Independent Peer Review of:
LLWR's Approach to the 2011 Environmental Safety Case and Methodology for the Assessment of Wells

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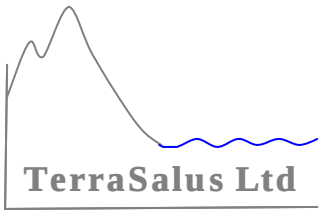

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Executive Summary

The Low-Level Waste Repository has been the principal facility in the UK for the disposal of Low-Level Radioactive Waste (LLW) since 1959. The site is owned by the Nuclear Decommissioning Authority (NDA) and is operated on behalf of the NDA by a Site Licence Company (SLC), LLWR Limited (LLWR).

Disposals at the LLWR are authorised by the Environment Agency (EA) under the Radioactive Substances Act 1993. Schedule 9 Requirement 6 of the LLWR Authorisation requires that *'Five years from* [the] *effective date of this Authorisation and at such intervals thereafter as the Agency specifies in writing, the operator* [shall] *update the Environmental Safety Case(s) for the site covering the period up to withdrawal of control and thereafter'*. The next update of the Environmental Safety Case (ESC) is due on 1 May 2011.

This report records the comments of an independent peer review panel that was asked by the SLC to review two documents that describe LLWR's proposed approach to the 2011 ESC.

The peer review panel considers that LLWR has set out its approach in an intelligently structured and highly commendable report, which makes a strong statement of intent for the production of a comprehensive environmental safety case, and that clearly establishes the relationships between decisions on the realities of site management and operation, and the evolving environmental safety case.

At a high level, LLWR's description of the role and nature of the ESC is appropriate, and the proposed approach for the 2011 ESC encompasses the breadth of issues that will need to be addressed. However, the approach needs to be updated to reflect recently published regulatory Guidance and to fully incorporate a thorough and on-going process of peer review. In addition to these two key points, we have made a considerable number of comments on aspects where the approach may need to be revised, clarified and/or specified in greater detail.

In particular, in 2008 the peer review panel highlighted the short period available for development of the 2011 ESC. LLWR's current approach includes a very significant programme of studies leading to the 2011 ESC. Many of these studies potentially interact, and LLWR has proposed a data freeze in April 2010. It would be useful for LLWR to present the programme for these studies, including a timeline or Gantt chart that illustrates how the results will feed into delivery of the ESC by May 2011.

LLWR could also have provided more detailed information on how it proposes to address two other key peer review comments from 2008 relating to (i) strengthening links between the ESC, facility design and facility operation, and (ii) assessing risks from coastal erosion of the facility. LLWR's programme should be designed so that it is subjected to peer review as a routine part of the work process. Enough time needs to be set aside for peer review and for the safety case development team to be able to consider and respond to peer review comments.

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1 Introduction

1. The Low-Level Waste Repository (LLWR) has been the principal facility in the UK for the disposal of Low-Level Radioactive Waste (LLW) since 1959. The site is owned by the Nuclear Decommissioning Authority (NDA) and is operated on behalf of the NDA by a Site Licence Company (SLC). United Kingdom Nuclear Waste Management (UKNWM) Ltd. holds a contract from the NDA for the management and operation of the LLWR, and shares in the SLC were transferred to UKNWM Ltd. on 1st April 2008.

2. Disposals at the LLWR are authorised by the Environment Agency (EA) under the Radioactive Substances Act 1993. The LLWR receives wastes from a range of consignors including nuclear power stations, fuel cycle facilities, defence establishments, general industry, isotope manufacturing sites, hospitals, universities and from the clean-up of historically contaminated sites.

3. In 2002, the previous operator of the site, British Nuclear Fuels plc (BNFL), provided the EA with environmental safety cases for the facility (BNFL, 2002a, b). These safety cases were reviewed by the EA (Environment Agency 2005) and, following a period of consultation, a new Authorisation was granted (Environment Agency, 2006). The Authorisation includes several schedules, of which Schedule 9 is a list of improvements and additional information that the operator must supply.

4. Schedule 9 Requirement 6 of the LLWR Authorisation requires that *'Five years from* [the] *effective date of this Authorisation and at such intervals thereafter as the Agency specifies in writing, the operator* [shall] *update the Environmental Safety Case(s) for the site covering the period up to withdrawal of control and thereafter'*. The next update of the Environmental Safety Case (ESC) is due on 1 May 2011.

5. The SLC has initiated a programme of work – the ESC Project – to address the Requirements of Schedule 9, and is subjecting the work of the programme to independent peer review.

1.1 Peer Review

6. Peer review is 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 directly involved in the programme or aspect of work. The EA has indicated that it expects peer review to be used as one means of building confidence in the environmental safety

cases, and has stated that such peer reviews should be fully documented and provided to the EA (Environment Agency 2005; Environment Agency *et al*. 2009).

7. In its review of the 2002 safety cases (Environment Agency, 2005a), the EA acknowledged that the previous operator, BNFL, had commissioned an independent peer review (Hill and Irvine 2002), but considered that this had been done at too a late stage in the development of the safety cases and that, as a result, not all of the peer review comments had been addressed adequately when the safety cases were submitted. The EA, therefore, emphasised in its review the need for peer review to begin at an early stage in the project and to be an active and continuous part of work leading to revision of the safety case.

8. Recognising the need for peer review, the SLC has established and is maintaining a new independent peer review panel. The panel was first assembled in 2007 (see Bennett *et al.*, 2008). The panel has been reconstituted in 2009 with essentially the same objectives, but slightly different membership (Appendix 1). The new peer review panel members were selected by the SLC during 2008 and early 2009, and have considerable expertise and experience in radioactive and conventional waste management, and in environmental management more generally. Importantly, the peer review panel members are completely independent of the team working on behalf of the SLC to develop responses to the Schedule 9 Requirements, including the environmental safety case.

9. The overall objectives of the peer review panel are to:

   - Provide timely independent review of key technical approaches, arguments, designs, assessments and safety cases being developed by the SLC's project team.

   - Work in such a way that it can be demonstrated to relevant stakeholders that a rigorous and effective process of review and scrutiny is operating.

10. The peer review work is focusing on issues that are the most important to the risks associated with the LLWR, and is assessing and commenting on whether the work of the ESC Project is consistent with policy, regulation and best practice, so as to identify areas where improvements may be made.

1.2 This Report

11. This Interim Review Paper has been produced in response to a request made in February 2009 by LLWR for a peer review of the following documents:

- LLWR (2008) LLWR Environmental Safety Case: Technical Approach to the 2011 Environmental Safety Case, LLWR/ESC/R(08)10010, Issue 1, 28 November 2008.

- Serco (2009) Methodology for the Assessment of Wells – Report to LLW Repository Ltd., SERCO/TAS/002888/001 Issue 1, January 2009.

12. The peer review panel has reviewed the documents with the objectives of identifying:

    - Whether LLWR's proposed approach to the 2011 ESC has the potential to lead to an environmental safety case that is consistent with the Environment Agency's Guidance on Requirements for Authorisation (Environment Agency *et al*. 2009).

    - Possible inconsistencies and gaps in LLWR's proposed approach.

    - Areas on which further, more detailed information will be needed from LLWR and which can be taken forward as the peer review progresses during the period until the next environmental safety case.

13. In keeping with best practice in independent reviews (e.g., NEA 2005a), neither the SLC nor its contractors have commented on the technical content of this report – the SLC has, however, had the opportunity to check for factual accuracy. The peer review panel has made its best effort to ensure that all information is accurate.

14. The report is structured as follows:

    - Section 2 gives a brief description of the peer review approach that is being followed.

    - Section 3 summarises the comments of the peer review panel on the two documents. This section is structured according to the structure of LLWR's ESC approach document (LLWR 2008). More detailed comments on Serco (2009) are provided as appropriate in Section 3.5.6, which deals with the assessment of water abstraction wells.

    - Section 4 presents conclusions from the peer review.

    - Section 5 provides a list of references.

    - Appendix 1 comprises brief CVs for the peer review panel.

2 Peer Review Approach

15. At the beginning of the peer review in 2007 it was agreed that:

- The peer review would be objective and undertaken to the highest standards of probity, based on the principles of good science and engineering. The approach to the review would be consistent with relevant international guidance on reviews of radioactive waste disposal programmes (NEA 2005a, b; IAEA 2007).

- The review panel would be strictly independent of, and separate from, those involved in the work of the ESC Project.

- Formal methods would be used to ensure that a clear and traceable record is made of review comments and responses received.

- The review would be conducted so that, as far as possible, the output from the review panel would represent a consensus view rather than a set of individual opinions. If there were significant un-resolvable differences of view amongst the review panel, then the different views would be recorded.

- The peer review would be conducted in a practical way that fits in with LLWR's schedule and enables it to respond and react appropriately to peer review comments. Peer review activities would, thus, comprise two principal activities: document reviews and peer review meetings.

- Key documents would be identified for review. The peer review panel would not seek to review all of the many deliverables that are being produced, but would, instead, identify key areas for review and select individual documents or related sets of documents for review. In addition, it was envisaged that the SLC would request peer reviews of particular documents.

- Documents would be reviewed by at least two members of the peer review panel. Results from document reviews would be recorded in Interim Review Papers (such as this report). These Interim Review Papers would be provided to the SLC's project team as they were produced, thus enabling early sight of the review comments and a chance to react as appropriate. The Interim Review Papers would form the basis for the development of formal Review Reports.

- Formal Review Reports would be produced at key times in the schedule and would be provided to the regulators, together with the SLC's responses to the peer review findings.

3 Peer Review Comments

3.1 General Comments

16. The peer review team considers that LLWR (2008) is an intelligently structured and highly commendable report, which makes a strong statement of intent for the production of a comprehensive environmental safety case (ESC). LLWR (2008) lays out the approach to developing the 2011 ESC in a logical manner that is easy to follow. In particular, the relationship between decisions on the realities of site management and operation, and the evolving environmental safety case (ESC) is established well. LLWR (2008) provides a much better balance of information on risk assessment, risk management and the approach to management of the LLWR than did earlier safety assessments (e.g., BNFL 2002).

17. LLWR (2008) was developed at a time when the Environment Agencies were developing new Guidance on the Requirements for Authorisation of near-surface radioactive waste disposal facilities. LLWR (2008) states in several places (e.g., page 6) that *'A key objective of the 2011 ESC will be to demonstrate compliance with the Requirements in the environment agencies' new draft guidance for near surface disposal facilities'*. However, the Environment Agencies' finalised Guidance was published in February 2009, and it is essential that the 2011 ESC demonstrates compliance with this, rather than with the draft Guidance.

18. We strongly recommend, therefore, that the 2011 ESC should be developed to comply with the published final version of the near-surface Guidance on Requirements for Authorisation (NS-GRA) (Environment Agency *et al*. 2009), and that LLWR (2008) should be updated to reflect the content and language of the NS-GRA. LLWR (2008) currently uses several terms (e.g., reassurance monitoring of performance, constrained optimisation, environmental performance) that are not clearly defined or used in the NS-GRA.

19. LLWR (2008) is written on the assumption that the reader has an intimate knowledge of the design of the facility, its past operational history and its past Authorisation history. In consequence, highly project-specific jargon is used to explain some key arguments. The audience for LLWR (2008) may be quite limited and so this may be an acceptable approach. However, the absence of illustrations was noticeable and a plan view of the facility in its regional setting and a simple cross-section showing key features related to design and management options or modelling proposals would make it much easier to follow the relevant arguments.

20. Although LLWR (2008) briefly introduces the NDA, the SLC and UKNWM Limited it would be advisable to provide more detail on the relevant responsibilities of these bodies at an early stage in the report.

21. The report is generally well written, but does contain a surprising number of grammatical / typographic errors. It is recommended that the next version of the document should be proof read more carefully prior to approval and release. Also, it is recommended that a paragraph numbering system is introduced to facilitate review.

22. Comments on Serco (2009) are provided in Section 3.5.6.

3.2 The Environmental Safety Case

23. The peer review team considers that, at a high level, LLWR's description of the role and nature of the ESC is appropriate. We agree that the ESC should be used as a tool for guiding the development, operation and closure of the LLWR, and that the ESC should be developed in an iterative manner. We also support the view, as implied in Figure 2.2 of LLWR (2008), that the ESC incorporates or encompasses the LLWR's management approach, the Site Management Plan, and the safety assessments.

24. Section 2.3 of (LLWR 2008, page 14) proposes that the 2011 ESC will be presented in three main elements relating to:

- System description and understanding.
- Options and Site Management Plan.
- Assessment.

25. We suggest that LLWR should consider a fourth element that would address management systems, safety culture and engagement with stakeholders. Also, it is not completely clear whether the assessment to be presented in the 2011 ESC will be only of the option preferred in the Site Management Plan, or whether results from assessments of different options will be presented to justify the choice of preferred option.

26. We consider that the fourteen *'safety arguments'* identified in Section 2.5 of LLWR (2008) would be largely appropriate (assuming that results from the on-going programme of ESC development work do provide positive support for them), but we note that in detail it is not clear:

- How best practice will be defined or identified (safety argument 2).
- How reliability of site understanding will be demonstrated (safety argument 6).
- That isolation can be regarded as a long-term safety function for a near-surface disposal facility, especially one that contains long-lived wastes and is expected to be eroded into the sea (safety argument 8).

27. We encourage the presentation of appropriate information on costs and other economic and societal factors in the 2011 ESC to support statements that LLWR has done all it reasonably can to keep impacts as low as reasonable achievable (ALARA) (safety argument 10).

28. In addition to conducting the safety case development work under a sound management framework (LLWR 2008, page 14), LLWR should plan its work components so that they may be subjected to peer review as a routine part of the work process (see NS-GRA paragraph 6.2.40). Enough time needs to be set aside for peer review and for the safety case development team to be able to consider and respond to peer review comments.

29. We also consider that the peer review panel should be explicitly identified in LLWR's list of the important stakeholders in the ESC (Section 2.6 of LLWR 2008). Related to this, it would have been helpful if the ESC approach report (LLWR 2008) had included a mapping between the various pieces of work planned for the period to the 2011 ESC and the previous comments and suggestions of the peer review panel.

30. We consider that LLWR's description of its environmental safety culture and management system (Section 2.7 of LLWR 2008) is impressive and commendable, but note that the report does not explain what evidence LLWR intends to present in the 2011 ESC to show that its management and quality systems are adequate and have been appropriately applied.

31. It would be useful to consider specific actions to ensure that all work performed for the ESC complies with the relevant LLWR policies. For example, audits of uncertainty treatment, configuration control and verification of numerical codes and input data could be explicitly mentioned (perhaps associated with the planned data freeze). Similarly the NS-GRA (Environment Agency *et al*. 2009) requires a detailed *'audit-trail'* identifying changes to the ESC and documentation. It is likely that such actions are already planned, but further details would bring greater confidence in their application.

32. LLWR (2008) does not explicitly discuss the information management requirements of the 2011 ESC, but the consistent use of a wide range of data, interpretations and models should be supported by appropriate information management and quality systems.

33. Given the long time periods associated with the operation, closure and control of the LLWR, particular thought needs to be given to the sections in the NS-GRA on resources and competencies (paragraphs 6.2.13-6.2.15) and on succession planning and knowledge management (paragraph 6.2.20).

3.3 System Description and Understanding

3.3.1 Wastes and Inventory

34. Section 3.1 of LLWR (2008) discusses the waste inventory. The peer review panel considers that LLWR has identified an appropriate strategy for reducing uncertainties associated with the inventory. In particular, we support LLWR's proposal to assess uncertainties associated with using waste *'fingerprints'* to supplement information from historical disposal records. Page 24 of LLWR (2008) states that, *'The inventory used in the 2011 ESC will be based on certain stated assumptions concerning the use of the different available waste treatment and disposal routes'*. It is not clear from this statement if the assessment results that will be presented in the 2011 ESC will address the uncertainties in the waste inventory, particularly those related to possible alternative assumptions regarding waste management and treatment.

3.3.2 Engineered System

35. Section 3.2 of LLWR (2008) addresses the engineered system:

- The text on page 25 discusses the importance of biogeochemical processes during waste degradation within the disposal facility, but is not particularly clear. For example, the reference to the need for *'more realistic models'* (plural) leaves the reader unclear whether DRINK qualifies as such or whether new models are to be developed. It would be helpful if the hierarchy of models envisaged for use in the 2011 ESC could be described more clearly and perhaps illustrated using an Assessment Model Flowchart.

- The text on page 25 suggests that *'For the 2011 ESC, we envisage using coupled models of chemical reaction and transport to examine* variations *in Eh and pH within components of the facility*'. It is not clear from this statement if the models proposed for use in the 2011 ESC will include the effects of microbial activity.

- The text on page 26 correctly acknowledges that localised fast water flows through the facility could have a range of potential effects. One effect not mentioned is the possibility that with fast water flows, radionuclide retardation may be reduced because there may not be time for equilibration between dissolved contaminants and fracture surfaces.

36. Notwithstanding these detailed comments, the peer review panel considers that LLWR's intent to focus on the most significant radionuclides, chemotoxic species and waste streams is appropriate. It would be valuable, however, to provide a brief explanation of how these key species

and waste streams are identified and, in particular, to note whether there is a documented screening process in place.

37. There are potentially significant uncertainties associated with variable partially-saturated hydrological conditions in the near-field and we support LLWR's intention to consider these. We note, however, that this is a difficult technical area and we have some doubts that there will be sufficient time before the 2011 ESC to develop and fully implement an approach to modelling partially-saturated conditions..

38. We note LLWR's suggestion (LLWR 2008 page 26) that expert elicitation may be used to quantify time-dependent water flows through the engineered barriers. This could be an appropriate approach, but its success would depend on how well the elicitation process was conducted. Given previous peer review comments on this topic (Bennett *et al*. 2008), we would suggest that if expert elicitation is taken forward, then more time should be allocated to the process so that a fully rounded and consistent set of parameter values can be developed. We would also suggest that it might be appropriate for one of the peer review panel to observe the elicitation process.

3.3.3 Geology and Hydrogeology

39. Section 3.3 of LLWR (2008) addresses the geology and hydrogeology of the site. It is good to see that LLWR's intention is to address previous review comments (e.g., Environment Agency 2005; Bennett *et al*. 2008). LLWR is planning to fill some gaps in geological knowledge by drilling new boreholes in the area between the facility and the coast. These new boreholes would also be used for *'long-term hydrological modelling'* (LLWR 2008). Details of the monitoring activities are not given, but we would suggest that LLWR could also use these new boreholes to monitor for key radionuclides and other contaminants in groundwaters.

40. Page 28 of LLWR (2008) states '*Since 2002, a revised geological interpretation has been put forward with the aim of providing a more suitable basis for subsequent hydrogeological interpretation and modelling. The revised geological interpretation has been used to underpin the engineering design, using a grouped, bulk lithofacies approach... However, although the approach does allow the representation of the drift deposits as a series of lithofacies packages, and the development of a 3-D geological model of the site, each unit is defined on the basis of a broad collection of lithologies. For example, lithofacies package LP2 is described as alternating tills, sands and gravels, so there may be a significant variation in physical properties within the lithofacies package. The validity of this approach is reliant on the assumption that sensible bulk properties can be assigned to each lithofacies package, despite the heterogeneous characteristics of each package*'. It might be interpreted that the second paragraph on page 28 explains how the rather

far-reaching assumption underpinning the use of the lithofacies package approach can be tested. If this is the case it should be made clearer than at present. The range of length scales for correlations that may be required to cover the various relevant assessment cases could usefully be mentioned.

41. It is not clear from the discussion in the report, that a robust description of the important hydraulic features and of the heterogeneity within different geological units (facies or stratigraphic) has been developed. Some work has been done to address the inter-relationship between geological and hydrogeological descriptions of the site. In particular work has been commissioned to:

- Review alternative conceptual models.
- Determine length scales of barrier features.
- Consider the application of stochastic models.

42. It would be encouraging to see specific work relating detailed geological descriptions to hydraulically significant features (barriers and transmissive features). It might also be useful to consider the conceptualisation and definition of hydrofacies (Eaton 2006) for the subsurface volume of interest.

43. In particular, any prediction of contaminant transport (for example relating to the proposed model of abstraction from water wells – see Section 3.5.6) is likely to require addressing the internal heterogeneity of some of the current lithostratigraphic/lithofacies units. See De Marsily *et al.* (2006) for a discussion of situations where addressing spatial heterogeneity is vital.

3.3.4 Environmental Setting

44. Section 3.4 of LLWR (2008) discusses climate and landform, and local resource use and human habits around the LLWR relevant to assessing the potential doses and risks associated with the facility.

- The text on page 30 indicates that LLWR is considering whether it may be possible to refine estimates of the timescales for site destruction by coastal erosion by using numerical models of local coastal processes. We agree that it is sensible to continue to update estimates of the likely timing of coastal erosion, but suggest that this should be done by considering a wide range of information, including recent developments in climate change science some of which (e.g., Brahic 2008; Carlson *et al*. 2008) suggest faster rates of sea level rise than those given in the 2007 IPCC impacts (Nichols 2007), and not only through local-scale modelling of coastal processes. The issue of concern would be if there was a possibility

that the facility could be inundated or begin to erode much sooner than previously estimated.

- Page 31 notes that, with the exception of improving the basis for estimating the likelihood of future agricultural or domestic wells (see Section 3.5.6), LLWR does not consider that additional site characterisation is needed in order to assess doses to currently exposed groups or doses and risks to potentially exposed groups (PEGs) in the future. The peer review panel considers that there might be a need for additional information gathering on human habits in a lagoon setting.

3.4 Options Assessment and Site Management Plan

45. Section 4.1 of LLWR (2008) discusses the relationship between the LLWR ESC and the NDA National LLW Strategy. The first paragraph of the section leaves the impression that the national LLW strategy will determine what wastes should be sent to LLWR, without reference to the ESC; moreover the final sentence clearly prejudges the case on overall justification. This is somewhat amended in the third paragraph, but the final paragraph again reverts to suggesting that the final inventory will be determined in advance of the ESC. Particularly in the context of environmental safety culture, much more weight needs to be given to the ESC as determining what waste LLWR can accept, as opposed to the national strategy's role in determining needs. There should be a two-way flow of information between the LLWR ESC and the NDA National LLW Strategy, and we are particularly interested to see details of how information from the developing LLWR ESC is used to inform Strategy development, as this will be important in ensuring appropriate use of the LLWR. It is noted that, given the schedule for Strategy development outlined on page 33 of LLWR (2008), there is very little time in which this important process needs to take place.

46. Section 4.2 of LLWR (2008) discusses potential changes to waste treatment and packaging. The text notes that some of the alternative waste treatments under consideration tend to increase the specific activity of wastes for disposal. The text also notes that, *'Benefit is currently taken for the grout in the Vaults in assessments because of its effect on near-field chemistry and hence the release of some radionuclides from the Repository'*, but this fails to recognise that the vault wasteform (grouted ISO containers) has a potentially more important role in preventing site cap subsidence and failure, which could lead to significant water inflows. When the grouted ISO container wasteform was selected, the role of the grout in influencing near-field chemistry and radionuclide release rates was recognised but not considered to be a primary or necessary function.

47. Appropriate changes to the wastes, the waste form, or waste packaging might well be made, but all of the potential effects of such changes will

need to be fully considered through safety assessment. For example, disposal of short-lived wastes with higher specific activities might be sensible and make best use of the facility (Environment Agency 2005).

48. Section 4.3 of LLWR (2008) discusses trench remediation. The peer review panel supports LLWR's plan to conduct a more detailed analysis of selective removal of wastes from the Trenches, as this was one of the main peer review comments made in 2008 (Bennett *et al*., 2008). The approach described by LLWR (2008) appears appropriate. The analyses to be carried out should take full account of information from previous staff with operational experience of waste disposal to the Trenches.

49. Section 4.5 of LLWR (2008) discusses the pre-closure period, and mentions possible alternatives to progressive capping, including tents. The peer review panel recommends that any consideration of such temporary cover structures should also consider the type of metal roofs used at LLW disposal facilities in other countries, for example at the French facility at Centre de l'Aube, as these might be more suited to conditions in West Cumbria. Given that one of the three safety case arguments proposed for the operational period is that *'Good practice is used to limit the releases from the facility by limiting the inflows to the repository and collecting, managing and treating the leachate arising'* (text at the bottom of page 40), the peer review panel considers that LLWR's proposal to undertake an options study to *'identify the optimal strategy for interim capping, leachate control during operations, and the timing of final capping'* is appropriate. At present, water inflows to the Trenches are limited by the interim cap, and leachates from the site are managed. However, water inflows to the vaults are not currently limited or prevented.

50. The peer review panel believes that LLWR is correct to consider the strategy for institutional control of the LLWR[1] (Section 4.7 of LLWR 2008), and considers that the proposed distinction between active and passive control periods is appropriate. However:

- Reference is made on page 34 of LLWR (2008) to '*re-assurance monitoring of performance'*. It needs to be carefully considered whether this terminology promises more than can be delivered. It is recommended that for the next release of the document the wording should be bought into line with Requirement 14 in the NS-GRA, and should accurately reflect the distinction drawn in the NS-GRA between monitoring for technical reasons in support of the ESC and monitoring for public reassurance.

[1] And not '*of the NDA'* as stated in the text of LLWR (2008).

- With respect to the bullet points on page 36 of LLWR (2008):
  - Site remediation should be identified in the list.
  - In addition to the retention of records, the list should identify retention of knowledge, experience and skills.
  - The peer review panel is unclear that there is any evidence regarding the effectiveness of markers to deter future human intrusion.

51. Section 4.9 of LLWR (2008) addresses optimisation. We are generally supportive of the approach outlined, but note that the bullet point on page 37 regarding the 'baseline' is not clear. In particular, it is not clear whether all elements of the current assumed site development will be retained or whether some decommissioning and site remediation will be carried out.

3.5 Assessment Approach

3.5.1 Integration of OESC and PCESC

52. LLWR (2008) proposes to integrate the operational environmental safety case and the post-closure environmental safety case. We consider that this is a sensible change from previous practice (e.g., BNFL 2002a; b) as it should eliminate the inconsistencies that occurred previously between the two separate assessments.

53. More detailed comments on Section 5.2 of LLWR (2008) include:

- Logically, it will be necessary to monitor boreholes for the concentrations of the particular radionuclides and chemotoxic species for which trigger levels are established. It is not clear that current monitoring at the site does measure individual radionuclide concentrations.
- It is proposed that, *'For at least one case, a single assessment calculation for the groundwater pathway will be undertaken to represent the evolution of the system from initial disposal through the operational period and into the post-closure period'.* The significance of this statement is unclear. It needs to be made clear what is meant by a case in this context, and why it is possibly acceptable to consider only the one selected. Information should be given on the process for making such a selection.
- That it is not clear why models of the release of contaminants from the facility during the operational phase will be developed so as to be cautious. Logically it ought to be possible to develop more realistic models for the operational period than for the post-closure

period when uncertainties will be greater. The use of overly cautious models can sometimes lead to sub-optimal decision making (e.g., regarding facility operation).

- That with regard to the last sentence of the section, it is essential, not desirable, to **compare** (rather than calibrate) the predicted near field behaviour with current monitoring data. Such comparisons must be made in an intelligent way; monitoring data may not be representative, and inappropriate calibration of models can lead to a loss of predictive capabilities.

3.5.2 Pathways, Scenarios and FEPs

54. Section 5.3.1 of LLWR (2008) discusses pathways, scenarios and FEPs.

55. Firstly, in addition to the main routes to exposure identified on page 41 (i.e., groundwater, gas, natural disruption and human intrusion), it may also be necessary to consider direct radiation exposures during the operational phase (e.g., BNFL 2002a).

56. Secondly, from a safety case development standpoint, although the concept of pathways is an approach that has been used in safety assessments for geological disposal facilities historically, the approach has been found to be problematic since it potentially separates the consequences of processes that will in fact interact during the evolution of a disposal facility. For this reason pathway-based analysis is no longer used in any of the current safety reports for geological disposal facilities from other countries. It also becomes very difficult to discern any significant difference between a pathway and some scenarios. As an example of the problems that are likely to be caused by this approach, the effects of progressive coastal erosion and sea level rise on the groundwater system would be expected to be included in the modelling of that system, even though they may not threaten the integrity of the engineered facility itself at the start of the post Authorisation period. Conversely when a process such as inundation does disrupt the facility, the uptake of radionuclides is likely to be mediated by groundwater. Therefore, it is recommended that the concept of pathway analysis is removed from the proposed approach.

57. Section 5.3.2 of LLWR (2008) discusses the approach to identifying the scenarios to be considered in the 2011 ESC. With regard to human intrusion, LLWR's intent to use stylised representations is appropriate and in line with best practice internationally. LLWR's proposal to assess both the immediate impacts of disruptive events and the longer-term effects of natural or human disruption events on the containment performance of the damaged repository is also appropriate. However, the text states, *'The assessment of the potential for, and impacts of, disruption of the site by unplanned human activities will use information-based descriptions of*

most likely and reasonable human activities at the site, but ultimately the cases selected for analysis will be necessarily stylised representations that illustrate possible events'. In our view it may not be sufficient to consider only the '*most likely'* scenarios. Further comments on the proposed approach to the assessment of human intrusion are given in Section 3.5.10.

58. With regard to the discussion of FEPs in Section 5.3.3 of LLWR (2008), we have some sympathy with the views expressed, especially given the short time in which the 2011 ESC needs to be developed, but note that it is best practice in safety assessment to use FEP lists and FEP screening to check that the assessment models do include the relevant processes, and to justify the means of their inclusion in the models. The effectiveness of LLWR's proposals with regard to FEPs will need to be judged at a later stage.

59. One aspect not discussed in LLWR (2008) is the extent to which LLWR has maintained and is planning to maintain links to the Issue Resolution Process and Issue Resolution Forms established by the Environment Agency in its review of the 2002 PCSC. The Environment Agency's Issue Resolution Forms gave additional guidance on many of the FEPs identified in the 2002 PCSC.

3.5.3 Treatment of Uncertainty

60. LLWR's approach to the classification of uncertainties is set out in Section 5.4.2 of LLWR (2008). We support both the points made by LLWR regarding the Guidance contained in the NS-GRA on quantifiable and unquantifiable uncertainties, and LLWR's proposed scheme for classifying uncertainties, which we regard as normal good practice.

61. With regard to scenario uncertainties (Section 5.4.3 of LLWR 2008), we note that LLWR could make more explicit statements regarding its intent to use independent peer review to build confidence in its selection and description of scenarios, and thereby assist the process of seeking consensus with the EA and other stakeholders on scenario uncertainty.

62. With regard to model uncertainties (Section 5.4.4 of LLWR 2008), LLWR's distinction of uncertainties related to the conceptual model, the mathematical model, the computer model and the mathematical model is clear and appropriate. However, we note that while the use of cautious models may be appropriate for the purposes of demonstrating compliance with regulatory targets, the use of more realistic models better facilitates appropriate optimisation and decision-making. Also, we suggest that LLWR should consider including a bias audit in its approach that recognises important exclusions from the model. This could build confidence in what appears overall to be a good process and could help to ensure traceability.

63. LLWR proposes to use a mixture of deterministic and probabilistic approaches for evaluating the implications of parameter uncertainty (Section 5.4.5 of LLWR 2008). This may be appropriate, but we have some reservations regarding the use of deterministic *'point value'* calculations. Overall, however, insufficient information is provided in LLWR (2008) for us to be able to judge the appropriateness of LLWR's proposed approach. We would need to understand the range of calculations proposed, and the balance between the use of such deterministic point value calculations and more investigative probabilistic calculations.

64. We recommend that a coherent and comprehensive approach to uncertainty should be implemented within the ESC, and that LLWR should have a documented and well-reasoned plan for uncertainty and sensitivity analysis. Ideally this approach could be implemented via the LLWR quality system to ensure that uncertainties are adequately managed. Consideration could be given to identifying a specific report on the management of uncertainty within the overall ESC document architecture (see Figure 2.2 of LLWR 2008). This document could include output from the register of uncertainties. Note also that the LLWR needs to provide explanations of the significance of the uncertainties for interested parties in an understandable manner – this might be accomplished within the planned *'accessible summary'* of the ESC.

65. In summary, the treatment of uncertainty is a key topic, which we propose should be an area for further peer review.

3.5.4 Treatment of Time-dependent Changes

66. Section 5.5 of LLWR (2008) proposes that only limited use will be made of time-dependent (non-steady state) assessment modelling in the 2011 ESC, and that the focus of any time-dependent work that is conducted would be on:

- Progressive disposal of waste and implementation of engineering measures at the site and consequent hydraulic and chemical changes during the period of Authorisation.

- Time-dependent degradation or failure of engineered barriers and consequent hydraulic and chemical changes after the period of Authorisation.

67. LLWR's text is not entirely clear. It will be essential to take account in the safety assessment of the temporal evolution of the disposal system and we assume that this is LLWR's intent. We assume that the text of Section 5.5 proposes the use of steady-state flow models and of compartment models in which the environmental media in most of the model compartments are in equilibrium at any instant of time.

68. Of the two areas identified in Section 5.5 in which time-dependent modelling may be carried out, we would regard the gradual degradation of engineered barriers and associated effects to be the main priority. Further comments on the use of transient modelling are given in Section 3.5.6.2.

3.5.5 Treatment of the Biosphere

69. The peer review panel considers that LLWR (2008) sets out an appropriate approach to the treatment of the biosphere. As noted in the previous peer review report, it will be important to ensure that all processes that may contribute significantly to the exposure of potentially exposed groups are incorporated into the assessment.

3.5.6 Groundwater-Mediated Pathways

3.5.6.1 Modelling of the Near-field

70. Sections 3.2.1 and 5.7.1 of LLWR (2008) discusses possible approaches to modelling of the near-field during assessments of impacts via the groundwater pathway. In places the text of LLWR (2008) is unclear, particularly regarding the discussion of cautious and realistic models (e.g., paragraph 1 on Page 49).

71. Two new areas of work are proposed:

- Work towards the use of more realistic models of radionuclide release that take account of the kinetics of release from the wastes.
- Empirical modelling based on results from monitoring of radionuclide concentrations in Trench leachates.

72. The justifications given in LLWR (2008) for these pieces of work are not particularly clear (for example, the text does not actually explain the potential significance of moving to the use of kinetic release models). However, as long as they can be justified scientifically, we consider that the use of process-based kinetic release rate models would be a sensible and positive step forward, as they have the potential to significantly improve estimates of radionuclide release and dose/risk impacts.

73. Although we recognise that empirical models based on present-day monitoring data may have their place and speak to some audiences, we are much less positive about such models because significant and often unjustified extrapolation is necessary if they are to be applied in long-term assessments, and because they tend not to enhance process or system understanding.

74. Page 49 of LLWR (2008) also describes a process involving work to better understand the inventory of particular waste streams. Unfortunately

the process that has been implemented is not described sufficiently clearly and further information is required.

75. In summary, therefore, while LLWR (2008) proposes an approach that includes sensible elements, without more detail on what exactly will be done in the assessment it is hard to comment further. This is an issue on which the peer review panel would like to continue to engage with LLWR as the 2011 ESC is developed.

3.5.6.2 Treatment of the Geosphere

76. Sections 3.3 and 5.7.2 of LLWR (2008) discuss hydrogeology, including the calibrated site-scale flow model. The model is described as providing *'a reasonable match to the observed head distribution'*. Head measurements are relatively insensitive to many aspects of the groundwater system. Gustafson and Strom (1995) comment that *'The pressure field is rather insensitive to the underlying conceptual model, whereas the transport outputs like breakthrough curves are more sensitive'*.

77. It would be useful to understand what data have been used to calibrate the model and what the model has been able to predict (rather than back-fit by calibration). In particular, successful predictions of flow and transport would lead to a significant increase in confidence in the model.

78. Given the observed contaminant plume from the site (tritium observations) it would seem that any credible projection of future contaminant transport should be able to explain the current observations (to the extent possible given uncertainty on past emplacement and treatment of wastes). It is not clear what the ability of current models in this area is; the report states that there is consistency with the *'conceptual model'* but does not discuss results from numerical models.

79. Given the expected transient changes in groundwater flow due to emplacement and subsequent degradation of the engineered barriers, coastal erosion, and effects of climate change, it may be useful to consider current transient behaviour as observed from long-term monitoring of the site and any observed changes due to the annual cycle. If conceptual and numerical models are consistent with observations over these timescales, greater confidence may be placed in any future predictions. Historical variations in head and flow may be useful in understanding the impact of future changes at the site, while variation due to annual cycles may be useful in understanding the impacts of future changes in climate. In summary, we suggest that the handling of transient conditions at the site should be an area for further peer review.

80. LLWR (2008) discusses the very large number of boreholes on the site (>1,000) and the observed vertical head gradients in some parts of the site. LLWR needs to demonstrate sufficient understanding of the current and

future hydraulic action of these boreholes. Similarly, it would be desirable to understand the distribution of off-site boreholes on the seaward side of the site, in terms of their ability to connect otherwise isolated transmissive horizons, and their potential future usage for water abstraction (e.g., for agricultural or domestic purposes). It would also be useful for LLWR to present:

- Plans for any engineering work on known boreholes prior to closure.
- An outline of how known boreholes (on and off site) will be treated within the ESC, particularly regarding whether they may provide significant vertical flow and transport paths, and/or be re-used for agricultural or other purposes.

3.5.6.3 Treatment of Water Wells

81. LLWR (2008) and Serco (2009) discuss approaches for assessing the risks associated with water abstraction from wells outside the facility during the period after Authorisation. Neither document addresses the treatment of water wells in the period of Authorisation; this seems to be a gap in the description of the proposed approach.

82. Serco (2009) concentrates on the radiological risk, but it would be sensible if any approach to assessing radiological risk from borehole abstraction was also applied to risks from the chemotoxicity of the contaminant plume from the facility.

83. Several key issues are discussed in Serco (2009):

- EA Guidance, including definition of relevant Potentially Exposed Groups (PEGs).
- Estimation of the probability that wells or boreholes may exist within the relevant area and time frame.
- Calculation of concentrations from such wells or boreholes.
- Definition of the appropriate source term.

3.5.6.3.1 EA Guidance and PEGs

84. Serco (2009) was developed prior to the release of the NS-GRA (Environment Agency *et al.* 2009) and considered the then available draft Guidance. In doing so, in some places the report (Serco 2009) confuses human intrusion with drilling of a well into a contaminant plume away from the disposal facility.

85. Three possible approaches to the definition of a PEG are discussed in Section 3.2 of Serco (2009):

- Recommended Approach: *'...the group of people that drill a well into the central part of the contaminant plume migrating from the LLWR and utilise the abstracted water (for various purposes)'*, where the central part of the plume is defined as that being within an order of magnitude of the maximum concentration.

- Alternative Approach: *'...those individuals abstracting water from wells whose concentrations are within an order of magnitude of the concentration in the well that abstracts water with the greatest concentration'*.

- Suggestion of Thorne (2000): *'...the household that uses water abstracted from the well that has the highest concentrations in the abstracted water'*.

86. We consider that the discussion of PEGs in Serco (2009) is unnecessarily complex. The NS-GRA (Environment Agency *et al*. 2009) suggests that it is necessary *'to consider different groups of people that could be at risk of exposure (potentially exposed groups) in order to identify a person representative of those people at greatest risk at a given time'*. Further, the NS-GRA (Environment Agency *et al*. 2009) suggests that the group's exposure to radiation should be *'reasonably homogeneous'*; there is no requirement to define a PEG that includes a minimum variation in exposures.

87. The first two approaches suggested in Serco (2009) appear to have been defined to create an order of magnitude variation in concentrations within the PEG. Given that this is the maximum recommended variation, approaches to PEG definition that have been designed to create this variation may be subject to challenge, especially as members of PEGs may also be exposed to other sources of contamination. Careful consideration would have to be given to the use of either approach because they might be viewed as being defined solely for the purpose of maximising the concentration range within the limits suggested by ICRP.

88. The simpler (at least in terms of definition, if not in computation) definition given by Thorne (2000) is described in the Serco (2009) report as being inappropriate because exposures would be homogeneous, but there is no requirement to generate variation in exposure within the PEG (in fact quite the opposite), and it is not actually clear that there would not be variation in exposure if the approach of Thorne (2000) was followed (e.g., related to abstraction rates and the range of behaviour within the exposed group).

89. We would suggest that the PEG could comprise people making residential use of the area between the repository and the coast, perhaps specifically in the area potentially overlying radioactivity migrating in groundwater. For consistency with assumptions made about the repository cap area, this could be the inhabitants of a smallholding. However, for this group the

exposure pathway is not certain to occur, as it is conditional on the probability of water supply being obtained from a well, together with the location and properties of the well, and the use made of the water, as discussed in Serco (2009).

90. We do not believe that any lack of homogeneity within a PEG (which might conceptually arise if the number of individuals in a PEG is small), is a very significant problem for PEG definition. Even if a PEG comprises just a single individual, the habits attributed to that individual could be sampled statistically from a reasonable (i.e. adequately homogenous) range of habits, and represented within an assessment model using a probability distribution.

91. In summary, the peer review panel is concerned that (rather than adopting an approach to the definition of PEGs that is too complex, too much of an artificial construct, optimistic, or chosen for ease of computation) an appropriate approach should be taken to the definition of PEGs for the well case, and that the approach should be consistent with that used for identifying the PEGs considered in other parts of the safety assessment. The identification of PEGs for the well case is a key topic, which we propose should be an area for further peer review.

3.5.6.3.2 Estimating the Probability of Wells

92. Serco (2009) recommends that several sets of assessment results are presented for the well pathway:

- PW1: Radiological impact conditional on the existence of a well intersecting the plume to an isolated house (bounding estimate of impact).
- PW2: *'Cautious'* estimate of absolute risk calculated as PW1 multiplied by the probability of the existence of the well as elicited for Nirex 97.
- PW3: Supplementary analysis based on map-based study of households/farms within 300-400 m of the cliff-line.
- PW4: Application of an event tree approach to demonstrate the various considerations that tend to militate against wells being located in the area and to emphasise the short period in which developments could take place.

93. In view of the relatively high assessed risks associated with this pathway in the May 2008 assessment (LLWR 2008b), an approach based on multiple lines of evidence seems desirable, and the calculation of a bounding estimate essential.

94. However, as a key factor in the risk calculation, the Nirex 97 elicitation results would require adequate documentation and justification, and even then might be challenged because of the different context for the elicitation[2]. For example, in the formal elicitation procedures discussed by Mishra (2002) the first step is definition of objectives, and *'The objectives of the elicitation should be defined explicitly and in a manner that reflects a clear understanding of how the judgments obtained will be used.'*

95. It is not clear that any briefing given to experts for the Nirex 97 exercise would have envisaged the use of the elicited values to determine the mean density of wells for an area of about 1 square kilometre relevant to the LLWR ESC, given that they were being asked to elicit *'median'* properties for a large area based on information from West Cumbria as a whole, which encompasses thousands of square kilometres. As a minimum, the Nirex 97 expert group should be consulted to determine whether they would consider the elicited values to be suitable for the proposed purpose.

96. Similarly, biases discussed within Nirex 97 and considered *'pessimistic'* with regard to the risks from a geological disposal facility might not be so with respect to the risks from the near-surface LLWR.

97. It would also be valuable to review the documentation of the Nirex 97 elicitation if it is to be used within the 2011 ESC, to understand the database used by the expert group in their deliberations. For example, it is not clear what data were used for the density of domestic boreholes, given that there is no current (and was not in 1997) requirement to register domestic boreholes abstracting less than 20 m^3/day.

98. For these reasons we support the proposal to conduct a map-based study, such as that proposed in Section 4.4.3 of Serco (2009), which should provide some 'ground truth' regarding the number of properties located within the coastal strip that make use of wells at the present day. A consensus was not reached among the members of the peer review panel regarding the potential pros and cons of conducting a new expert elicitation to determine the probability of a well being present (see Section 4.4.4 of Serco 2009).

99. Page 24 of Serco (2009) sets out a mathematical approach to quantifying the probability of one or more wells in the area of interest, for the case where wells are assumed to be randomly located. Serco (2009) recognises that this assumption (that wells are randomly located) might not be appropriate and we agree. Wells are not likely to be located on a random basis but, rather, would be sited at least partly on the basis of knowledge

[2] The NS-GRA states *'the developer/operator should... ...document explicitly expert judgements that have been made and the reasons given by experts to support their judgements.*

about the hydrogeology of the area and its ability to supply the water required.

100. Page 33 of Serco (2009) discusses the Special Area of Conservation (SAC) status of the area between the facility and the coast, and speculates on whether the status of this land might in the future have an effect on the probability of wells being drilled in this area. In our view and consistent with Principle 4 of the NS-GRA (Environment Agency *et al*. 2009), it would be unreasonable to rely for safety on qualitative arguments regarding the maintenance of the SAC or to take quantitative credit for such active institutional controls in safety assessments for more than a few hundred years at most. We are only somewhat reassured, therefore, by the statement in LLWR (2008) that *'quantitative account of such mitigating factors would not be included within the estimate of annual risk'*.

3.5.6.3.3 Radionuclide Concentrations in Wells

101. Section 5 of Serco (2009) discusses approaches to estimating the radionuclide concentrations that might be 'sampled' by a well. Based on these considerations, Section 7 of Serco (2009) recommends:

- Use of a GoldSim model based on the most up-to-date 3D groundwater flow and transport model calculations.
- Cross-comparison of the GoldSim results with those from the corresponding 3D flow and transport calculations.
- Additional simple probabilistic calculations for a small number of realizations for key radionuclides using detailed 3D transport models to build confidence in the GoldSim results.

102. It is likely that the concentrations from the 3D flow and transport model will represent *'volume averaged'* concentrations calculated using upscaled properties. It is not clear that current 3D flow models would be adequate for prediction of the required concentrations. The assessment needs adequately to capture the possible effects of flow in heterogeneous units (e.g., flow along preferential flow paths such as palaeochannels), and of dilution and drawdown that may occur around the well. It is not clear that volume averages from models without abstraction could be used as conservative upper bounds (as suggested on page 21 of Serco 2009).

103. As noted above, LLWR (2008) recognises that with regard to current geological definitions of the site, *'The validity of this approach is reliant on the assumption that sensible bulk properties can be assigned to each lithofacies package, despite the heterogeneous characteristics of each package'*. 3D flow and transport models using these geological descriptions would, therefore, be based on a clearly questionable assumption, and might not be fit-for-purpose with regard to prediction of concentration from borehole abstraction.

104. LLWR (2008) suggests that more detailed characterisation/description approaches, together with probabilistic models relevant to hydraulic features are currently under consideration. Such models might usefully form the basis for *'insight'* models utilising highly detailed descriptions of the expected hydrofacies.

105. Such detailed hydrofacies insight models could be useful in building confidence in the derivation of any upscaled flow and transport properties for the 3D flow and transport models. See for example Frippiat and Holeyman (2008) or Zinn *et al*. (2003). Further, these insight models could be of value in demonstrating under what circumstances models using such upscaled properties could be used to estimate conservatively concentrations from abstraction boreholes.

106. In addition to the consideration of detailed scale models, any larger scale models used to predict future contaminant concentration should be consistent with current observations of transport from the site (e.g., observed tritium plume positions and concentrations), and with the models of groundwater flow used in the rest of the safety assessment.

3.5.7 Modelling of the Estuary and Lagoon

107. Section 5.7.4 of LLWR (2008) indicates that LLWR is currently developing models to assess releases, exposures and risks for estuary and lagoon systems. The approach described appears broadly reasonable, but we note that the models should be supported by, and developed from, unbiased descriptions and conceptual models of the physical systems. As the work is new and has not been subject to peer review by this panel, we propose that modelling of the estuary and lagoon should be an area for further peer review.

3.5.8 Gas-Mediated Pathways

108. Section 5.8 of LLWR discusses the gas pathway, and identifies the relevant nuclides as tritium, carbon-14, radon and thoron. We agree that these are the most relevant nuclides, but would clarify the point that although the concentration of thoron is supported by longer-lived parent radionuclides, the effect of thoron's short half-life is that it generally decays before migrating any significant distance.

3.5.8.1 Radon

109. LLWR (2008) proposes *'to keep the assessment of radon separate from the assessment of other radionuclides'*. An alternative view is that the assessment should include all relevant sources and radionuclides, including radon where relevant. The NS-GRA (Environment Agency *et al.* 2009) states, *'The developer/operator needs to assess potential exposures of possible intruders to the radiological dose that might arise*

from a range of possible exposure scenarios. These scenarios should consider the exposures that arise from the potential exposures form [sic] *the inventory of waste to be disposed of including any gaseous emissions from the waste such as radon; this should not include exposures to naturally occurring radon. Due to the large uncertainties associated with exposures to radon the developer should present these both aggregated with other exposures and individually'*.

110. LLWR will, therefore, need to ensure that the 2011 ESC presents the assessment results in a way that satisfies the Guidance (e.g., with and without the contribution from waste-derived radon).

111. The NS-GRA (Environment Agency *et al*. 2009) makes no reference to comparisons of assessment results with the radon action level for houses of 200 Bq/m^3, and so we recommend making comparisons only with the dose criteria.

112. We also note that the Guidance quoted above (NS-GRA para. 6.3.39) only appears in a section on human intrusion – the NS-GRA (Environment Agency *et al*. 2009) appears to say nothing about how to present radon doses for other scenarios. The Guidance above could also be interpreted as applying specifically only to intruders. These aspects should be clarified with the EA prior to the 2011 ESC.

113. We agree that it would be sensible to assess concentrations of Rn-222 only, and to use HPA's generic dose coefficients for indoor air, rather than to attempt to model equilibration with daughters and the unattached / attached fractions of the aerosol. We also welcome the intent stated in LLWR (2008) to consider radon migration through the facility cap.

114. LLWR (2008) suggests that alternative designs for the final site cap will be considered, including vented designs and caps designed to prevent any radon release. We support LLWR's intention to consider alternative cap designs, but we are yet to be convinced that a cap could in practice prevent all radon release.

3.5.9 Coastal Erosion

115. Section 5.9 of LLWR (2008) discusses the approach to assessing the consequences of coastal erosion.

116. As noted in the previous peer review report (Bennett *et al*. 2008) there is a need for a better geomorphological description of the coast during possible erosion processes to support the identification of potential exposures. As a result of developing such a description of how erosion might actually proceed, it is possible that additional exposures may be identified that need to be assessed. For example, there might be periods of sea-level stability, or temporary sea-level falls, within the overall trend of increasing sea level, during which exposures might occur.

117. We also consider there is a need for more detailed modelling of the behaviour of eroded wastes and radionuclides in the intertidal zone and their transfer to biota.

118. As the work on modelling exposures during erosion of the facility is new and has not been subject to peer review by this panel, we propose that it should be an area for further peer review.

3.5.10 Human Intrusion

119. An approach to the assessment of the potential impacts of human intrusion is described in Section 5.19 of LLWR (2008). As noted in the last peer review report (Bennett *et al* 2008), we agree with LLWR's definition of what constitutes human intrusion; this is consistent with the Guidance given in the NS-GRA (Environment Agency *et al*. 2009).

120. LLWR's proposed approach to assessing the potential impact of human intrusion is set out in a series of bullet points on page 57 of LLWR (2008). There are aspects of LLWR's proposed approach that may not be consistent with the NS-GRA (Environment Agency *et al*. 2009). The approach proposed in LLWR (2008) includes considering the likelihood or relative probability of human intrusion event and including this in the assessment of the acceptability of such consequences. In particular, LLWR (2008) proposes '*to determine a set of intrusion events* [for assessment] *that is representative in terms of both potential impact and relative likelihood'*. This approach could lead to some valid human intrusion scenarios being eliminated from consideration at too early a stage (e.g., on the basis of poorly known estimates of relative likelihood), and seems to mix assessment of the consequences of human intrusion (under regulatory requirement R7) with consideration of optimisation (under regulatory requirement R8).

121. The NS-GRA (Environment Agency *et al*. 2009) makes clear that the assessment of the consequences of human intrusion should be made against a dose standard on the basis that intrusion is likely because, after the period of Authorisation, wastes in a near-surface disposal facility are potentially vulnerable to commonplace human actions. The assessment of the potential doses from human intrusion needs to be made in an open and transparent way, so that the results from the assessment can properly inform subsequent optimisation studies and lead to appropriate decision-making.

122. The NS-GRA (Environment Agency *et al*. 2009) also expects:

- Assessment of the consequences of human intrusion on the environment.

- Assessment of the consequences of intrusion by non-human species.

- Consideration of the potential for severe deterministic injury.

123. These latter three aspects do not appear to be mentioned in LLWR (2008).

3.5.11 Non-radiological Assessment

124. LLWR (2008) discusses different approaches that could be taken for assessing the non-radiological impacts associated with the disposal facility. LLWR proposes what appears to be a broadly sensible approach, but without more detail on what exactly will be done in the assessment it is hard to comment further. This is an issue on which the peer review panel would like to continue to engage with LLWR as the 2011 ESC is developed.

3.5.12 Non-human Species Assessment

125. LLWR recognises the need stated in regulatory Guidance to address impacts to non-human species, and proposes a review of some previous assessment work on this topic, consideration of recent environmental monitoring data, and some new calculations as part of the 2011ESC to assess the impacts of radionuclides on non-human biota.

126. We note that, in practice, where assessments have been made of the impacts to non-human biota from near-surface LLW disposal facilities using approaches derived from projects such as the EC ERICA and FASSET programmes[3], the assessed impacts are often very low and essentially trivial (e.g., BNFL 2002b). So, although we recognise the need for such assessments to be carried out, we suggest that they should be proportionate in their extent and level of detail to the level of risk. Possibly the work could focus on aspects of the LLWR disposal system that are in some sense unusual or that have not been considered before (e.g., exposures to eroded wastes in the lagoon system, or in the eroding cliff face).

3.5.13 Radiological Capacity

127. LLWR's description of its proposed approach to determining radiological capacity (Section 5.13 of LLWR 2008) includes, '*...our approach would be to estimate reference capacities that would correspond to meeting the risk guidance level or in the case of human intrusion, the relevant dose criterion*'. We consider that this part of the proposed approach is appropriate and responsible, especially since some have argued that higher risks or potential doses could be tolerated if a sufficiently strong optimisation argument was made.

128. LLWR also proposes '*...to base the radiological capacity calculations on reasonable and credible rather than extreme scenarios or calculation*

[3] see www.erica-project.org and www.ceh.ac.uk/protect/

cases'. The success of this approach will depend on LLWR entering into and having successful dialogue with its stakeholders, including the regulators and the peer review panel, to consider what the reasonable and credible scenarios should be.

129. LLWR suggests that annual disposal limits should not be used, but does not identify what alternative means might be used to regulate the rate of waste disposals. Environment Agency (2003) identifies several reasons for regulating the rate of waste disposals, including providing flexibility for future waste disposal by preserving disposal capacity. Environment Agency (2003) suggests that a reasonable approach might involve establishing fixed total disposal limits for each four-year period between Authorisation reviews. A four-year period was suggested in Environment Agency (2003) as a period over which it would be reasonable to expect that the ESC and the national inventory would be updated, and which would allow reasonable time for gathering of further information and any necessary research and development.

130. We agree that limits on disposals over a year (or other time periods) may have a role in providing some protection against future changes in knowledge. For example, in the absence of such limits a particular nuclide may be accepted quickly in substantial quantities against an inventory limit currently considered to be acceptable – only for subsequent assessment or monitoring to result in downward revision of the inventory that would be acceptable. In any case, it is premature in a document on the **approach** to the ESC, to make any such proposal as it prejudges the outcome of the ESC.

131. LLWR plans to take account of the *'additivity'* of contributions to radiological impacts made by different radionuclides, but proposes to do this in a way that at present is not sufficiently clear and on which we would need more detailed information to develop a judgement as to its appropriateness.

4 Conclusions

4.1 Proposed Approach to the ESC

132. The peer review panel considers that LLWR has set out its overall approach in an intelligently structured and highly commendable report (LLWR 2008), which makes a strong statement of intent for the production of a comprehensive environmental safety case, and that clearly establishes the relationships between decisions on the realities of site management and operation, and the evolving environmental safety case.

133. At a high level, LLWR's description of the role and nature of the ESC is appropriate, and the proposed approach for the 2011 ESC encompasses the breadth of issues that will need to be addressed. However, the approach needs to be updated to reflect recently published regulatory Guidance and to fully incorporate a thorough and on-going process of peer review.

134. In addition to these two key points, we have made a considerable number of comments on aspects where the approach may need to be revised, clarified and/or specified in greater detail. The more significant of these comments lie in the areas of:

- Demonstrating LLWR's management and quality systems are adequate and have been applied appropriately during development of the ESC.
- The need to consider a wide range of information to assess whether the site could be inundated or begin to erode much sooner than previously estimated.
- Using the ESC to determine what wastes the LLWR can accept, rather than relying on the National LLW Strategy to determine disposal needs and define what waste must go to the LLWR.
- Using safety assessment to consider the implications of changes to the wastes, the waste form, or waste packaging.

135. Our main comments on the approach to safety assessment relate to:

- The use of pathway-based analysis in the safety assessment.
- Prioritisation and the identification of the most important radionuclides, other contaminants and waste streams.
- The use of FEP lists and FEP analysis.
- The treatment of human intrusion and, particularly, the identification of human intrusion scenarios.

- The identification of PEGs associated with off-site boreholes and wells, and the approach to assessing radionuclide concentrations in such boreholes and wells.

- The use of expert elicitation.

136. There are also several areas which the peer review panel suggests should be subject to further peer review:

- The approach to the treatment of uncertainty.

- The approach to modelling the near-field.

- The approach to handling of transient conditions at the site.

- The approach to modelling exposures during erosion of the facility.

- The approach to assessment of non-radiological impacts.

- The approach to assessment of radiological capacity.

4.2 Peer Review

137. With regard to the process of peer review, we suggest that LLWR (2008) would have benefited from peer review in late-2008 before it was submitted to the EA.

138. More generally, the documents would benefit from the inclusion of more explicit references to previous peer review comments (e.g., Box 1) and indicate how those comments have been, or are being, addressed. In particular:

- We note that Box 1 Issue 1 (the short period available for development of the 2011 ESC) remains highly relevant. One particular feature of LLWR's current approach is that it includes a very significant programme of different studies leading to the 2011 ESC. Many of these studies potentially interact, and LLWR has proposed a data freeze in April 2010. It would be useful for LLWR to present the programme for these studies, including a timeline or Gantt chart that illustrates how the results will feed into delivery of the ESC by May 2011.

- LLWR (2008) could usefully have provided more detailed information on how Box 1 Issue 3 (linking engineering design and operational decisions to the ESC) and Issue 4 (risks from coastal erosion of the facility) are to be addressed.

139. Peer review should be an ongoing and interactive process that continues throughout the programme leading to the safety case. LLWR should,

therefore, plan its programme so that it may be subjected to peer review as a routine part of the work process. Enough time needs to be set aside for peer review and for the safety case development team to be able to consider and respond to peer review comments.

Box 1 Issues highlighted in the 2008 peer review report
1. There is only a short period in which to develop the next safety case. Simply documenting the safety case might take a year towards the end of the period. Good planning will be essential if the various components of the safety case are to be brought together at the right time and with appropriate levels of consistency, quality assurance and peer review. It would seem sensible, therefore, for the SLC to maintain the valuable momentum developed during recent months.
2. The next safety case will need to include a safety assessment that includes a more comprehensive treatment of uncertainty. Planning the approach to the treatment of uncertainty should probably be one of the more strategic issues that should be considered at an early stage.
3. There is a need to better integrate the engineering design and optimisation work with the safety case. Decisions on facility operation should be checked for consistency with the environmental safety cases.
4. The risks from coastal erosion of the facility need to be assessed in a thorough and robust way.
5. A more convincing and well-supported understanding of groundwater movements and potential radionuclide transport should be demonstrated in order to confirm that ground and surface water pathways are now a less prominent issue in long-term performance.
6. The issue of localised waste retrieval needs to be assessed with much greater transparency, in order that risks can be shown to be ALARA.
7. The implications of coastal erosion for the suitability of the site for near-surface radioactive waste disposal should be considered further with regulators and stakeholders.

5 References

1. Bennett, D., Bath, A., Fleming, G., Garrard, G., Holton, D. and Jones, S., 2008. Independent Peer Review of LLWR Response to Environment Agency Schedule 9 Requirement 2.

2. BNFL, 2002a. Drigg Operational Environmental Safety Case. British Nuclear Fuels plc.

3. BNFL, 2002b. Drigg Post-Closure Safety Case: Overview Report. British Nuclear Fuels plc.

4. Brahic (2008) Sea Level Rises Could Far Exceed IPCC Estimates, New Scientist, 1 September 2008.

5. Carlson, A.E., LeGrande, A.N., Oppo, D.W., Came, R.E., Schmidt, G.A., Anslow, F.S., Licciardi J.M. and Obbink, E.A., 2008. Rapid Early Holocene Deglaciation of the Laurentide Ice Sheet, Nature Geoscience 1, 620-624.

6. De Marsily, G., Delay, F., Goncalves, S.J., Renard, P., Teles, V. and Violette, S., 2006. Dealing with Spatial Heterogeneity. Hydrogeology Journal, 13(1), 161-183.

7. Eaton, T.T., 2006. On the Importance of Geological Heterogeneity for Flow Simulation. Sedimentary Geology, Volume 184, Issues 3-4, 15 February 2006, Pages 187-201, Heterogeneity in Sedimentary Aquifers: Challenges for Characterization and Flow Modeling, Geological Society of America Annual Meeting 'GeoScience Horizons 2003'.

8. Environment Agency, 2003. Linkage between Post-Closure Safety Case Review and the Authorisation Process for Radioactive Waste Disposal Facilities. R&D Technical Report P3-090.

9. Environment Agency, 2005. The Environment Agency's Assessment of BNFL's 2002 Environmental Safety Cases for the Low-Level Radioactive Waste Repository at Drigg. Report No. NWAT/Drigg/05/001, Version 1.0.

10. Environment Agency, 2006. Certificate 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.

11. Environment Agency, Scottish Environment Protection Agency, Northern Ireland Environment Agency, 2009. Near-Surface Disposal Facilities on Land for Solid Radioactive Wastes: Guidance on Requirement for Authorisation. February 2009.

12. Frippiat, C.C. and Holeyman, A.E., 2008. A Comparative Review of Upscaling Methods for Solute Transport in Heterogeneous Media. Journal of hydrology, 362, 150-176.

13. Gustafson, G., Strom, A., 1995. The Äspö Task Force on Modelling of Groundwater Flow and Transport of Solutes: Evaluation Report on Task No 1, the LPT2 Large Scale Field Experiments. SKB International Cooperation Report 95-05.

14. Hill M.D. and Irvine, T.J., 2002. Final Summary Report on the Independent Peer Review of the 2002 Drigg Post Closure Safety Case.

15. HPA, 2009. Radiological Protection Objectives for the Land-based Disposal of Solid Radioactive Waste, Advice from the Health Protection Agency. HPA Report RCE-8. February 2009.

16. IAEA, 2007. Regulatory Review of Post-Closure Safety Assessments for Radioactive Waste Disposal Facilities. International Atomic Energy Agency Safety Report, Vienna.

17. LLWR, 2008a. LLWR Environmental Safety Case: Technical Approach to the 2011 Environmental Safety Case, LLWR/ESC/R(08)10010, Issue 1, 28 November 2008.

18. LLWR, 2008b. Volume 5: Performance Update for the LLWR, LLWR LTP 10005.

19. Mishra, S., 2002. Assigning Probability Distribution to Input Parameters of Performance Assessment Models. SKB Technical Report TR-02-11. Swedish Nuclear Fuel and Waste Management Co, Stockholm, 2002.

20. Nagra, 2002. Project Opalinus Clay – Safety Report 'Demonstration of Disposal Feasibility for Spent Fuel, Vitrified High-level Waste and Long-lived Intermediate Level Waste (Entsorgungsnachweis)', Nagra Technical Report NTB 02-05.

21. NEA, 2005a. International Peer Reviews for Radioactive Waste Management: General Information and Guidelines. Organisation for Economic Co-operation and Development, Nuclear Energy Agency Report No. NEA 6082.

22. NEA, 2005b. International Peer Reviews in the Field of Radioactive Waste: Questionnaire on Principles and Good Practice for Safety Cases. Organisation for Economic Co-operation and Development, Nuclear Energy Agency Report No. NEA/RWM/PEER(2005)2.

23. Nicholls, R.J., Wong, P.P., Burkett, V.R., Codignotto, J.O., Hay, J.E., McLean, R.F., Ragoonaden, S. and Woodroffe, C.D., 2007. Coastal Systems and Low-lying Areas. Climate Change 2007: Impacts,

Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 315-356.

24. UK Nirex Limited, 1997. Nirex 97: An Assessment of the Post-closure Performance of a Deep Waste Repository at Sellafield: Volume 3 - The Groundwater Pathway, Nirex Report No. S/97/012.

25. Serco, 2009. Methodology for the Assessment of Wells – Report to LLW Repository Ltd., SERCO/TAS/002888/001 Issue 01, January 2009.

26. Thorne, M.C., 2000. Potentially Exposed Groups in the Context of Solid Radioactive Waste Disposal, AEA Technology Report AEAT/R/ENV/0299.

27. Zinn, B. and Harvey, C.F., 2003. When Good Statistical Models of Aquifer Heterogeneity Go Bad: A Comparison of Flow, Dispersion and Mass Transfer in Connected and Multivariate Gaussian Hydraulic Conductivity Fields. Water Resources Research, 39.

Appendix 1 – The Peer Review Panel

Dr David Bennett

Dr David Bennett (BSc., PhD., FGS) is Director of TerraSalus (EarthSafety) Limited. He has over 18 years experience in providing strategic and technical consultancy advice on radioactive waste management and its regulation. He is a geologist and geochemist, and has contributed to over 80 published papers and reports in the area of radioactive waste management.

His specialities include disposal facility uthorisation and licensing, regulatory review and interpretation, peer review, risk and safety assessment, safety case development, engineered barrier systems, radioactive waste immobilization, and geochemical and radionuclide transport modelling. He has also contributed to a range of consultative BPEO studies and options appraisals on waste management and disposal.

Dr Bennett has contributed to radiological assessments and nuclear waste management programmes in Belgium, Finland, France, Germany, Japan, Spain, Sweden, the UK and the US, and has also contributed to several international programmes run by the European Commission, the International Atomic Energy Agency (IAEA) and the OECD Nuclear Energy Agency (NEA).

In the period from 1996 to 2005, Dr Bennett managed and participated in all aspects of the Environment Agency's review of the 2002 safety cases for the low-level waste repository (LLWR) near Drigg. Dr Bennett has since been a member of the independent peer review panel that is reviewing the development of new safety cases for the LLWR. He is also a member of the international BRITE group, which is reviewing near-field aspects of the Swedish spent fuel disposal programme on behalf of the Swedish Radiation Safety Authority. Dr Bennett is lead consultant to the NEA for its Engineered Barrier System (EBS) project, and has recently contributed to an international peer review of the Electric Power Research Institute (EPRI)'s assessment capability for radioactive waste disposal at Yucca Mountain in the US. Dr Bennett is assisting the IAEA with projects on safety cases and safety assessments for near-surface radioactive waste disposal, and is also contributing to several NDA projects on geological disposal.

Prof. George Fleming [4]

Professor George Fleming (BSc., PhD., FREng., FICE., FCIWM., CEnv) is Managing Director of EnviroCentre Limited, and Emeritus Professor of civil engineering at Strathclyde University. His research publications include contributions to 15 books and over 250 publications in journals, keynote addresses, papers at conferences, reports, plus the production of 4 video documentaries and a permanent exhibition.

[4] Prof. Fleming was unable to contribute to this particular peer review task, but is otherwise and active member of the panel.

He specialises in environmental management, including hydrology and water and soil resources engineering, where he has pioneered the development of computer aided design and simulation techniques. He has undertaken research into the uses of dredged material, landfill hydrology, real-time drought and flood forecasting, river basin management, land-use, and river engineering for fishing improvements. He currently leads a major trial to manage contaminated dredgings in the North Sea.

Professor Fleming has acted as consultant to many national and international organisations, including the United Nations FAO, IAEA, ILO, WMO; agencies such as the Scottish Development Agency, Highland and Strathclyde Regions, Monklands, Inverclyde, Dundee, Clydebank, Lochaber, Glasgow and Annandale and Eskdale District Councils; the SSEB and CEGB; and a number of private companies including Jacobs Babtie, Binnie & Partners, Mott MacDonald, EPDC, Bovis, Wimpey Waste, Clydeport Ltd, Patersons of Greenoakhill, Peel Holdings and Port of Tyne.

Significant projects include dams in Kenya, Labuan and Brunei; Strathclyde Park; flooding in Sutherland; numerous landfill sites; Glasgow Garden Festival Project; Dinorwig Power Station Project; reservoir management in the Alps; flood control in California, Chicago and Brazil.

Professor Fleming was appointed to the DTi's Overseas Projects Board in June 1991, and to the Boards of the Scottish International Resource Project and to the Scottish Exports Forum in 1996. Professor Fleming was elected to the Council of the Royal Society of Edinburgh and served as Convenor of the Royal Academy of Engineering in Scotland for eight years. Professor Fleming was President of the Institution of Civil Engineers in 2000, and served on various boards and committees. Following the completion of his Presidency, he became Chairman of the ICE Waste Management Board and is still heavily committed to Engineers Against Poverty (formerly The Telford Challenge).

Prof. Alan Hooper

Professor Alan Hooper is currently Director of Alan Hooper Consulting Limited. He was appointed as a visiting professor in the Earth Science and Engineering Department at Imperial College London in 2008.

Alan Hooper was awarded a first class honours degree in chemistry from Nottingham University in 1968 and a Ph.D. for research into the thermodynamics and crystal structures of complex oxide systems by the same university in 1971. He worked in the Research Division of the Central Electricity Generating Board (CEGB) for seventeen years, initially studying the safety of operation and maintenance of advanced power reactor systems, in particular sodium-cooled fast reactors. In 1980, he joined the Nuclear Decommissioning Project and was responsible for research into the safety implications of decommissioning strategies for the UK's first generation of gas-cooled Magnox reactors. From 1985 he was responsible for the specification and implementation of the research programme to support the retrieval and

conditioning of the CEGB's intermediate-level wastes for eventual geological disposal. In 1987 he developed improved source terms for radionuclide releases from CEGB low-level wastes under the geochemical conditions at the national disposal facility near the village of Drigg in west Cumbria: this was in support of the CEGB's submission in response to the requirements of a revised disposal authorisation. He also developed the ANABET analytical system, subsequently available for use in other countries under licence to the CEGB, that enabled more highly sensitive analysis of trace quantities of alpha- and beta- emitting radionuclides in environmental samples.

Alan Hooper joined Nirex, the national organisation responsible for the long-term management of the UK's radioactive waste, in 1988 and thereafter held a number of senior management positions in the organisation. He was responsible for the research and safety assessment programmes for a number of years, and, for some time, for the specification and implementation of the site characterisation studies at Dounreay and Sellafield. At the time of his retirement Alan Hooper was the Chief Scientific Advisor at the UK's Nuclear Decommissioning Authority Radioactive Waste Management Directorate. In this role he was responsible for advising on the overall science and engineering programme and its key deliverables, on communicating the programme to scientific institutions in the UK and internationally, and on benchmarking it against international best practice.

Alan Hooper was a member of the Scientific Advisory Committee to the Aspo Hard Rock Laboratory in Sweden and played a leading role in initiating some of the large-scale experiments conducted in the facility. He gave evidence to the public inquiry into the rock characterisation facility at Sellafield and has also given evidence to various parliamentary select committees. He is the named inventor of the specially formulated backfill material proposed for use in the Nirex Phased Geological Repository Concept for intermediate-level wastes that remains the reference concept for assessments of disposability of packaged wastes.

Twice, at the invitation of the French Government Ministries he chaired an international review of the French geological disposal programme, on the second occasion, in 2005, in support of the policy decision to be made in France in 2006. He is a member of the Site Investigation Expert Review Group (SIERG) established by SKB (Sweden) to support the siting process for a geological repository and is Chairman of the Independent Technical Review Group established by the Nuclear Waste Management Organisation of Canada to review its technical programme.

For several years Alan Hooper was a member of the UK delegation to the OECD Nuclear Energy Agency (NEA) Radioactive Waste Management Committee and its Integration Group for the Safety Case, through which he has co-authored documents to explain the nature and purpose of the post-closure safety case for geological repositories, and associated confidence-building measures. Previously he was Chairman of the NEA's Site Evaluation and

Design of Experiments Co-ordinating Group for seven years, promoting initiatives such as The Clay Club, GEOTRAP Project and workshops on specialist topics such as conceptual modelling. He has also chaired various technical specialist groups for the IAEA working on the scientific and technical basis for radioactive waste management and the associated safety requirements, and advising on the IAEA Waste Action Plan. This included chairing the group that developed the IAEA publication on the scientific and technical basis for the near-surface disposal of low- and intermediate-level radioactive waste. He has served on various advisory groups to the British Geological Survey.

Alan Hooper has authored more than 40 papers accepted for publication in the peer-reviewed chemistry and materials science literature and a similar number of papers published in conference proceedings. He has authored a total of about 200 reports published by CEGB or Nirex and has contributed to books on the subject of radioactive waste management

Prof. Steve Jones

Professor Steve Jones (BA., PhD) is Principal Consultant at the Westlakes Research Institute. He is also an Honorary Professor of Environmental and Occupational Toxicology, at the University of Central Lancashire, and is a Visiting Professor at the Industrial Ecology Research Centre, at the University of Liverpool. He has over 16 years experience at senior level in industry and as a consultant, largely concerned with the assessment and management of environmental issues and the interactions between business needs, scientific issues and understanding, legislation and regulatory policy, public and political expectations.

He is an invited independent member of the National Dose Assessment Working Group, concerned with methodologies for assessing doses to the public from radioactivity in the environment. He acts as peer reviewer for many scientific journals in the fields of radiation protection, dosimetry, radioecology and occupational medicine

His experience includes:

- Direction of industrially focused R&D in the environmental and life sciences.
- All aspects of practical health physics, including radioactivity measurement, dose assessment, environmental monitoring, occupational exposure control, discharge assessment and emergency preparedness.
- Interpretation of occupational and environmental epidemiological data.
- Preparing environmental assessments and working with environmental legislation and regulators to negotiate authorisations and consents.

- Development of environmental policy and related environmental management systems, and conducting environmental liability reviews in relation to due diligence.

- Legally-related scientific work, both as scientific advisor and an expert witness, in both civil and criminal proceedings, together with judicial review and public inquiry work concerned with environmental impact issues.

- Participation in BPEO, MADA and related environmental decision-making processes, involving stakeholder dialogue and concerns about environmental performance and safety.

- Acting as an expert for the FCO in relation to actions against the UK Government in respect of Sellafield's discharges to the Irish Sea.

- Contributing to the development of integrated waste strategies for nuclear sites.

- Participating in collaborative European research projects on protection of the environment from ionising radiation.

Mr Bill Lanyon

Mr Bill Lanyon (MA) is a Director of Fracture Systems Ltd. He has worked on the modelling and interpretation of flow in fractured rock for over 25 years. He is a hydrogeologist and is a member of the American Geophysical Union, the Society of Petroleum Engineers, the Royal Statistical Society and the Association for Project Management.

He has specialised in the computer modeling of flow in fractured rock and contributed to the development of the NAPSAC Discrete Fracture Network model.

Within the UK, he has participated in the DEn Hot Dry Rock Project, the Nirex Sellafield Geological Investigations and Dounreay ILW Shaft Studies. Within the Sellafield Investigations he worked largely on the hydrogeology of the Borrowdale Volcanics within the post-completion testing, interpretation and safety assessment teams and coordinated the development of the hydrogeological dataset.

Within the Swiss national programme for radioactive waste disposal he has worked on geosynthesis/geodataset development for the Krystallin-1, Wellenberg and Entsorgungsnachweis (Opalinus Clay) Repository Projects.

He has extensive experience in Underground Research Laboratories (URLs) having worked on the OECD/NEA Stripa Project; a variety of experiments at the Grimsel Test Site covering Excavation Damage Zone, gas migration through

engineered barriers and colloid formation and migration; EDZ and gas migration experiments at the Mont Terri Rock Laboratory.

He has provided expert review to SKB, NAGRA and Nirex and is currently the reviewer for the SKB Äspö Modelling Task Force for Task 7: Modelling of the Olkiluoto Site in Finland and has acted as a reviewer to the JAEA Mizunami URL.