Prepared by Ann McCall	[signature]	Date 31-03-2010
Checked by Karin Pers	[signature]	Date 16-04-2010
Approved by Claes Lindberg	[signature]	Date 20-04-2010

International Peer Review of the Approach and Preparations for the Environmental Safety Case Project
– International Peer Review Group

Prepared by SKB IC for LLWR Ltd., United Kingdom

SKB International Consultants AB

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Box 1091, SE-101 39 Stockholm, Sweden

Phone +46 8 459 8400

Executive Summary

The Low Level Waste Repository Ltd (LLWR) is undertaking a programme of work leading to the production of an Environmental Safety Case in May 2011 (the 2011 ESC). The 2011 ESC will be submitted to the Environment Agency (EA) in order to satisfy a Requirement under the terms of the LLWR's current authorisation.

The LLWR has commissioned a review by an international team of peers with experience from other radioactive waste disposal facilities – the International Peer Review Group (IPRG). The aim is to provide insights and perspectives from experts operating other disposal facilities that will help the LLWR ESC team address issues that are being confronted in developing the 2011 ESC.

The International Peer Review Group consists of safety assessment professionals associated with the SFR facility in Sweden, the Centre de l'Aube facility in France and the El Cabril facility in Spain. The organisations involved were SKB of Sweden, Andra of France and Initec – a Westinghouse Company – from Spain.

A number of observations, questions and recommendations have been made as a result of this peer review exercise. These are made from the perspective of 'peers' who are associated with the preparation of safety case submissions and the licensing and authorisations of facilities for the disposal of LLW in Sweden, France and Spain. It is known that the project was still under development and as such some of the observations and recommendations may already have been acted upon whilst the review was still in progress.

The main observations and recommendations concern the ambitious scope and timescales for the preparation of the ESC for submission to the regulator in May 2011. The expectations on this ESC appear to be from many sources and from many perspectives. This presents a potential risk for the project and one that should be addressed by levelling the expectations through discussions with stakeholders.

A further related observation is that the structure of the ESC appears to be still under development and it is not clear to the IPRG what the regulators are being asked to authorise on the basis of the ESC submitted in 2011.

It is also noted that a unique feature of the LLWR facility is that there is actual data on site releases and that this should be seen as a positive feature and used within the ESC to demonstrate the growing understanding that LLWR Ltd has developed of the site.

Overall the LLWR ESC team are to be commended on the work done to date to gain a better understanding of the inventory of waste already disposed of at the site and are encouraged to continue with these efforts. The assessment approaches and tools and models appear to be very much in line with international practices however a number of unique features are noted regarding the nature of the LLWR site and the approaches to the scenarios being considered: in particular those regarding evolution of the site, coastal erosion and human intrusion.

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1. Introduction

The Low Level Waste Repository Ltd (LLWR) is undertaking a programme of work leading to the production of an Environmental Safety Case in May 2011 (the 2011 ESC). The 2011 ESC will be submitted to the Environment Agency (EA) in order to satisfy a Requirement under the terms of the LLWR's current authorisation [i]. The Environmental Safety Case (ESC) is developed to demonstrate that people and the environment are sufficiently protected from hazards which could arise as a result of the disposal of radioactive wastes to the proposed facilities.

The LLWR ESC team is committed to producing a high quality ESC, fully consistent with the Environment Agencies' Guidance on Requirements for Authorisation (the GRA) [ii]. It is understood that the ESC Project has a standing Peer Review Panel consisting of suitably qualified individuals from the UK, covering a range of expertise, engaged in an ongoing process of review of the ESC and its technical underpinning.

To complement this ongoing review processes, the LLWR has commissioned a review by an international team of peers with experience from other radioactive waste disposal facilities – the International Peer Review Group (IPRG). By commissioning this review the ESC team within LLWR Ltd are subjecting their work to a broad range of technical scrutiny. The aim is to provide insights and perspectives from experts operating other disposal facilities that will help the ESC team address issues that are being confronted in developing the 2011 ESC. The review was conducted on work in progress and the IPRG viewed the documents at a point in time and not the complete set of final documents that are planned by LLWR Ltd for the ESC.

1.1 Objectives

The objective of the ESC team is to deliver on schedule a technically sound ESC that presents the arguments and evidence concerning safety, such that the EA can make confident reasoned decisions as to the authorisation of disposal of radioactive waste at the LLWR and the conditions that should attach to any such authorisation.

The objective of the IPRG is to provide an internationally-based independent review of key technical approaches, arguments, designs, assessments and documents that form components of the developing ESC. The focus was the overall strategy for, and approach to, the 2011 ESC and specific issues identified by the LLWR (rather than a comprehensive detailed technical review). The LLWR ESC team have not requested a detailed peer review of individual documents, rather an overall peer review of the Project and the issues it faces along with constructive comments and advice based on overseas experiences of similar or related issues. The comments made within this peer review report are intended to provide a constructive input to the LLWR ESC team to assist with the successful achievement of the task and the ongoing dialogue with the UK regulators.

The IPRG in carrying out this review has provided, in some cases, independent technical challenge but also sought to provide constructive advice and a different perspective where appropriate. We hope this will assist the LLWR ESC team in producing and presenting a good quality and technically sound ESC, but LLWR Ltd retains sole responsibility for the ESC and its content.

1.2 Scope

To gain an overall understanding of the Project, the following documents were made available to the IPRG; these are also listed in the reference section of this report:

- Technical Approach Document [iii]

- Submission against Requirement 2 on Authorisation, five volumes [viii]
- EA review comments of R2 submission, five volumes [xix]
- LLWR Peer Review Panel comments and LLWR replies [v],[vi]
- EA review summary of 2002 Safety Cases [iv]
- Project Execution Plan – Programme schedule [xi]
- Risk register – Regulatory Guidelines (NS-GRA) [x]
- ESC Project Memo LLW/ESC/MeM(09)022 [xx]
- Memo. LLWR: Hydrogeological Models Engineering Performance Elicitation Workshop [xxi]

The review team have used the information within these documents to gain an understanding of the LLWR repository facility and the issues and approaches facing the ESC team. In addition, a number of issues have been raised and discussed during meetings and dialogue between the review team and the LLWR Ltd ESC team.

The IPRG's work has focussed on issues that are:

- important to the development and evaluation of options that may be available to promote the safe and efficient use of the LLWR;
- important to the assessment of impacts associated with the LLW Repository, its operations and post-closure performance;
- important to the clear presentation of evidence and arguments that must be achieved within the ESC.

The boundaries of the International Peer Review (IPR) are as follows:

- comments and observations regarding the UK regulatory regime and UK policy are the views and perspectives of team members and are intended to offer constructive ideas to the LLWR team based on other national practices;
- The IPRG will not be expected to be aware of studies and results emerging during the ongoing development of the ESC;
- The time and resources allocated to the IPRG are finite and the team is not expected to be aware of the detail of all issues;
- IPRG members have considered the UK approach to regulating the disposal of solid LLW, and in particular with the recently revised regulatory guidance known as the 'NS-GRA' [ii]. It was not the role of the IPRG to address compliance of the ESC Project with this guidance.

The full terms of reference for the International Peer Review prepared by the LLWR Ltd ESC team are contained in Appendix A along with the list of the review team members.

1.3 International Peer Review Group

This International Peer Review has been conducted by a group comprising safety assessment and operations experts from:

SKB, Sweden, with knowledge of safety assessment and operational experience of the Swedish SFR Facility for disposal low and intermediate level radioactive waste. SFR has been in operation since 1988.

Andra, France, with knowledge of safety assessment and operational experience of the Centre de l'Aube facility for low and intermediate waste disposal. This has been in operation since 1992.

Initec Spain, a Westinghouse group company involved in the safety assessment and licensing of the El Cabril facility for Enresa which is the facility for the disposal of low and intermediate level radioactive waste in Spain. This facility has been in operation since 1992.

The International Peer Review Group has been led by SKB Sweden.

The work has been conducted over the period June 2009 to February 2010 and has involved two meetings with the LLWR ESC team to provide a dialogue through which insights, experiences and advice has been discussed in order to assist the LLWR ESC team.

This final report has been edited by SKB based upon the dialogue, views and text provided by the team members in different countries. It should be remembered that each country has its own social and political context governing the siting and operation of disposal facilities and that the regulatory and licensing of such facilities may differ from country to country. To provide context and the basis for some of the comments made and to offer suggestions of how the UK might approach some of its recognised challenges the IPRG team has provided some of this context within this peer review report and as appendices where appropriate.

The structure and format for this report reflects the main technical topic areas described by the LLWR team as key aspects of the ESC being prepared by LLWR Ltd. These are:

- Optimisation
- Waste Inventory
- Near Field
- Geology and Site
- Assessment

It was considered to be useful to formulate the comments by following this structure. The report first sets out general comments and views from the International Peer Review Group and where appropriate examples of these views are also highlighted in the more detailed sections throughout the report.

2. Environmental Safety Case – General Issues

In addition to the expertise on current international practices, our advice on assessment takes into account the overall understanding acquired from the documents provided for the purposes of this review. The following information has been gleaned from our reading of the documents supplied for this review and this appears to us, as informed readers, to be key information that has shaped our review comments and recommendations.

2.1 Wastes and Repository design

The Low Level Waste (LLW) repository (LLWR) located near Drigg (Cumbria) has been used to dispose of radioactive waste since 1959. The total area for waste disposal at the LLWR is 40 hectares. The total area is split into two different parts, trench area and vault area.

Up until 1995, the waste was "tumble tipped" into 7 clay lined trenches (trenches 1-7). The trench area has seven quasi parallel clay-lined trenches with around 800,000 m^3 of wastes. The waste, from the early UK nuclear programme including from research and development activities, was historically deposited by tipping in the trenches between 1959 and 1995. At present, these trenches are full and covered by an interim earth cap, which incorporates a plastic membrane to minimise water ingress.

Although the activity of wastes disposed of in trenches is generally known, at present some uncertainties remain, related to total activity and its distribution.

However, as from 1988, a more engineered solution for disposing of waste (vault 8) was made operational, with waste packaged in steel containers (half height ISO containers) being positioned in a concrete vault. This vault is to the west of the trenches area in the north part of the site. The wastes are cement grouted within the containers before being placed in the vault. Vault 8 has a total capacity of 200,000 m^3 and at present is considered full.

A second vault (vault 9) is being built at the south of vault 8. This will take waste for the period until 2015. Vault 9 is not currently authorized for waste disposal only for waste storage. There are future plans for constructing other vaults (vaults 10 to 15) occupying the rest of waste disposal area on the site.

The floor and walls of vaults are of reinforced concrete. The present design of the vaults includes bentonite layers inside the concrete floor slab ("sandwich"). This design is applicable for vault 9 (and possibly for future vaults).

The total expected activity to be disposed of in the vaults has been estimated but the actual value is obviously dependent of the future waste production and waste management practices.

The design and placement of a final cap to be built over the trenches and vaults is being studied. Its thickness is projected to be around 6 m.

Some modifications in the design of the engineered barriers on the site such as cut-off walls and vertical drains as part of the design for the final cap, are being analyzed in order to enhance the repository performance.

2.2 Updated situation of the assessments

Figure 1: *Overview of the LLWR facility (courtesy of LLW Repository Ltd).*

The long-term assessments are based on estimations of the activity already existing in the trenches and in Vault 8 and the activity expected to be disposed of in the future vaults. The activity is generally considered as an average for each area of the site.

The likely scenario (normal evolution) that results in exposures and doses is through groundwater contamination by rainwater that leaches from the waste and then transports the nuclide activity eventually into the sea (Update assessment. Volume 5, Schedule 9, Requirement 2. Cases A, B, C and D).

In the situation where cut-off walls would permit some horizontal water flows, it has been assumed that small quantities of water could be discharged to the terrestrial environment by the E-W stream and streams in the local area (Update assessment. Volume 5, Schedule 9, Requirement 2).

Radiation doses may be received as a consequence of the consumption of contaminated marine foodstuffs, in the first case, and from the use of contaminated water and the agricultural use of soils that have been contaminated by flooding, in the second.

A complementary scenario has been assessed by postulating the potential existence of a well for individual use, namely drinking water and agricultural and farming purposes. There is a reasonable likelihood that a well would be present somewhere in the release pathway.

The finalization of the design of the repository (final cap and vertical drains), mentioned above, has been included within the simulation that represents the overall performance of the barrier system. (Update assessment. Volume 5, Schedule 9, Requirement 2).

Also, the emission of radioactive gases by biochemical degradation of wastes has been assumed as a normal exposure scenario (C-14). The possible scenarios through which doses could be received are by consumption of contaminated foodstuffs and animal products and through root uptake of vegetables grown on the site area.

After the institutional period, some intrusion scenarios have been selected including a specific evaluation to take into account the radon exposure. A new approach and human intrusion cases have been proposed for the 2011 ESC and the radon modelling is being modified. The assessments give credit to the existence of a final cap (6 m thick) over the waste.

Because some site studies seem to indicate that in future there could be changes in the coast close to the repository, some scenarios named “coastal erosion” scenario, “estuary” scenario and “lagoon” scenario have been postulated. The first one implies the sea reaching the repository and consequently the waste being disseminated on the beach: a person is supposed to be on the beach for recreational or occupational purposes; this person would be exposed each year to the disseminated waste and to the still intact part of the repository, assuming this would constitute a cliff adjacent to the beach. The two other scenarios assume that an estuary or lagoon could be produced by material deposition avoiding the actual streams (E-W and Drigg streams) flow into the sea: in those cases the use of the estuary and the lagoon for leisure activities would derive in exposure and doses to individuals.

At present, it is assumed that the coastal erosion scenario could happen between 750 and 2,000 years, affecting firstly the vaults and then the trenches successively. However, the assessment has been performed independently for vaults and for trenches, assuming 1,000 years as a reference time of occurrence.

The doses received by members of a potentially exposed group relate to some average of radionuclide concentrations on different scales. For some pathways and cases (e.g. human intrusion), these doses relate to specific activities on single packages, whereas in other cases (e.g. some groundwater pathway cases), doses relate to specific activities averaged over all the waste disposed.'

An observation is that the overall strategy seems to be in most respects similar to the case in other countries. The same is true for most of the details in the assessment.

2.3 IPRG Understanding of the Context of the Environmental Safety Case

This section presents how the Environmental Safety Case for the LLWR is perceived by the IPRG.

In 1999, the repository was operated by British Nuclear Fuels Limited (BNFL). In 2006, the operator changed and became British Nuclear Group Sellafield Limited (BNGSL).

The LLWR site is now owned by the Nuclear Decommissioning Authority (NDA) and is operated on behalf of the NDA by a Site License Company (SLC). In 2008 the contract for operating the site was awarded to United Kingdom Nuclear Waste Management – UKNWM – Ltd, a consortia comprising: URS Washington Group, Areva, Studsvik UK and Serco. This consortium has formed the legal entity LLW Repository Ltd who are now responsible for the ESC for the site and who have commissioned this peer review.

The Environment Agency of England and Wales (EA) required in 2000 that BNFL provide information about the environmental safety of the LLWR during its operational lifetime [Operational Environmental Safety Case (OESC)] and after its final closure [Post Closure Safety Case (PCSC)]. This was prepared by BNGSL in 2002 and assessed by the EA between 2002 and 2005 [iv]. The EA identified a number of limitations in the safety case. The EA concluded that the 2002 safety cases failed to make an adequate or robust argument for continued disposals of LLW because:

- Estimates of doses and risks from existing disposals to members of the public in the future significantly exceeded current regulatory targets;

- BNFL indicated that the LLWR was likely to be destroyed by coastal erosion in 500 to 5,000 years; and
- The 2002 safety cases included insufficient consideration of optimization and risk management, to demonstrate that impacts would be as low as reasonably achievable (ALARA).

Because of these, the authorization granted in 2006 to the BNGSL concerned disposal in vault 8 only (the SLC had also planning permission to construct Vault 9 at the site to *store* LLW, but did not have planning permission or authorization to *dispose* of LLW to Vault 9).

As part of the authorization granted in 2006 the EA also required that an updated environmental safety case be delivered by May 2011.

In addition to the requirements for this updated environmental safety case to cover the items described in schedule 9 of the EA's document, it is understood that the EA is also anticipating that the ESC in 2011 will address wider expectations:

(a) To demonstrate that best practice is being applied to keep the peak risks from the site as low as reasonably achievable (ALARA); and

(b) To provide a substantiated proposal concerning the radiological capacity of the site (the amount of waste that could be disposed of while still allowing a satisfactory environmental safety case to be made).

There is continuous dialogue between the EA and LLWR Ltd on the preparation of the ESC and in 2008, a report was provided to the Environment Agency, setting out the LLWR ESC team's response to Requirement 2 of Schedule 9 of the Environment Agency's current Authorization.

It is expected that the ESC by 2011 will also address further EA comments on this report, in particular the following:

a) Its rejection of the licensee proposal to consider the dose criteria for intervention as the most appropriate criteria for judging the assessed long term performance of the trenches

b) Some precision on the adequate treatment of uncertainties, in line with the indications given in the new GRA

c) The recommendation about a better treatment in the assessments of the waste heterogeneity

d) The consideration of the potential for the coastal erosion to be delayed

e) A requirement to analyse the waste activity limitation and radiological capacity linked to the results of the evaluations, including those derived from intrusion scenarios.

Lastly, the NDA is working on a UK strategy for the management of solid low level radioactive waste and a consultation document on this subject was sent out in June 2009. The Low Level Waste Repository plays an important role in the UK strategy for LLW and this also raises a level of expectation on the ESC in 2011.

The IPRG can already state at this stage that the expectations associated with this ESC are significant:

1. As for all safety cases for nuclear waste repositories, it must substantiate an adequate level of safety for the repository (taking into account the "safety case" history for the site and the associated requirements of the EA). Important inputs as such lessons learnt from monitoring and knowledge of the inventory must not be neglected.

2. It must also address the above mentioned wider expectations from the EA (points a-e above

3. It responds to the LLW strategy set out by the NDA by assessing the impact of different waste processing scenarios, hence the LLWR ESC is a central plank of the UK's future LLW strategy and as such the NDA has expectations for this ESC from the perspective of the site owner.

The expectations that go with this ESC must be looked at in the light of the very short time now left before it is to be produced (delivery by May 2011). The ambition of the LLWR is very high and the expectations of what the ESC will provide are complex.

Recommendation: That the LLWR team has a strong dialogue with regulators and other stakeholders to level the expectation of the final product. This could take the form of continued regular dialogue with regulators, meetings, workshops to address specific topics etc.

2.4 Requirements concerning the 2011 Environmental Safety Case

The formal requirements for this Environmental Safety Case are described in the Guidance on Requirements for Authorisation (GRA) for Near Surface Disposal facilities on Land for Solid Radioactive waste (published by the EA). It is not the object of this document to synthesize the contents of this guide, and the following elements will just be highlighted:

- The guidance document concerns the Environment and does not cover the Nuclear Safety Case (which is covered by other documents under the responsibility of the Health & Safety Executive), and the ESC should therefore not go into worker (or public) radiation safety.
- The guidance puts forward 5 principles and the associated 14 requirements that are listed in the next figure.

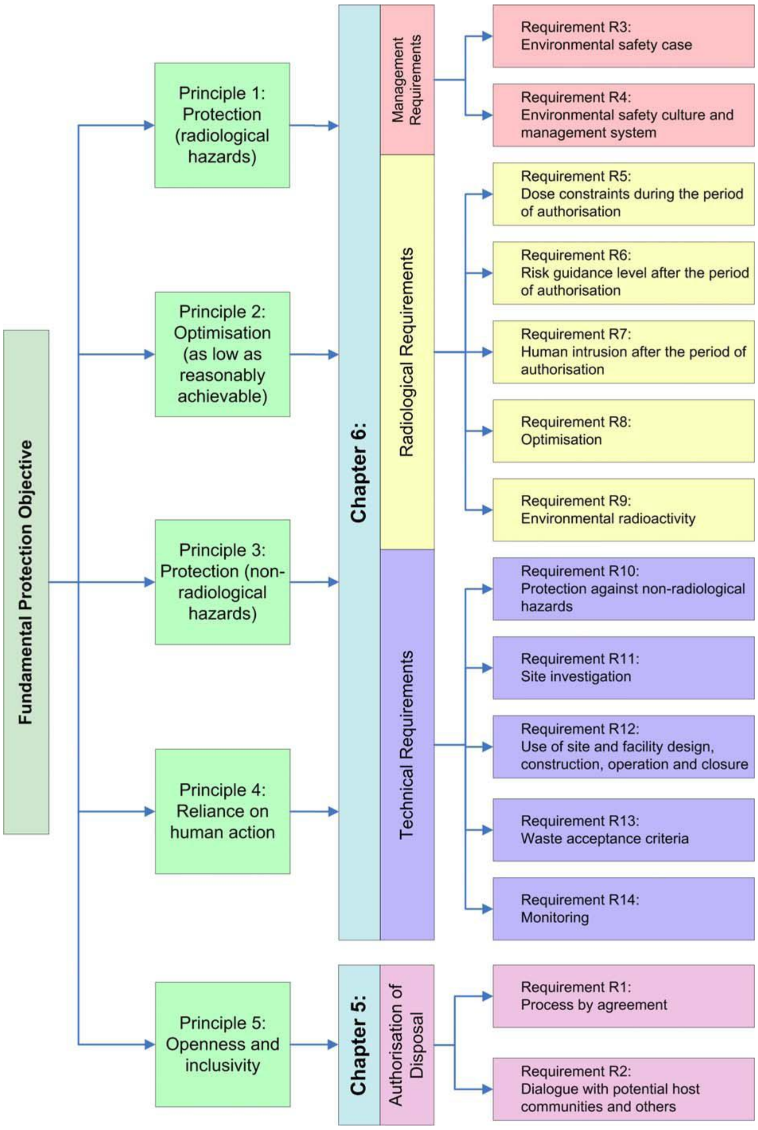

Figure 2: *Extract from Guidance on Requirements for Authorisation (GRA) for Near Surface Disposal facilities on Land for Solid Radioactive waste (published by the EA).*

Associated to these formal requirements, no doubt less formal requests can be expected to appear through the exchange meetings organised by the LLWR ESC team with the EA.

2.5 Structure of the ESC

It is understood from dialogue that the structure of the ESC as envisaged by the LLWR project team and described in ESC project documentation is as follows:

1. System description: description and understanding of the disposal system, including the site and its future evolution, the disposal facility as it exists today and how it will be developed, the waste already disposed and expected future wastes that would be suitable for disposal at the facility.

2. Options and site management plan: identification, description and broad evaluation of options for the future development and management of the facility up to closure and beyond, including options related to past and future waste disposals and overall management of the site.

3. Assessment: performance and safety assessments of the facility during disposal operations, while under active management following completion of disposals, and after the end of active management of the site.

The safety strategy and assessment would be described in the third part and a less technically detailed document is also being planned for the LLWR stakeholders.

It is understood from the LLWR team that this structure is described in a document produced on behalf of the LLWR ESC team in 2008 and that the structure has evolved since. However the IPRG does not have a reference and has not reviewed the document describing this evolution.

These three components of the ESC are obviously very interrelated and the factors that are related within all three sections are at least the following:

- The physical (volumetric) capacity of the site for disposal. This is currently limited to the trenches 1-7 and vault 8. This will then evolve to encompass the capacity of vault 9 (under construction) and all the other future vaults (10-15). A limiting factor to the future capacity being the future authorisations delivered by the EA itself.
- The total radiological and toxic capacity or inventory of the site that must be taken into account for assessment calculations. The waste already disposed of at the site represents a radiological inventory that is estimated based on historic records and could be modified through retrieval and on-going monitoring as a result of ongoing uncertainty reduction studies. The radiological content of future waste streams is very much dependant on the type of waste treatment and disposal strategies that are described in the LLW strategy being established by the NDA and is at this time subject to uncertainty.
- The waste packages, these are miscellaneous and partly in drums in the trenches 1-7 and HHISO metallic and grouted in vaults 8-9. Future waste packages have not yet been formally defined and packages can have long term safety related functionalities (see "engineered elements").
- The engineered elements of the site can be separated into:
  - the vault elements including the walls and any grouting which can have long term safety related functionalities. These can be either physical through their hydrogeological capacity or chemical through their sorption characteristics, and these are specific to each part of the repository, whether it be trenches, vaults 8-9 or future vaults.
  - the capping system and the corresponding elements both existing and future including the timing of the construction of the final cap.
  - the elements influencing the hydrogeology of the repository, including drainage systems and potential cut-off walls.

  Each of these elements influences either the confinement capacity of the repository or affects the way the radionuclide migration must be modelled.
- The question of coastal erosion and the timing of its impact on the repository both for water and air pathways scenarios. This is a major external event and the related uncertainty affects the safety assessment of the site as a consequence of this event being coupled to human intrusion scenario within the safety assessment.

The process of producing the ESC must also take into account the simultaneous optimisation process that will contribute to the ESC contents. This is an iterative process looking at applying the ALARA principle to the repository and its components (principle number 2 of the GRA as given in the previous figure) and therefore also impacts some of the above listed factors. The overall process is only made more complex by the pursuit of more than one objective.

Feedback must be emphasised in order to provide arguments supporting the optimisation process. This serves to illustrate how complex the overall picture appears to be to those not closely involved in the description of the site and the preparation of the ESC and the challenging task that lies ahead for the LLWR ESC team in producing a coherent ESC.

2.6 International Approaches and Experience

The presentation, approach and clarity of purpose are key features of any safety case, however how this is achieved in practice typically varies to suit the regulatory arrangements and social context of each country. The IPRG brings together practitioners from three different countries and it is against these different backgrounds that the following comments and views are made in order to provide information that may assist the LLWR ESC team. Two examples of ESC documentation structure in other European countries can be found in Appendices B and C, however the following ideas are based mainly on the experience gained in the production of the three successive safety cases that have been produced since the beginning of operations at Centre de l'Aube (1992, 1996 and 2004). It is not the objective of this document to compare the contents of safety cases in different countries. For one it is admitted that there is no universal structure. For another, as already mentioned by the IAEA during the ISAM exercise and also in the NEA safety brochure document, the safety case must clearly describe the characteristics of the components of the repository and related functions with important input data being the waste nature and inventory which is always specific. The case of the Centre de l'Aube is different in that the evolution scenarios are different and the safety case demonstration appears more straightforward than for the LLWR case (the waste is better known, the operations phase to date is much shorter, the centre is more modern etc.).

However, based on the Centre de l'Aube experience and with the objective of presenting what is in our minds a complex safety case, one could apply the following ideas:

- Regarding data to be input to the ESC, scenarios could be used to address the variability of the very important input data that is waste inventory but also the external and internal perturbation that can occur due for instance to the location of the disposal and the variability of components.

For example two basic waste radiological inventory scenarios could be developed, one supposing that the future waste streams be left as such and the other supposing maximum economically feasible waste volume reduction is applied (the corresponding radiological inventory would be considered along the same lines first supposing no physical volume reduction operations were being done and then supposing maximum effort is undertaken).

- For elements that are certain but for which there is uncertainty as to their occurrence date, then a given date could be decided on and the uncertainty could be addressed through sensitivity analysis (this could be appropriate for the date of the capping or for dates linked to the coastal erosion phenomenon).

- Uncertainty on parameters could be addressed using different sets of data (three sets of data are used for the Centre de l'Aube ESC: the initial data used for the licence application, the current data that seems appropriate and the 'best estimate' data that represents the state of the art) and through sensitivity analysis.

Recommendation: A key recommendation from the IPRG is that more consideration should be given to the presentation of the ESC in terms of giving a clear picture or 'story' regarding the site and the authorisation that is being sought from the regulators. This is an observation that is further developed during the later sections of this review report. A key part will be the arguments dealing with scenarios to be taken into account in the safety assessments. The uncertainty management and a clear argument explaining why the coastal erosion may be considered as an alternative scenario could be presented.

2.7 European Directive

The review team was asked to provide information on what effect the European Directive on releases to groundwater had on the disposal facilities in the respective countries and to offer any information or advice on the approach to non-radiological assessment. This is the subject of this section of the report.

In Sweden the non-radiological assessment is part of the Environmental Impact Assessment and not part of the safety submission. An analysis of non-radiological hazards was not included in the recent assessment for the SFR facility in Sweden but in the original licensing of the facility in 1988. The authorities and their reviewers did not have any comments on this. In the ongoing licensing for an extension of SFR both a safety assessment and an EIA have to be presented. The safety assessment is used in the application to the regulating authority SSM and the Government (under the Nuclear Activities Act) and the Environmental Impact Statement (EIS) is the base for the application to the Environmental Court (under the Environmental Code).

Landfill rules are not applicable to the SFR facility in Sweden. However, small landfills for VLLW exist at the NPP sites and in Studsvik.

The situation in Spain is quite similar to the one in Sweden. The non-radiological assessment is part of the Environmental Impact Assessment and it is not part of the safety submission (Safety Report).

An evaluation of toxic chemical impacts has not been specifically required. Nevertheless, the toxic chemical risk of the "El Cabril" facility is controlled by the identification and evaluation of the toxic chemicals included in the process of characterization and acceptance of waste packages and also by means of a non-radiological monitoring programme of groundwater and surface waters, established and carried out around the facility since the start of operation. If necessary, this programme would be adapted in order to assure the fulfilment of the European Directive's requirements.

In France this evaluation is done with an approach that uses toxicological reference values to evaluate the effects on health by expressing chemical impact as excess individual risk for carcinogenic elements and hazard coefficient for non carcinogenic elements. The elements are boron, antimony, chromium, arsenic, lead, mercury (both organic & inorganic), uranium, beryllium, cadmium and nickel.

Following a question by the French safety authority, Centre de l'Aube is examining certain issues linked to the European Directive.

3. Optimisation

The presentation of optimisation and demonstration of optimisation in the Technical Approach document (section 4.9) is sound and reasonable. However, it is unclear if it is relevant for an environmental safety case for an authorisation. In their comments EA states "Reconsider and compare the applicability of different technologies (and combinations of technologies) for reducing risks to provide soundly based assessments of the best practicable option;" and "Consideration should be given to the implications of any innovative waste disposal approaches (e.g. different packages or different waste treatment technologies) for the ESC and site optimisation".

The experience from other assessments, such as in Sweden and France, is that it is difficult to include design comparison in a safety case. Even with just a few different options the assessment can grow very rapidly. A separate repository evolution has to be presented for each combination of options. Each evolution may generate a number of calculation cases, which may have different uncertainties associated with them. In the end, it may be difficult to compare the options and possibly also to show compliance.

Most importantly it must be clear which option is the reference one that is the actual subject of the authorisation. Especially since the Technical Approach document states "the best way forward is not necessarily the one that offers the lowest radiological risk".

Observations from the review team are that:

- Clarity of the preferred design is not clear
- Presentation of any variants must be clear
- There is a transparency issue of how the various cases and scenarios included in the ESC are derived, there is a high level strategy for optimization, but it is unclear how the variants discussed are derived
- Confusion can be introduced when discussing different comparisons which can lead to issues and challenges regarding QA and checking that consistent data is used for all calculations
- Based on experience for other assessments, it may be difficult to keep design options open in a Safety Report and an approach using a specified 'reference design' is typically adopted
- It may be better to keep the optimisation as a separate parallel project and have the optimisation report as a separate supporting document.
- It is not totally clear to the IPRG what the regulator actually expects when it comes to optimisation.

In the Inventory and Near Field document the 'Single Option' design is introduced. This seems to be a very reasonable approach for the ESC, but it is not clear at this stage how this is consistent with the discussion about design options discussed in the Technical Approach document and if it will meet the expectations of the EA.

Recommendation: If acceptable from the regulators' point of view it may be a good idea to exclude the discussion on design options from the ESC. Design options could then be treated in a separate study, where also other issues than radiological risk are studied. From a regulator's perspective this would help to clarify the point of what exactly the regulators are being asked to authorise and give an opportunity to discuss the regulators expectations regarding optimisation.

It should be noted that that the discussion and the recommendation in this section are based on the impression of the IPRG from the written information received (Technical Approach document). In the discussion with the LLWR ESC team it has become clear that the actual intention for the ESC is already very close to what is said in the recommendation. The only concern then may be that other stakeholders may have different expectations for how the optimisation (regarding options comparison) is treated.

4. Inventory

The waste inventory of the LLWR can be divided into several groups:

- Existing, historical, waste disposed of in trenches 1-7
- Existing waste presently stored in the engineered vault 8
- Future waste disposal in vault 9, presently under construction
- Future not yet designed and constructed vaults 10 - 15 needed for future waste arising primarily from decommissioning.

To meet requirements from near field assessments it is desirable to know in great detail not only the radionuclide inventory in the waste but also the content of different materials, in particular material and related characteristics (e.g. organics) that can influence the behaviour of the radionuclides.

For LLWR the knowledge of waste stored in vault 8 is well known whereas the old trenches have great uncertainties in their waste contents. An interesting observation concerning waste material distribution is that the relative content of "unknown" material is reported three times higher in vault 8 than in the old trenches (Figure 4.3 in Volume 3 [viii]). In addition the contents of radionuclides in vault 8 have been reduced by a factor of two from 2002 to 2008 inventory just by using actual data.

Data on future wastes should be easier to determine. The acceptance criteria (Conditions for Acceptance, CFA) can be formulated in a way that necessary data on radionuclides and material are documented on each waste package before disposal. It is important to quantify uncertainties in the estimates of both material and radionuclides in the waste packages. The Waste Acceptance Criteria or Conditions for Acceptance are a key tool in requiring consignors to take more responsibility for characterising their wastes and are key to controlling uncertainty in the safety case. The IPRG has not seen or reviewed any documents on the Conditions for Acceptance but their importance as a key tool for the LLWR team should be noted and their role should be discussed in the ESC.

In general terms waste accepted for disposal in shallow land disposal facilities, like the LLWR, would contain mainly short lived radionuclides so that release of the site is possible after a post-closure institutional control period of a few hundred years. .

A key observation is that in the LLWR, due to the history of the site, the predicted quantities of long-lived radionuclides seem to be significant although it is acknowledged that LLWR are taking steps to get better understanding of the historic disposals. Since the normal evolution lifetime of the LLWR is expected to be somewhere between a few hundred to some thousands of years dispersion and dilution into the sea is possible this has to be assessed in the long term by the LLWR ESC team. This is a unique feature of this site and therefore it is important that the LLWR ESC team formulate the future strategy and determine the timeframes over which the evolution of the site has to be assessed.

Assuming the timeframe of interest is a few thousand years long-lived radionuclides may be accepted provided the expected impact on the environment during that period is likely to be acceptable (based on the safety analyses). This implies that the intrusion scenarios should be a major consideration along with the time frames for the assessments as these will be a useful tool in assessing the future of the site and assessing whether the historic wastes and associated activity limits of long-lived radionuclides could be accepted.

It is suggested that the maximum inventory of radionuclides is used for the assessment of specific vaults and trenches and that these are applied for scoping calculations to satisfy the safety requirements for release and impact on the environment for all scenarios. In the same way the quantities of material possibly interfering with the release of radionuclides have to be estimated.

Recommendation: If the primary target is seek authoriation for the existing facilities, a safety case based on existing waste disposed of in vault 8 and estimations for the next vault 9 could be an option. Estimations for future vaults (excl vault 9) should be considered as variations of this case. Estimations of waste already disposed of, and steps to improve data on waste in the trenches 1-7, should be described in the ESC.

There appears to be a big difference between estimated contents of radionuclides in the 2002 and 2008 estimates for trenches and vault 8. Quantification and estimates of material has not been performed in the 2002 inventory and hence any changes due to better understanding of the waste are not possible to detect when compared to the 2008 figures. The 2008 estimation is reported but without any indications of uncertainties.

Recommendation: The use of actual data as far as possible (actual data should override the data from the national inventory) should be a basic principle for estimating contents of radionuclides and materials in the waste. It is commendable that the LLWR team have been able to establish that the radionuclide content of vault 8 is possibly reduced by half just by applying actual data. The vault has been in use since 1988 and a significant part of it should have been filled by 2002. It seems that the estimation made 2002 did not take the actual inventory into consideration.

Recommendation: To get a better understanding and quantification of data for the trenches use of existing documents is a good start (as it is done in the new update). Back fitting of data from vault 8 as it was done in the 2002 update seems not to be reliable because of e.g. the large heterogeneity in the waste. To reduce the uncertainties in the content of the trenches a good approach is to go back to the waste producers and see if there is any information available that is not already documented at the repository site. The information can be written documents or knowledge of employees at the waste producer’s sites.

Recommendation: LLWR are encouraged to continue the efforts put into the understanding of historical waste in the trenches as this seems to give good results in reducing uncertainties and to better understand the inventory as a whole.

5. Near Field

The comments in this section are based on the written information received [viii Volume 3] and information provided during the two meetings with the LLWR team held during the review. It has become clear that the activities and plans for the near field work are far more mature than the picture that is presented in the Technical Approach document [iii] and Requirement 2 Vol 3 Inventory and Near Field[viii Volume 3].

In the Technical Approach document it is stated: "The engineered system includes the various engineered barriers (e.g. cap and cut-off walls), the waste itself, surrounding backfill and waste containers. There is a need to understand a range of processes that affect the leaching and mobility of contaminants from the waste and the resulting evolution of conditions over time."

The Single Option design seems to be a good idea for the ESC however it is unclear what this is defined as and if this is consistent across the presentation of the ESC. Different figures are used for the engineered barrier system – EBS – in different sections. They all have their merits, but should preferably be combined into one specification with a figure.

The description of the engineered barriers is rather thin and ambiguous in the documentation available. Details about the design are missing and the materials used in the different components are not specified. It would be an advantage if the intended performance of the main engineering features was included in the assessment documentation. Specific questions that arise for the IPRG and which need to be clearly addressed are:

- How well can the barriers be characterised and described at the point when the repository is eventually closed?
- What are the associated uncertainties in the initial state of the near field?
- How does the leak detection layer in the vault construction work and what is its purpose?
- What is expected from the bentonite enhanced soil?
- Is there bentonite in the double liner of the vaults as well?
- Are the vertical drains a part of the safety case or not?

Recommendation: The IPRG encourages the LLWR ESC team to make a description of the expectations of the different barriers in the near field. An example could be that the cut-off walls will (or are expected to?) limit the ground water flow through the trenches, which is achieved by their low hydraulic conductivity. At this stage it would be sufficient to describe the beneficial properties of the barriers without quantification, since it may be difficult or unnecessary to give quantitative expectations at this stage. This will aid in the description of the barrier evolution.

Recommendation: The initial state of the near field should be clearly defined and described. This should include materials and dimensions as well as the associated uncertainties such as failed construction, stray materials, etc. It could also be worthwhile to document the properties assigned to the different materials, both maximum and minimum values. This will aid the quality assurance, since it makes sure that everyone uses the same data.

An observation is that the expected evolution of the near field is not clearly documented. The important issues should be how the repository evolves chemically (affects RN-transport properties) and hydraulically (affects the groundwater flow). Hydraulic properties are needed to evaluate the chemical buffering capacity, but it may also be needed to perform a mechanical assessment to describe the hydraulic evolution.

A further observation is that it seems that much more attention is given to calculations of radionuclide release than to the description of the initial state of the barriers and the repository evolution. The overall presentation of barrier properties in the documentation is weak. However, the IPRG is aware that more information is available. The IPRG review raises the following as examples of the types of questions and information that the ESC would be expected to address, with the structure of the ESC providing the context for how important these are to the overall ESC from the site.

- How will the bentonite interact with the concrete wall in the vaults?
- What will be the mechanical evolution of the cap – will the settlement lead to an increase or decrease of the groundwater flow?
- Component degradation and properties were evaluated through expert elicitation. This is an interesting approach, which very well may have its merits. However, it is unclear if it is sufficient and more documentation is needed in the ESC to justify this.
- Laboratory and/or field measurement data for the conductivities of the different components should be presented within the assessment. The conductivities selected for the different components generally seem a little high. This may be justified for radionuclide transport, but may affect the repository evolution differently, since it may affect bathtubbing and desaturation.
- The assumption that the conductivity of certain components will remain constant may be reasonable. However, other evolution paths should be considered.
- What is assumed about porosity or solid to water ratio in the trenches and vaults?
- Has the self-compaction and settlement of the trenches been modelled? How is the process assumed to affect the performance?
- The settlement of the trenches will most likely have limited impact on radionuclide transport and overall risk from the repository. However, the settlement has been monitored and data do exist. It would increase the confidence in the ability to describe the repository evolution within the system assessment if this process could be successfully modelled.
- It seems rather bold to assume that the vertical drains will function as designed. The performance of the vertical drains needs better justification if they are to be included in the ESC. It could be claimed that the drains are “active” barriers while all the other repository components are “passive”. It seems rather difficult to ensure the long term performance of drains.
- Under what circumstances is bathtubbing expected to occur? What kind of performance is needed from the drains? What is the likelihood for bathtubbing without the drains? The EA also seems to have some doubts about the drains.
- The possibility of unsaturated conditions in the repository is a case that seems to require more attention. Under what circumstances would the repository become unsaturated? What are the critical parameters/boundary conditions/assumptions in the model? At first glance an unsaturated near field would give a lower flow and less RN-transport from the repository, but can it be claimed that this always is the case? Will there be preferential pathways where the water will go? How will an unsaturated near-field affect the geochemical conditions? Will there be oxidation during unsaturated periods? Will this affect sorption and solubility?

- It is assumed that the trenches will re-oxidize after 4,000 years; it is unclear if this is important for the performance of the repository. Were the results from DRINK systematically compared with results from the site monitoring? It would be nice to see the monitored values reported in Figure 3.1 and 3.2 [in viii Volume 3]. If such comparisons are done this could inform the understanding of the oxidation modelling.
- Are there results from any laboratory investigations of the uranium waste form available? How well is the congruent dissolution approach for uranium in the fluoride residues justified? Addressing such issues could further increase the confidence in the dissolution model.

The IPRG are overall very supportive of the LLWR team approach to use alternative release models and see this as an excellent approach however, as noted above, it is not always apparent why you assume what you assume and how the assumptions evolve with time.

Recommendation: The IPRG suggests a focus on the description of the evolution, not on the calculations and properties of the barriers. This is a further development of the earlier observation in Chapter 2 regarding the presentation of the ESC.

Recommendation: Even more emphasis could be put on the monitored data from the site. Data and observations could be collected in a separate report/section and these could then be used to confirm modelling results. The importance of this for confidence building cannot be underestimated.

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6. Geology and Site

The description and the modelling of the site has not been the focus of the current review. The general impression is that the LLWR ESC team has a high ambition when it comes to site understanding and use of site data in the safe case. The model development and the modelling approach also seem appropriate and reasonable. There are a number of strong points in the assessment of the site performance:

- There is a single geological concept both for regional and local scale
- The geological model has been used to underpin the hydrogeological conceptual model
- A number of different possible pathways for radionuclides have been identified
- The effects of the **presumed** climate changes on the geosphere have been fully considered.
- The new site-scale model provides a good match to the observed groundwater heads in the vicinity of the site, which builds confidence in the results
- The groundwater flow model has been used as the basis for developing a predictive model of the effects of planned engineered barriers, which means that the issue about consistency between near- and far field is considered
- The use of site data (tritium) to verify the model strengthens the assessment
- The view has not changed significantly from the 2002 hydrogeological conceptual model, which indicates that the understanding of the site from a hydrogeological point of view is good

The IPRG acknowledges that the EA had a large number of comments on the Site Understanding report. However, most of these comments refer to either:

1. The structure of the presentation
2. Details in the site description and the modelling

The EA comments need to be responded to, but most of them do not seem to have a critical impact on the outcome of the overall ESC.

The overall conclusion is that the conceptual and mathematical representation of both the geology and hydrogeology meet high standards. The presentation in Requirement 2 Volume 4 Site Understanding is also clear and convincing.

The coastal erosion evolution pathway is unique to the LLWR and adds a considerable challenge to assessment. Comments about how the coastal erosion is considered in the assessment are presented in the next section.

The assumptions about the hydraulic properties of the engineered components are discussed in Section 5.

7. Assessments

This section is intended to examine and compare the key issues identified by the LLWR group with, firstly, current practices in countries with near-surface repositories and, secondly, with international applicable guidelines. Our goal is to provide some technical advice for improving the preparatory work of the LLWR ESC team for the 2011 ESC although it is acknowledged that the LLWR team will need to also take into account the UK specific radioactive waste national policy, the repository history and the mandatory character of national applicable regulations and guidance.

7.1 Selection of scenario and applicable risk and dose guidance.

It is clear that the acceptance of the performance assessment and the safety evaluation of a repository must be judged according to risk and dose limitation criteria. In this sense it is necessary to determine which criteria would be applicable to each scenario.

The 1997 GRA established only the value of 10^{-6} per year as a risk target for the post-closure assessment.

The new GRA (2009) modifies this position, on one hand, clarifying that the dose equivalent to the risk of 10^{-6} per year is around 20 microSv/y if the probability is considered to be one and higher than 20 microSv/y if not, and, on the other hand, establishing a guidance of 3 mSv/y to 20 mSv/y applicable to intrusion scenarios.

In our opinion, the new guidance allows an easier management of the scenarios in the ESC and facilitates the agreement between the EA and the repository operator about the consideration of performance criteria applicable to the whole repository. To this end, we consider, in the case of the LLWR, that the risk guidance level of 10^{-6} is the acceptable criterion applicable to the groundwater analysis, C-14 gas scenario and coastal erosion scenarios, and the 3-20 mSv/y is the criterion applicable to the results of intrusion scenarios (including radon).

In relation to human intrusion scenarios the new GRA also indicates that these scenarios must be considered on the basis that they are likely to occur, and adds some clarification statements about these this type of scenarios

We interpret that the new GRA recommends that these scenarios must be reasonable and based on current human practices and they do not need to include any further discussion about probabilities of occurrence or any quantification of uncertainties linked to practices.

Taking into account the GRA considerations about human intrusion and EA objections to the previous selection of human intrusion scenarios, we consider it important to get an early agreement with the regulators as to which human intrusion scenarios should be evaluated in the ESC. It is understood that the LLWR team is making progress in this area. (See further discussion in subsection 7.7.)

Using other types of performance indicators apart from dose and risk could also be an aid in the assessment, see subsection 7.4.

7.2 Treatment of uncertainties (scenarios, models, parameters)

The management of uncertainties is a key aspect of an environmental safety case. Different kinds of uncertainties are to be considered, such as those associated to the global and specific definition of scenarios, the characteristics of present and foreseen wastes and facilities, models, parameters, etc.

In general, we consider that the analysis of uncertainties for the 2011 ESC, as well as the strategy for treating uncertainties and the identification of sources of uncertainties, are appropriate. The IPRG broadly supports the LLWR technical approach to uncertainties described in its Technical Approach (2008) document (section 5.4). However, our experience shows that the most important thing is to reach an agreement with the regulator about the precise definition of scenarios. This agreement should cover the evolution of the system, the characteristics of the wastes and the timescales involved. Then, our advice is to focus on these specific uncertainties first, and to proceed to study the remaining, less important items, only after that.

In our view, making a catalogue that includes every uncertainty identified and classifies uncertainties in for instance two classes (those that "can be reliably quantified" and those that cannot) may be an adequate approach that is in agreement with new GRA and, in addition, makes it possible to address the untreated uncertainties in future, if required. It should be noted that there are other possibilities that can be similarly classified for example those which are related to the design, those which are related to site. It is advisable that the catalogue of uncertainties includes some comments on untreated uncertainties and their significance.

7.3 Safety functions

Safety functions are mentioned in the beginning of the Technical Approach Document: "understanding of the system performance in terms of safety functions." "This will include a qualitative analysis of the safety functions of the facility and the features or controls that satisfy or enhance each function." "We will illustrate a thorough understanding of the performance of the existing and planned disposal facilities in terms of safety functions, e.g. isolation of the waste, containment of radionuclides and attenuation of releases, and the features and processes that promote or potentially reduce those functions." This is a good ambition but the results are missing from the rest of the documentation.

Safety functions have been shown to be a valuable tool in safety assessment in many national programmes (e.g. Belgium, France, Sweden and Finland) and have the potential of being useful for the ESC as well. Safety Functions should be seen as a tool and may be applied differently in different assessments. As an example, safety functions were used in the recent assessment for the SFR facility in Sweden [xii]. A summary of the use of safety functions in the SFR assessment is presented in Appendix D. The recent review of the SFR assessment by the Swedish regulating authority (SSM) encouraged the use of safety indicators in future assessments.

The method of employing safety functions and safety performance indicators proved to be a good tool for analyzing the future function of the repository as well as for arriving at a comprehensive set of scenarios.

Recommendation: A safety function methodology may very well be used for the LLWR. The key benefits would be:

1. that the description of the repository evolution can be focussed on the issues that are important for the performance

2. scenarios can be selected in a systematic/structured way. Most likely the same scenarios will be identified, but the selection process will be transparent

7.4 Alternative safety indicators

The dose/risk safety indicator provides a measure of radiological impact on future humans due to the existence of a repository. Several aspects of biosphere development are highly uncertain, even over a relatively short time perspective. The evaluation of safety depends on a number of assumptions made in order to handle these uncertainties. It is, therefore, of interest to complement the dose/risk indicator with alternative indicators that do not require detailed assumptions about the biosphere or concerning human habits.

For distant futures, the dose indicator can be complemented with other safety indicators, e.g. concentrations in groundwaters or near-surface waters of radionuclides from the repository or the calculated fluxes of radionuclides to the biosphere.

A problem with alternative indicators is that there is, in general, no obvious criterion with which the calculated quantities can be compared. In some cases, calculation results can be compared with natural concentrations or fluxes at the site or elsewhere. However, such criteria do not provide points of reference for man-made radionuclides. The problem can be partly overcome by comparing naturally occurring sum concentrations/fluxes of α- and β-emitters to the corresponding repository related quantities, or by comparing overall toxicities by scaling by dose per unit intake values.

EU SPIN Project

An EU project [xiii] concludes that two alternative indicators could preferably be used to complement the dose indicator. These are:

- Radiotoxicity concentration in biosphere water: preference for medium time frames, i.e. several thousand to several tens of thousands of years.
- Radiotoxicity flux from the geosphere: preference for late time frames.

The project also reports on reference values that could tentatively be used for comparisons to calculated concentrations and fluxes of radionuclides from the repository.

Finnish activity release constraints

The Finnish Radiation and Nuclear Safety Authority STUK has issued activity release constraints to the environment [xiv]. These nuclide specific constraints are defined for long-lived radionuclides only. The effects of their short-lived progeny have been taken into consideration in the constraints defined for the long-lived parents. The nuclide-specific release rate constraints are

- 0.03 GBq/y for the long-lived α-emitting isotopes of Ra, Th, Pa, Pu, Am, Cm,
- 0.1 GBq/y for Se-79, I-129, and Np-237,
- 0.3 GBq/y for C-14, Cl-36, Cs-135, and the long-lived isotopes of U,
- 1 GBq/y for Nb-94 and Sn-126,
- 3 GBq/y for Tc-99,
- 10 GBq/y for Zr-93,
- 30 GBq/y for Ni-59,
- 100 GBq/y for Pd-107 and Sm-151.

The constraints apply to activity releases that arise from the expected evolution scenarios and that may enter the environment after several thousands of years, whereas dose rate constraints are applied in the shorter term. In applying the above constraints, the activity releases can be averaged over 1,000 years at the most. The sum of the ratios between the nuclide-specific activity releases and the respective constraints shall be less than one. It should be noted that the Finnish regulator derived these constraints partly based on a set of reference biospheres considered possible in the future at the planned disposal site for HLW and spent fuel, Olkiluoto at the coast of the Baltic Sea, and partly on natural fluxes of radionuclides established for similar environments. The reference values of the Finnish regulatory guide are thus not directly applicable for other disposal concepts and sites [xiii].

The Finnish activity constraints have been used as one alternative indicator in SKB's safety assessment for the future repository for HLW and spent fuel [xv]. These constraints are strictly applicable only in the Finnish regulatory context, but are still deemed useful as an alternative indicator for the Swedish safety assessment. Also, measured concentrations of naturally occurring radionuclides in ecosystems at one of the candidate sites will be used as an alternative indicator.

Other studies

A study performed jointly by the Swedish Nuclear Power Inspectorate and the Swedish Radiation Protection Agency in 2002 [xvi] compiled from the published literature a substantial database of elemental abundances in natural materials and, using these data, calculated a range of elemental and activity fluxes arising due to different processes at different spatial scales. The authors conclude that these fluxes should be comparable to results from safety assessment calculations.

IAEA has published a study entitled "Safety Indicators in Different Time Frames for the Safety Assessment of Underground Radioactive Waste Repositories" [xvii] and has conducting a research programme on natural concentrations and fluxes [xviii].

7.5 Scenarios: Overall understanding and justification of selection. Use of FEPs

We acknowledge that a great effort has been made, including a lot of studies and investigations, to evaluate the safety of the repository for the long-term and to manage in a comprehensive way the repository history together with the current situation and the foreseen future use as a national repository for low level wastes.

An overall approach should take into account the time frame of the assessment (extended in the future), the nature and characteristics of wastes (real and foreseen), the repository design and the form in which the wastes are disposed of (i.e. the whole engineered barrier system) as well as the characteristics of the site and the environment.

Internationally the approach to determining the scenarios for assessment is to use a FEP analysis (Features, Events and Processes), or at least an adapted FEP list, as a tool for checking the completeness of the selection and record tracking to register the arguments and support studies that justifies the scenarios finally selected. The IPRG supports any intention by the LLWR group to adopt this method. More information on how this is approached in Sweden along with a description of the approach to using safety functions is discussed in the following section 7.6 and in Appendix D.

First of all it is observed by the IPRG that the four major areas – groundwater pathway, gas pathway, human intrusion and site evolution (coastal erosion) – cover broadly any significant potential radiological risk associated to the repository in the future. It is not considered that there are any other areas that should be considered. This should be drawn out more clearly in the presentation of the overall picture (story).

The global assessment approach is considered appropriate. The selection seems to be complete (even more than necessary, in some cases) and in line with international practices.

The scenarios linked to groundwater pathway and gas pathways are typical long-term exposure scenarios considered and included in the safety assessment of any near-surface disposal facility. Human intrusion scenarios are also commonly postulated and evaluated for similar repositories. The evaluation, in this case, is to establish or verify acceptable radiological limitation in the wastes, mainly for long-lived nuclides, or to test the suitability of a repository when the former is not possible.

In addition, it is common that some external events related to potential site and environment future changes be analyzed as alternative scenarios separately and/or included as sensitivity cases of typical usual scenarios. Within this set, scenarios included in assessments of other near surface facilities consider a gradual modification of natural and engineered barriers or relatively minor disrupting changes.

In the case of LLWR, the possibility of coastal erosion affecting the repository between some hundreds to a few thousands of years implies a major change of site conditions that strongly influences the analysis of exposure scenarios, adding new and different potential exposure scenarios, modifying the other groups of scenarios and making more complex the global assessment.

The IPRG have not found any specific reference to this or a similar event being considered in a long-term safety evaluation of any other near-surface repositories. We consider that addressing this challenge and the effort by the LLWR group to manage the selection and assessment of such scenarios, is unique and commendable.

7.6 Normal scenarios (Groundwater and gas pathway) modelling

According to the documentation analyzed by the IPRG, we would point out the following general issues.

In our opinion, the groundwater (GW) scenario has been properly defined, analyzed and developed and we understand, at least in broad terms, the discussion on that matter between EA and the LLWR group. It seems that a more precise definition of the abstraction well scenario and the use of better models and adjusted parameters, would lead to a radiological impact inside targets.

Despite this the IPRG has an observation in relation to the timescales for the GW (normal evolution) scenario. Considering the occurrence of the coastal erosion scenario at some point into the future (as EA comments), we believe that the time of evaluation of the GW (normal evolution) scenario must be extended up to a longer time (it could be 10,000 years). Over this period of time the degradation of barriers should be considered. We are fully aware of the implications of this approach:

- It fulfils the EA expectations in relation to the coastal erosion.
- It is consistent with our suggestion of separate evaluation of scenarios for a better interpretation of results and, definitely, adds more clarity to the ESC.
- It is not contrary to the evaluation of the coastal erosion scenario. This coastal erosion scenario would be an alternative scenario, like the well scenario has been treated by LLWR (Update assessment. Volume 5, Schedule 9, Requirement 2).

Recommendation: The coastal erosion scenario could be considered as part of the normal reference groundwater scenario but this is a matter for the LLWR team to decide. However it is the IPRG view that under all circumstances the 'no coastal erosion' scenario should be part of the considerations of the evolution over extended timescales.

7.7 Intrusion scenarios: Approach and cases

We consider that the assessment of human intrusion for the 2011 ESC is broadly consistent with the GRA Requirement 7 and the comments given by the EA, while also providing a technically reasonable and proportionate approach to the assessment of human intrusion. Therefore, this ESC fulfils the three goals intended, namely:

a) To assess consistency with the dose guidance levels and to assist in reaching decisions on waste acceptance and radiological capacity (generally the radiological capacity is not directly derived from scenario – it is based on inventory; if impact is acceptable, the inventory becomes the total activity capacity)

b) To assist in optimisation of the disposal system and protection, and

c) To present illustrations to broaden the safety case

The analysis to substantiate credible and reasonable scenarios included in this category seems complete and detailed. We note that the emphasis on the characteristics of the site and environment to rule out some scenarios appears to be quite different to other near surface disposal facilities and it has been questioned in some cases by EA. Unlike the design phase, the final safety documentation is simpler for other facilities than LLWR. In particular, of the three points a), b) and c) singled out above, only point a) is usually addressed for other facilities.

We point out that dwelling scenarios rely on the thickness (around 6 m) and effectiveness of the future cap to impede any disturbance of waste material. Also we notice that some additional intrusion scenarios have been postulated "after" coastal erosion reaches the repository, in the horizon beyond 750 years.

It is clear that wastes with long-lived nuclides already disposed of in LLWR are a challenge for this assessment as they condition the selection of scenarios and impose stringent requirements on the design and emplacement of the final cap (strength, durability, etc).

The LLWR team are encouraged to maintain the discussions with EA to agree and define precisely the intrusion scenarios to be considered, also to make every effort to warrant the performance requirements of the final cap.

Doses for intruders are generally proportional to the specific activity of the waste and the doses are used to limit the activity of waste consignments. Doses through groundwater pathway are dependent on the total disposed activity. As a consequence, it is noted that some of the doses in the intrusion scenarios (B2+B7 scenario) are dependent on two variables: the local specific activity and averaged specific activity. These could be equal or different; this fact makes it difficult to use this scenario to establish waste acceptance criteria –WAC. The B2 + B7 scenario is not easy to be managed as a limitation case. Hence we suggest that this scenario is not considered, at least not in the way it is currently defined (i.e. for activity limitation of wastes packages).

7.8 Coastal erosion scenario

The modelling tasks performed in order to investigate the impact of coastal erosion on the repository are commented on here, although the supporting documents (Thorne and Kane 2007) have not been included in the review.

The LLWR team has separated and highlighted this issue from site and geology and the IPRG proposes to do the same. Key issues raised by the IPRG are:

- Consideration of how coastal erosion affects at first the environmental conditions and ultimately the waste acceptance criteria for the site and if coastal erosion would limit the extension of the facility.
- Consideration of the coastal erosion scenario and, given that the site contains some historic long-lived wastes, the potential impact on the demonstration of the safety and

performance of the site. This will need careful consideration and discussion with regulators and stakeholders, particularly regarding future scenarios to be assessed.

- The combination of scenarios could be a key issue, e.g. tidal aspects of coastal erosion and the case of a partially eroded repository.
- It is essential that scenarios without coastal erosion are included in the analysis in order to cover a wider range of possible future climates.
- As the coastal erosion (CE) modelling which defines the time for site termination is highly sensitive to assumptions on future climate it is essential for the project that the climate models underpinning the coastal erosion scenarios are up to date and also cover a wide range of possible climate evolution scenarios.
- A key issue for the LLWR ESC team is how to address the controversial aspects of interest to stakeholders and advice on the presentation of controversial scientific issues could be useful. Moreover, the IPRG considers that these issues are largely matters that should be addressed in setting national policy and regulatory framework.

The evaluation of the general coastal erosion (CE) scenario considering its occurrence in the short time, long time and indefinite time, as it is suggested by EA and accepted and assumed by the LLWR group is fully supported by the IPRG. We also consider the present approach from the LLWR group to continue in the long-term with the monitoring program already developed and the use of a workshop to address the key question of whether there is scope for developing better numerical models of CE are commendable activities.

As a consequence of the considerations above, we believe that a final decision about the determination of the timescales for calculations of the general CE scenario as well as the precise definition of specific scenarios over such a timeframe must be made only after finishing the corresponding studies and activities and taking into account their outcomes. This view is relevant not only to the general CE scenario but also to those that we understand as "CE derived scenarios", namely the "lagoon" and "estuary" scenarios.

We note that the inclusion of the "Beachcomber" hypotheses, as an additional sub-scenario, required by the EA, have not yet completely developed. . Taking into account the heterogeneities in the trenches the IPRG considers that a precise definition of all potential dose pathways in the "CE – Beachcomber scenario" must be agreed with EA as early as possible.

Recommendation: Agree with the EA the conditions for the human activities in the beach that require evaluation in the CE scenarios and give further consideration to the presentation of controversial scientific issues to stakeholders as part of the effective communication of the ESC.

7.9 Waste heterogeneity, activity limitation and radiological capacity.

It is evident that the consideration of waste heterogeneity is a concern, in particular the heterogeneity in the specific activity of wastes and, as a consequence, in the analyses of those scenarios whose results are more dependent on specific activity (i.e. intrusion and the main coastal erosion scenario – exposures and doses in the beach –).

In other repositories the heterogeneity in the specific activity (except in the case of sealed sources whose treatment for medium and long-lived nuclides constitutes an international concern not generally solved yet) is analysed jointly with the specific activity limitation and waste acceptance criteria linked to the analyses of typical intrusion scenarios. We note that the EA comments suggest the same approach in relation with future waste and vaults.

Appendix E presents the specific approach used in Spain to manage these issues.

In SFR there is no limitation on specific activity in the waste packages. Limitations are put on package dose rate (for handling) and on nuclide specific activity contents in each disposal chamber (for safety assessment). This is applied through the derivation of waste acceptance criteria which logically can only be applied to new packages and not to waste already consigned. In the case of LLWR where waste is already disposed of in the trenches the assessment of intrusion scenarios based on estimates from previous records would determine adequate safety performance of this area of the site.

Furthermore, the necessity to analyse the coastal erosion scenario, (beach cases) including "beachcomber" activities with reference to the assumed risk criterion could be the most restrictive scenario within the safety case for some long-lived nuclides.

In order to improve the general knowledge and understanding of the influence of waste heterogeneity on the doses/risk results it would be a good practice to perform analyses for each nuclide important for intrusion scenarios. The results and conclusions from these analyses would need to be discussed with the EA before making any decision concerning a suitable management of these issues in the ESC.

8. Conclusion and Summary Statements of IPRG

A number of observations, questions and recommendations have been made as a result of this peer review exercise. These are made from the perspective of 'peers' who are associated with the preparation of safety case submissions and the licensing and authorisations of facilities for the disposal of LLW in Sweden, France and Spain.

The key point that the review team would like to make at this point in the development of the ESC by the LLWR Ltd is that the presentation of the ESC needs careful and clear presentation. This comment is intended to be constructive and examples and advice on how this can be improved, based on international experience of similar facilities, have been made throughout this report.

Regarding the approach to the assessment the LLWR site is unique from other national disposal sites in a number of aspects, such as the site was given and there is no site selection assessment to refer to and that the site is at a coastal location.

Against this backdrop the LLWR team are to be commended on the work being carried out and the efforts to engage in continued dialogue with the regulators to address a number of significant issues and risks associated with completing the ESC to the very challenging timescale of May 2011.

It should be noted that the review was limited in terms of duration and the status of the technical reports to be read. It was also the case that the review was carried out whilst documents and the approach was still under development and hence some of the observations and recommendations may have been addressed by the LLWR team.

9. References

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ii	Environment Agencies, Near-Surface Disposal Facilities on Land for Solid Radioactive Wastes: Guidance on Requirements for Authorisation, February 2009.
iii	Technical Approach to the 2011 ESC, LLW Repository Ltd., November 2008 (LLWR/ESCR(08)10010)
iv	Review Summary of 2002 Safety Case Overview Report: “The Environment Agency’s Assessment of BNFL’s 2002 Environmental Safety Cases for the Low-Level Radioactive Waste Repository at Drigg.” NWAT/Drigg/05/001 (Version:1.0), June 2005
v	Peer Review of Requirement 2 Submission, LLWR_2008-8-2 Version 1, September 2008
vi	LLWR ESC Response to the Peer Review Comments on Requirement 2 LLWR/ESCR(09)10008
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viii	Schedule 9 Requirement 2 Volume 1 – Managing Liabilities Volume 2 – Determining Future Strategies Volume 3 – Inventory and Near Field Volume 4 – Site Understanding & Appendix Volume 5 – Performance Update
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x	Risk Register
xi	PXP Project Execution Plan LLWR/ESC/PM(08)001
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xviii	IAEA 2005. Natural Activity Concentrations and Fluxes as Indicators for the Safety Assessment of Radioactive Waste Disposal. IAEA-TECDOC-1464, November 2005
xix	Environment Agency Review of LLW Repository Ltd's "Requirement 2" submission, draft for information, 3rd March 2009 Volume 1 – Overview Volume 2 – Assessments of Options for Reducing Future Impacts from the LLWR Volume 3 – Inventory and Near Field Volume 4 – Site Understanding Volume 5 – Performance Update of the LLWR
xx	ESC Project Memo LLW/ESC/MeM(09)022
xxi	LLWR Memo LLWR/ESC/MeM(09)035, Hydrogeological Models Engineering Performance Elicitation Workshop, August 2009

Appendix A – Terms of Reference

LLW Repository Ltd

International Peer Review Group (IPRG)

Terms of Reference

Issue 1, 23rd September 2009

Background

The Low Level Waste Repository (LLWR) is undertaking a programme of work leading to the production of an Environmental Safety Case before 01 May 2011 (the 2011 ESC). The 2011 ESC will be submitted to the Environment Agency (EA) in order to satisfy a Requirement under the terms of the LLWR's current authorisation [i].

The LLWR ESC team is committed to producing a high quality ESC, fully consistent with the environment agencies' Guidance on Requirements for Authorisation (the GRA) [ii].

We value peer review as an important process to provide independent technical challenge to ESC. The GRA comments on the use of peer review, see Annex 1. We agree with these comments but also consider that, to be most effective, the peer review should be managed as a dialogue aimed at improving the ESC.

The ESC Project has a standing Peer Review Group (PRG) consisting of suitably qualified individuals from the UK, covering a range of expertise, with whom we are engaged in an ongoing process of review of the ESC and its technical underpinning.

To complement this ongoing review processes, the LLWR has commissioned a review by an international team of peers with experience from other radioactive waste disposal facilities – the International Peer Review Group (IPRG). This should help to build confidence with our various stakeholders, including the regulator, that our work is subject to a broad range of technical scrutiny. It should also provide insights and perspectives from other operating disposal facilities that will help the ESC team address issues that we are confronting in developing the 2011 ESC.

Objectives

The objective of the ESC team is to deliver on schedule a technically sound ESC that presents the arguments and evidence concerning safety, such that the EA can make confident reasoned decisions as to the authorisation of disposal of radioactive waste at the LLWR and the conditions that should attach to any such authorisation.

The objective of the IPRG is to provide an internationally-based independent review of key technical approaches, arguments, designs, assessments and documents that form components of the developing ESC. The focus should be on the overall strategy for, and approach to, the 2011 ESC and specific issues identified by the LLWR (rather than a comprehensive detailed technical review).

The IPRG should provide independent technical challenge but also seek to provide constructive advice. This will assist the ESC team in producing and presenting a good quality and technically sound ESC, but the LLWR retains sole responsibility for the ESC and its content.

Scope of review

The IPRG's work will focus on issues that are:

- important to the development and evaluation of options that may be available to promote the safe and efficient use of the LLWR;
- important to the assessment of impacts associated with the LLWR, its operations and post-closure performance;
- important to the clear presentation of evidence and arguments that must be achieved within the ESC.

The boundaries of the IPR are as follows:

- comments and observations regarding the UK regulatory regime and UK policy are the views and perspectives of team members and are intended to offer constructive ideas to the LLWR team on other national practices;
- The IPRG will not be expected to be aware of studies and results emerging during the ongoing development of the ESC.
- The time and resources allocated to the IPRG are finite and the team is not expected to be aware of the detail of all issues.

IPRG members will need to consider the UK approach to regulating the disposal of solid LLW, and in particular with the recently revised regulatory guidance known as the 'NS-GRA' [ii]. They will not need to address compliance of the ESC Project with this guidance, however.

Approach to the review

The review will comprise the following stages:

1. LLWR meets with the IPRG lead member and possibly some other members, to explain the key aspects of the study and the work programme.
2. IPRG undertakes preparatory reading.
3. LLWR drafts Terms of Reference (ToR, this document) and identifies key issues facing the ESC Project.
4. IPRG visits the LLWR for a two-day meeting. Presentations would be made by the LLWR on the ESC Project. The emphasis, however, would be on discussion and exchange of information. This meeting would include a site visit and agreement of the ToR.
5. IPRG undertakes any further document review required and draft their report.
6. IPRG visits the LLWR for a one-day meeting to present and discuss their report. This meeting could be at a location convenient for air travel, such as Manchester.
7. LLWR provides comments on the factual accuracy of the draft report.
8. IPRG produces final issue of their report.
9. LLWR produces a reply to the IPRG's report, identifying how they will address any issues raised or any disagreements.

References

i Environment Agency, 2006, Certification of authorisation and introductory note, Disposal of radioactive waste from nuclear site, British Nuclear Group Sellafield Ltd., Low-level waste repository Drigg, Cumbria, Authorisation number BZ2508/BZ2508, effective 1 May 2006.

ii Environment agencies, Near-Surface Disposal Facilities on Land for Solid Radioactive Wastes: Guidance on Requirements for Authorisation, February 2009.

Document history		
Draft 1	31-07-09	TS draft for internal comment.
Draft 1b	05-08-09	Including AB and AH comments.
Issue 1	23-09-09	Addressing IPRG comments from Meeting on 17th and 18th September 2009 (AB).

Annex 1: Extracts from the Near-Surface Disposal Facilities on Land for Solid Radioactive Wastes: Guidance on Requirements for Authorisation

Peer review, p.35:

6.2.40 Where appropriate for some technical work, peer review should be used to supplement other approaches to quality management, because these other approaches cannot, in general, identify lapses or weaknesses in technical quality. Peer review involves independent specialists in a particular technical field examining work performed by specialists in the same field. The rigour with which peer review is carried out needs to be proportionate to the significance of the work being reviewed to the environmental safety case. The peer review process must not be inappropriately curtailed. There needs to be a clear-cut stage in which the originators of the technical work respond to the reviewers' comments. The process ends only when the organisation that has commissioned the peer review is satisfied that a suitable end point has been reached. The relevant environment agency will expect to see the comments made by peer reviewers and the responses to those comments, and will take them into account in its regulatory judgements. Peer review is important both to quality management and to the application of sound science and good engineering practice.

Glossary, p.107:

Peer review – A formally documented examination of a technical programme or specific aspect of work by a suitably qualified expert or group of experts who have not been involved in the programme or aspect of work.

Annex 2: The International Peer Review Group

The International Peer Review Group (IPRG) consists of experts of longstanding experience and international reputation, each of whom has experience of the operation of, and/or development of safety cases for, of disposal facilities for radioactive waste.

We value the individual expertise that each member of the group brings to the peer review process and believe the combined expertise covers the expertise required to provide informed and robust technical challenge of the ESC.

The members of the Group are:

Patrik Sellin, SKB

Jan Carlsson, SKB

Fredrik Wahlund, SKB

Ann McCall, SKB

Sylvie Voinis/Richard Poisson, Andra

Ana Lázaro/Elena Silvan, Initec

Members of the IPRG are appointed for their individual expertise. The IPRG will develop its review based on the member's individual and joint expertise. The review report shall be the view of the IPRG and its members and shall not be attributable to any organisation to which any of the members may be affiliated.

Annex 3: Security

Some documents or data made available to the IPRG may be classified as "restricted" according to guidance from the UK Office for Civil Nuclear Security (OCNS).

Any such documents or data:

- will be clearly identified and marked as such by the LLWR;
- must be kept securely (i.e. locked away when not in use) and not stored on a networked computer (unless the network is secure);
- must not be copied, reproduced or transmitted except by LLWR, which will only be done as necessary for the work;
- returned to LLWR on completion of the work, or written confirmation given that they have been destroyed.

Appendix B – Structure of ESC documentation, France

Structure of the most recent update of the equivalent document for the Centre de l'Aube (French LLW repository in the Aube district)

The licensing process in France requires that a safety case be produced in preliminary form along with the license application. In this case, this was done in 1986. This safety case was then produced in provisional form in 1992, along with the beginning of waste disposal operations on the site. It was then produced in final form in 1996. A revised version was provided in 2004 to take into account 10 years of operations and the associated evolutions. It was sent to the French safety authority in 2004 and was organised in same manner as was the previous document in 1996 (the appropriate paragraphs have been detailed): A review was organised by the safety authority and his technical support provided a review report in view of a expert standing committee meeting in view of establish a position. The safety report is one of the documents to be provided within a set of required files according to the French Act of 2006 and related decree of 2007. The elements described below give a short overview of type of information that are provided for the Centre de l'Aube (there is no universal plan, some guidance exists):

1. **Introduction, general presentation of the safety regime for the Aube centre, general presentation of the centre**

The basic rule for the long term safety of this site is a "Fundamental Safety Rule", published by the French Safety Authority for this type of repository. To summarize:

The nuclear-power industry and the use of radioactive sources in various activities – especially in the industry, medicine, research and national defence – generate radioactive waste. Most of it consists of low level short live waste, and very low level waste which are currently managed over the long term in Andra's disposal facilities located in the Aube District.

Risks associated with radioactive waste are induced mainly by the radiation emitted par the radionuclides they contain. Radiation exposures have been divided in several types, but all refer to the total or partial exposure of the human body and, consequently, to a risk or more or less reversible risks to cells that are isolated or located within a single organ. Potential impact may result from:

- *the exposure to a radiation source without any contact between the victim and the radionuclides. Protection against that risk consists in placing sufficiently-thick shielding screens between both;*
- *the surface contamination of the skin after contact with items releasing radionuclides. Protection against that risk consists in ensuring the containment of those radionuclides within envelopes that need to be maintained clean externally. The waste is therefore handled under the non-dispersible form of a "package";*
- *any internal contamination resulting from the inhalation of radionuclides in gaseous or airborne form. Protection against that risk involves the same precautions as for external contamination, which is to ensure the containment of radionuclides within sealed enclosures and to filter aerosols likely to transport radionuclides, and*
- *any internal contamination resulting from the ingestion of radionuclides contained in drinking water or food originating from air- or water-contaminated crops. It is*

against such type of risk that it is essential to design efficient engineered barriers.

Hence, the role of the disposal facility for radioactive waste is to protect human beings (workers in the facility and/or any individual who may be concerned by the different forms of contamination listed below) against the radiation hazards of the waste. Such protection is compulsory over diffrente life phases of the centre de l'Aube, consistent with the radioactive half-life of the radionuclides contained in the waste. In the case of the Aube centre, majority of radionuclides are short-lived (around 31 years or less) and require protection for a few hundreds of years (in the order of 300 years). In addition due to the inherent nature of the waste, it is also necessary to protect human beings against the toxic chemicals which may be associated with the waste (non possible to be separated) or ultimately with their containment.

The life of the repository and consequently the safety analysis is therefore divided into the following phases:

- *Operations (and we are looking at 50-70 years starting in 1992),*
- *Monitoring phase lasting 300 years at the most, during which the site is supposed to be monitored and protected,*
- *Post monitoring (in that case human intrusion has to be considered) based on passive safety.*

2. Description of the site, the environment, the facilities and their operations :

This section aims to present the different operations involved into the facility (conditioning, storage, disposal, handling ..), the knowledge of the relevant components of the disposal including technical and organisational description. Lesson learnt from monitoring and past events that occurred in the Centre are also presented and are an important part as they help in building confidence into the safety case and therefore the safety analysis.

3. Safety analysis

This part starts by an explanation at first the methodology that have be utilised and its consistency with the other practices (including international practices) .

The safety analysis describes the potential pathways (air transfer and water transfer) . As an example, for air transfer in the post monitoring phase then the document describes the system at that stage, the models used for describing this transfer by air and then the results of the calculations for the 3 important scenarios that are : a road being constructed going through the site, a house being built on the site and the possible use, by inhabitants (and children), of earth from the site.

Regarding the Safety analysis related to transfer by water, it covers the following:

- *The transfer paths both in the monitoring and post monitoring phases*
- *The general set of hypothesis for the calculations associated to the normal evolution scenario :total radiological & toxic inventory, characteristics of the vaults, of the geology*
- *Detailed description of the radionuclide transfer model*
- *Result of the quantitative evaluation of the normal evolution scenario*
- *Sensitivity studies related to the uncertainties that have been established:*
  - *study concerning the total inventory,*

- *concerning the vault characteristics,*
- *concerning the transfer parameters both in the water table and in the biosphere,*
- *concerning the level of saturation of the host rock,*
- *concerning the mode of decay of the concrete the vaults are made of.*

- *Quantitative evaluation of alternate scenarios*
- *Toxic chemical evaluation*

Appendix C – Structure of ESC documentation, Spain

Spanish LILW Repository "El Cabril" – Structure

The "El Cabril" repository project takes, even from the beginning of the project, the French "Centre de L'Aube" repository as "reference facility". Consequently, contents of the equivalent to the ESC documentation described for "Centre de L'Aube" in Appendix B are broadly similar to "El Cabril", although some differences can be highlighted as follows:

- It does not include any risk evaluation other than radiological
- Regarding human intrusion, "residential", "road construction" and "agricultural" scenarios have been evaluated. In the agricultural scenario, just the feature of crops grown in contaminated soils has been considered, i.e. water ingestion or water irrigation sub-scenarios have been not considered
- Time of evaluation in human intrusion scenarios has been 500 years for "agricultural" scenario and 300 years for others

Results of these human intrusion scenarios constitute a solid base to achieve the waste acceptance radiological criteria.

Regarding the safety analysis related to transfer by water, it covers the following:

- The transfer paths both in the institutional control and post closure periods
- The general set of hypothesis for the calculations associated to the normal evolution scenario: Reference inventory, characteristics of vaults, of biosphere and geosphere.
- Detailed description of the radionuclide transfer model
- Result of the quantitative evaluation of the normal evolution scenario
- Sensitivity studies related to the uncertainties that have been established:
    - concerning the models: vault and packages characteristics, groundwater pathways through geosphere, transport mechanisms
    - concerning the transfer parameters: geosphere parameters, water infiltrated into repository
- Quantitative evaluation of alternative evolution scenarios:
    - The first alternative scenario assumes a partial cover failure
    - The second alternative scenario implies activity release by water due to an unusual rise of water table

Appendix D – Use of safety functions in the assessment for SFR

The main purpose of the safety assessment for SFR was to show whether the final repository could be considered to be radiologically safe in the long term. This was done by comparing estimates of radiation doses from calculated releases of radionuclides from the repository with regulatory criteria. In a long-term perspective, the primary safety function of SFR is to retard the migration of nuclides from the waste. This gives most radionuclides time to decay before they risk reaching the biosphere. An important purpose of the present safety assessment is to show that this retardation is sufficient to ensure safety under many different conditions for a long time.

It was important to be able to support all claims and assumptions in the assessment with scientific and technical arguments in order to lend credibility to the calculated results. Demonstrating understanding of the final repository system and its evolution is an important part of every safety assessment.

The repository system – broadly defined as the deposited nuclear waste, the waste containers, the engineered barriers, the host rock and the biosphere surrounding the repository – will change with time. The future state of the system will depend on the following:

- the initial state of the system,
- a number of thermal, hydraulic, mechanical and chemical processes that act internally in the repository system over time (internal processes),
- outside forces acting on the system (external processes).

Internal processes include, for example, groundwater movements and chemical processes that affect engineered barriers. External processes include future climate and climate-related processes, for example glaciation and land uplift, or the current process of global warming. Future human interventions could also affect the repository.

The initial state, the internal and external processes and the ways in which these factors together determine the evolution of the repository can never be fully described or understood. Uncertainties of various kinds are therefore associated with all aspects of the repository's evolution and thereby with the safety assessment. How these uncertainties are managed is therefore of central importance in all safety assessments.

A nine-step method based on the method developed for the SR-Can assessment was used in the assessment. An overview of the method is presented in Figure 4 below.

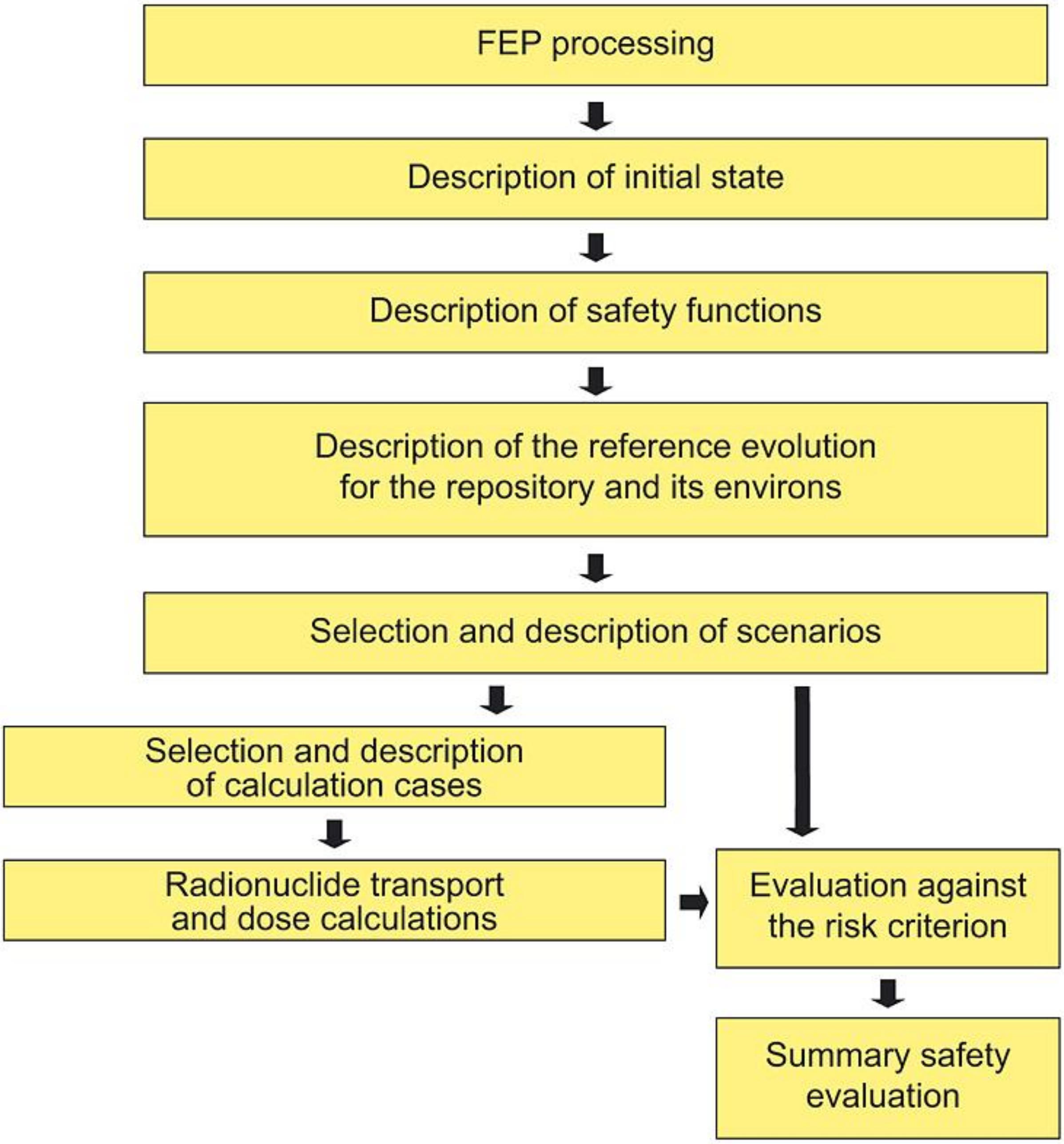

Figure 4: *Overview of the nine steps in the method used in the SFR safety assessment.*

The initial step in a safety assessment is to identify all the factors that are important for the evolution of the repository and that should be studied in order to gain a good understanding of the evolution and safety of the repository. This is done in a screening of all features, events and processes (FEPs) that are of importance for the evolution of the repository.

The initial state of the system is described based on the state of the repository, the rock and the biosphere at the time of closure, (for SFR in the year 2040), and comprises the point of departure for the further analyses. The description of the initial state is based on the technical design of the repository and present-day knowledge of conditions in the repository and its environs.

A safety function is a property by means of which a repository component, such as a barrier, contributes to the long-term safety of SFR. There are two overall safety principles for SFR – limited quantity of radioactivity in the waste and retardation of radionuclide transport.

The overall safety principles were broken down and described as a number of specified safety functions. An example is engineered barriers, which contribute to restricting the water flow through the waste and thereby the transport of solutes from the repository. The corresponding safety function is then the ability to restrict advective transport. A safety performance indicator is a measurable or calculable quantity by means of which a safety function can be evaluated. In the example with engineered barriers and their ability to restrict advective transport, hydraulic conductivity is a suitable quantity for determining whether this safety function is maintained.

The fact that a safety function cannot be fully maintained does not necessarily mean that the safety of the repository is jeopardized, but rather that more in-depth analyses and data are needed to evaluate safety. On the other hand, the safety of the repository is not guaranteed even if all safety functions are maintained. Quantitative calculations are required to ensure, for example, the risk criterion is fulfilled.

Safety functions and indicators are tools for analyzing the future performance of a repository and for arriving at an extensive set of scenarios. But all scenarios do not necessarily have to undergo extensive analysis with transport and dose calculations. Safety functions and safety performance indicators for SFR was identified and defined at expert group meetings

When all features, events and processes of importance for the evolution of the repository have been identified, they are studied. The results of these studies were documented in a series of background reports. Based on the overall picture provided by the information in these background reports, a reference evolution was described for the repository. The reference evolution is a reasonable example of the repository's future evolution, and the relevant time horizon is 100,000 years.

The description of the reference evolution has been divided into three time periods:

- The first 1,000 years after closure, i.e. the period up until 3,000 AD.
- The period from 3,000 AD to 20,000 AD.
- The period from 20,000 AD until around 100,000 AD.

For each period, a description was given of the evolution of the repository and its environs and the status of the safety functions are evaluated. In order to structure the descriptions of the evolution in the repository, they were divided into four categories: thermal, mechanical, hydrogeological and chemical (TMHC).

A set of scenarios was defined, described and analyzed. Uncertainties in the future evolution of the repository as it is described in the reference evolution were managed by also studying alternative repository evolutions in accordance with applicable regulations. The basis for this analysis was the repository's reference evolution, which constitutes the main scenario. A set of scenarios were based on the safety functions. Each function corresponds to an alternative repository evolution, and possible courses of events that could lead to loss of the function are studied. This was done by studying, based on the FEP analysis, what factors could cause a loss of the function in question. The purpose was to find evolutions that are less favourable for the function than that described in the main scenario. Firstly, the possibility that there are additional uncertainties that were not addressed in the reference evolution was examined for the phenomena that were studied in that evolution, and secondly, the question of whether there are relevant phenomena for the function that were not included in the reference evolution was studied.

If the possibility of such a scenario occurring cannot be ruled out, it is classified as a less probable scenario and an attempt is made to estimate its probability. If no reasonable causes of a scenario can be identified, it is classified as a residual scenario.

The main scenario and the less probable scenarios are included in the summation of risk for the repository. Residual scenarios may be analysed, but their consequences are not included in the summation of risk.

In accordance with the regulatory requirements, a set of scenarios where human intrusion is studied is also selected. Also according to the regulations and general recommendations, no probability estimates are made for these scenarios and they are not included in the summation of risk for the repository. In addition, a number of hypothetical scenarios intended to shed light on the importance of barriers and barrier functions are selected, in accordance with the regulations. These hypothetical cases are not included in the summation of risk either.

To judge the consequences of the scenarios that are relevant according to the preceding paragraph, they had to be described with the aid of calculation cases and analyzed with the aid of mathematical models.

The calculation cases were divided into three groups corresponding to the three scenario groups: main scenario, less probable scenarios and residual scenarios.

Radionuclide transport from the repository (the near field) through the rock (the geosphere) to the biosphere and the dose which man can obtain from exposure to radionuclides, was calculated quantitatively. An uncertainty assessment was performed for certain input data that have been found in previous safety assessments to be of essential importance for the results. This uncertainty assessment provided a parameter interval that was used for probabilistic calculations. Uncertainty and sensitivity analyses were carried out for both the radionuclide transport and the dose calculations.

The risk was calculated by multiplying the probability of the scenarios by the calculated dose consequence. The calculated risk was compared with the risk criterion.

The assessment of the long-term safety of SFR was based on an integrated evaluation of both quantitative and qualitative results. Calculated doses and risk estimates were compared with criteria stipulated in the regulations. The long-term protective capability of the different barriers was discussed on the basis of results of the analysis of repository evolution. The reliability of different analyses and assessments was discussed and evaluated.

Appendix E – Spanish Safety Case Approach

The Spanish safety case analysis examines situations relating to conditions anticipated both now and in the future including events associated with the normal evolution of the disposal facility and less probable accidental and intrusion events.

The safety assessment performed has a dual objective: a) the derivation of waste activity acceptance criteria for disposal; b) the demonstration that an acceptable level of protection of human health and the environment will be achieved both now and in the future.

To generate scenarios for both phases considered, systematic methods purporting to be transparent, justified and documented have been applied.

Scenarios related to the operational phase are developed using a methodology based on the preparation of an operational activities list and on the identification of the possible events associated with each activity during the progress of the radioactive wastes from reception to final disposal, taking into account the design of the facility and its operating methods and instructions.

Scenarios related to the post-operational phase are developed applying an approach based on the preparation of a list of factors (features, events and process), identifying the relevant factors for disposal performance.

The scenario generation process results in the identification of important scenarios to accomplish the safety assessment objectives. The scenarios are classified in two groups: those relevant to the assessment of specific activity waste limits and those that are relevant to the demonstration an acceptable level of protection of human health and the environment. This does not mean that the scenarios are different for each group; one or more scenarios may be relevant for both groups.

The analysis carried out to support the proposed activity limit is based on calculations for each single radionuclide. The scenario development methodology and subsequent formulation and implementation of model processes ensure that the analysis is coherent.

Radiological impact

Several scenarios have been studied with regard to the potential migration of radionuclides through water flow. The impact of the disposal was assessed for normal and altered situations, and in both cases according to highly pessimistic assumptions regarding the behaviour of natural and artificial barriers. It is assumed that a group would live close to the facility.

The calculations take into account the migration of radionuclides through the bottom layer and the terrain. Normal evolution scenario and other altered scenarios have been studied, for instance, the total cover failure scenario or rising of ground water level.

Air transfer scenarios include scenarios relating to the operating phase of the facility, accidental fire and disposal unit drop scenarios, and to long-term inadvertent human intrusion scenarios, such as road construction scenario and agriculture scenario.

The road construction scenario involves the excavation in depth of the whole disposal for the construction of a large public work (road) after surveillance period (300 years). For the evaluation of this scenario it is assumed that the excavated radioactive material is distributed around the excavation. Likewise, there are particles in air coming from the mixture soil-waste which will produce an increment of the dose per inhalation.

The intruder-agriculture scenario involves an intruder who is assumed to occupy a dwelling located on the disposal facility and ingest food grown in contaminated soil by the decomposed waste excavated and distributed around the building during construction activities. It is considered that this scenario occurs at 500 years after closure of disposal.

In all analysed scenarios the radiological impact is lower than the value limits established in the design.

Also in order to protect the workers, scenarios considering external radiological exposure and the potential impact under accident conditions have been analysed. These types of scenarios are also considered to derive waste activity limits.

Waste acceptance criteria (WAC)

In order to determine the maximum admissible activity content of a waste disposal unit, scenarios relating to external radiological exposure during normal operational conditions, accidental operational conditions and long-term inadvertent human intrusion situations have been considered.

The specific activity limit for a nuclide is derived from the calculated dose for unit specific activity, thus providing the maximum specific activity which leads to the reference dose limit, applying the direct relationship between dose and activity for each radionuclide.

The activities assessed for each scenario have to be compared to determine the limiting scenario for each radionuclide; i.e., the scenario potentially leading to the most restrictive activity limit. An adequate correspondence between scenarios and elementary volumes of the facility should be taken into account in order to obtain the average specific activity limit of a waste disposal unit and for the whole repository.

The acceptability for disposal of a disposal unit in the cells or the whole repository depends on the fulfilment of the acceptability index, defined as:

$$IA = \sum \frac{A_{Mi}}{A_{M\max i}}$$

where:

A_{Mi}: is the specific activity of radionuclide i (Bq/g) in the mass waste.

A_{Mmaxi}: is the specific activity limit for radionuclide i (Bq/g) in a waste assuming radionuclide i is the only radionuclide in the waste.

In order to guarantee the homogeneity of the distribution of the activity in the repository, it is considered that the degree of heterogeneity is limited to 10 between the whole repository and the disposal unit. Thus, the acceptability index for the repository must not exceed 1 and for the disposal unit must not exceed 10.

$$IA_{Repository} \leq 1$$

$$IA_{Disposal\ unit} \leq 10$$

Radiological capacity

The radiological capacity for a radionuclide is its Admissible Maximum Activity (AMA) if there is not a previous limitation (to store activity) because of the specific activity limitation criteria, i.e. WAC. When the limitation of specific activity operates, it is not necessary to define the radiological capacity for such a radionuclide.

The radiological impact in the long term by the water pathway will be acceptable whenever the stored activities of radionuclides were lower than its radiological capacity.

To determine the radiological capacity, for each radionuclide in a repository, it is necessary to assess the limitation of activity which would derive from the WAC, specific activity by mass of stored wastes, and then to compare this value with the AMA.

Finally, the control of the acceptability index at the time any disposal unit is accepted, and the verification of the radiological capacity, ensures that the radiological impact will remain below the value limits established in the design.

SKB International Consultants AB
Box 1091, SE-101 39 Stockholm, Sweden
Phone +46 8 459 8400