistic parameter values (large apertures, high flows) and BRITE considers that several of the results are highly questionable.
- It was agreed that BRITE should define a QPAC calculation of bentonite migration into a fracture and erosion at the gel/sol front that takes account of wall friction and chemistry, including the diffusion of Ca and Na at the gel front.
- BRITE considers that further support is needed for SKB's claims regarding the conditions when advection can begin in a deposition hole (7,200 kg of buffer mass loss). Could advection begin at lower mass losses? The assumptions regarding the effects of buffer mass loss need to be valid for high-Ca bentonites, not pure Na-bentonites.
- The BRITE group is concerned that the effects on buffer performance of buffer mass loss in a deposition hole should be fully considered even before the onset of advective conditions (e.g., increased diffusivity, increased microbial activity, loss of other safety functions). BRITE also needs to consider how many deposition holes could be affected by these changes.
- BRITE considers that following buffer mass loss, some buffer homogenisation will probably occur, but that this process will not lead to complete homogenisation, as assumed by SKB, especially for real bentonite materials.
- SKB is assuming Darcy flow in its model of bentonite migration through a fracture. A study will be required to show that this approximation is acceptable.

- The fracture apertures assumed in SKB's initial assessment of the consequences of buffer erosion appeared on average to be rather narrow.

- The Grimsel water used in SKB's initial assessment of the consequences of buffer erosion is not representative of sub-ice sheet glacial waters - it is a poorly-buffered, extremely dilute water that has a pH of ~9 to 10 *in situ*, but this drops to near neutral values when the water is abstracted. BRITE suggested investigating whether water compositions from beneath the Greenland ice sheet are available, as these might be more representative.

- SKB is proposing not to rely on any effect of filtration of eroded buffer material. BRITE considers that it would be very difficult to make a convincing safety argument that filtration would be effective in mitigating buffer erosion in the disposal system.

- The loss of buffer mass will affect the backfill above. SKB should assess the effects on the backfill and, for example, determine if and by how much the backfill/buffer interface could move up or down.

- KTH presented a preliminary assessment of the effects of spalling on buffer erosion. This presentation seemed to imply that the effects of spalling on buffer erosion were minor, but the assessment had not considered the case where a deposition hole was intersected by more than one fracture.

List of Appendices