Geological Disposal

RWMD approach to issues management

March 2012
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Preface

This report is Version 2 of RWMD’s approach to issues management and supersedes the original report published in August 2011. Version 2 has been published to include the outcome of our evaluation of issues that have been added to the issues register in Appendix B of this report. This therefore subsumes content from previous documents that we have produced in response to issues, including the response to the Nuclear Waste Advisory Associates’ Issues register. This report also includes new issues that have been raised and added to the register in the period August 2011 to March 2012.

Version 2 includes a number of improvements that have been identified as we have gained experience of operating the issues management process. These are:

- Removing the management of opportunities from within the issues management process. However we will still use the process as a way of identifying opportunities (by allowing them to be raised as issues by regulators and stakeholders) but by managing them alongside management of risks within the NDA risk register;
- Focusing the process on issues raised externally by the regulators and stakeholders which fit with the definition of being challenges or concerns. For completeness we have also included the internal issues that are evaluated as important in the generic Disposal System Safety Case and those raised through operating disposability assessments of waste packaging proposals;
- Removal of the term ‘key issue’ and removal of the screening of ‘key issues’ in the issues management process. Issues are already categorised in relation to how important or significant they are within our process for identification and delivery of the technical programme;
- Expanding the evaluation step of the process to address all issue topics. In previous communications we had proposed that this step would only apply to the more important issues in our programme;
- Providing reference to specific sections of existing documentation where more information can be found on the current state of knowledge for a particular topic. We have also provided references to sections of our research and development programme document where the relative importance or significance of each topic area within our work programme is described to support the majority of the evaluation responses;
- As part of our future plan to produce a technical programme document we will communicate our work to address externally raised issues together with the information needs identified internally. We expect this to form the basis of the reporting and monitoring for step 4 of the issues management process;
- Addition of a new section to this report describing the status of our work programme to address issues raised, the expert review of Version 2 of the issues register, and a brief description of the more important issues in our programme; and
- In response to commitments previously made, or in response to stakeholder feedback, we have made a number of improvements to the presentation of the issues register in Appendix B.
Executive Summary

The Nuclear Decommissioning Authority (NDA) has established the Radioactive Waste Management Directorate (RWMD) to manage the delivery of geological disposal for higher activity radioactive wastes, as required under UK Government policy published in the Managing Radioactive Waste Safely (MRWS) White Paper.

As implementer for geological disposal in the UK and in preparation for future phases of the geological disposal programme (e.g. surface-based investigations and beyond), we are developing a process for managing issues, focussing on those raised by regulators and stakeholders. The process has also been developed to make our approach to managing issues more open and transparent, and to provide an opportunity for all who take an interest in geological disposal to provide input on our approach and influence our work programmes.

In this summary we present our developing issues management process introducing the types of issues raised externally that affect our programme and how we manage these, noting that issues raised by regulators and stakeholders are one of a range of inputs that influence our work programme. This report outlines our overall approach to how we are developing an issues management process, including the work we are undertaking to develop an ‘issues register’ and the development of a process to communicate and report periodically on all issues. In developing the process we have been taking into account comments from stakeholders and regulators, an approach we plan to continue, hence the process described in this report should be seen as work in progress.

We use the term ‘issue’ to mean any challenge, or concern that is raised internally or externally that could affect the implementation of a geological disposal system.

Issues concerning geological disposal can be raised from a range of sources. These may include organisations and others working in relation to geological disposal, including any individuals or groups who take an interest in our work. These are documented and managed by the issues management process described herein. Issues raised to date are mostly scientific, technical or environmental in their nature, although they may also be economic, social or ethical. For completeness we have included the internal issues that are evaluated as important in the generic Disposal System Safety Case and those raised through operating disposability assessments of waste packaging proposals. Other internally raised issues which are often information needs are already documented and managed by our technical programme and therefore have not been reported herein.

All issues raised have been grouped into topics, evaluated and recorded on our register. These will be pro-actively monitored regularly to ensure they are being managed effectively in our work programme. This will integrate with our existing mechanisms for monitoring progress of work to address information needs prioritised in our work programme.

Of all the issue groups, two of the more important issues relate to gaseous releases of carbon-14 and the long term risks that could arise from disposal of uranium stocks. Herein we describe the work we are doing to establish integrated project teams specifically focussing on work to address these and these are supported by the issues management process.

The next phase of developing the issues management process will focus on engagement with issue raisers (both regulators or stakeholders) in order to discuss and identify issues that have been addressed and therefore can be closed together with the development of later steps of the issues management process and improvements to the functionality of the issues register.
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<tr>
<td>CoRWM</td>
<td>Committee on Radioactive Waste Management</td>
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<td>DSSC</td>
<td>Disposal System Safety Case</td>
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<td>DECC</td>
<td>Department for Energy and Climate Change</td>
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<td>EA</td>
<td>Environment Agency</td>
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<td>GDF</td>
<td>Geological Disposal Facility</td>
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<td>GWPS</td>
<td>Generic waste package specifications</td>
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<td>HLW</td>
<td>High-level radioactive waste</td>
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<td>HSE</td>
<td>Health and Safety Executive</td>
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<td>ILW</td>
<td>Intermediate-level radioactive waste</td>
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<td>IRP</td>
<td>Issue resolution process</td>
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<td>LLW</td>
<td>Low-level radioactive waste</td>
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<td>LoC</td>
<td>Letter of compliance</td>
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<td>MCCIP</td>
<td>Marine Climate Change Impacts Partnership</td>
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<td>MRWS</td>
<td>Managing Radioactive Waste Safely</td>
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<td>NDA</td>
<td>Nuclear Decommissioning Authority</td>
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<tr>
<td>NGO</td>
<td>Non-governmental organisation</td>
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<tr>
<td>NWAA</td>
<td>Nuclear Waste Advisory Associates</td>
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<tr>
<td>NWAT</td>
<td>Nuclear Waste Assessment Team</td>
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<tr>
<td>ONR</td>
<td>Office for Nuclear Regulation</td>
</tr>
<tr>
<td>RWMD</td>
<td>Radioactive Waste Management Directorate</td>
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<tr>
<td>R&amp;D</td>
<td>Research and development</td>
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<tr>
<td>SF</td>
<td>Spent fuel</td>
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<td>WMO</td>
<td>Waste management organisation</td>
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## Term

<table>
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<th>Term</th>
<th>Definition</th>
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<tr>
<td>Issue</td>
<td>We use the term ‘issue’ to mean any challenge, or concern that is raised internally or externally that could affect the implementation of a geological disposal system.</td>
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<tr>
<td>Issues register</td>
<td>Register of raised issues, organised into issue groups that are managed by our issues management process.</td>
</tr>
<tr>
<td>Issue topic</td>
<td>Informative title used to refer to a group of similar or related issues that correlates with areas of our work programme.</td>
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1 Introduction

The Nuclear Decommissioning Authority (NDA) has established the Radioactive Waste Management Directorate (RWMD) to manage the delivery of geological disposal for higher activity radioactive wastes, as required under UK Government policy published in the Managing Radioactive Waste Safely (MRWS) White Paper [1]. As implementer for geological disposal, we are developing a process for managing issues, focussing on those raised by regulators and stakeholders. This report outlines the approach we are adopting to do this, specifically communicating our developed issues register and our plans to maintain and improve this. It builds on and supersedes an earlier note distributed for discussion with the West Cumbrian MRWS partnership [2]. In developing the process, we have been conducting early engagement activities and have been taking into account comments from stakeholders and regulators, an approach we plan to continue. Hence the process described in this report will continue to be developed and improved as we gain experience of its operation and feedback from others.

This introductory section summarises our approach to issues management, including its aims and objectives, how it has been established so far, and describes those involved with issues management. This includes ourselves, the regulators, our contractors, waste producers, academics, the wider nuclear industry, communities participating in the MRWS site selection process, and all those who take an interest in geological disposal. This section also provides readers with common context on the different aspects of geological disposal within our work programme, which are supported by the issues management process.

This report is Version 2 of RWMD’s approach to issues management and supersedes the original report published in August 2011 [3]. The main report describes the updated issues management process, the improvements that we have made to the process from experience of its operation, how the issues management process has influenced our work programme and its current status. We describe the next steps planned for developing further the process including plans for improving the issues register. Version 2 of the issues register is in Appendix B, which has also been updated to include:

- new issues that have been raised and added to the register in the period August 2011 to October 2011;
- the outcome of our evaluation of issues; and
- a number of improvements to the presentation of the issues register, as described in the introduction to Appendix B.

Improvements to the issues management process and issues register that have been implemented since the last publication are described in Section 4. Subsequent sections of the report and register reflect these improvements.

1.1 What do we mean by issues management?

We use the term ‘issue’ to mean any challenge, or concern that is raised internally or externally which could affect the implementation of a geological disposal system.

Issues concerning geological disposal can be raised from a range of sources. These may include organisations and others working in relation to geological disposal, including any individuals or groups who take an interest in our work. These are documented and managed by the issues management process described herein, focussing on those raised by regulators and stakeholders. Issues raised to date are mostly scientific, technical or environmental in their nature, although they may also be economic, social or ethical. For
completeness we have included the internal issues that are evaluated as important in the generic Disposal System Safety Case (DSSC) [4] and those raised through operating disposability assessments of waste packaging proposals. Other internally raised issues which are often information needs are already documented and managed by our technical programme and therefore have not been reported herein.

In order to ensure that all issues are properly considered and, where appropriate, incorporated into our work programme, we have developed a process to provide:

- A clear view of the issues;
- Visibility of the work we have planned or ongoing in our programme to address issues; and
- A basis for documenting issues, how they have been evaluated, and then responding and engaging with issue raisers on the way in which we are managing and, where appropriate, addressing issues.

In order to integrate the issues management process with other RWMD processes and avoid duplication, we have not applied a formal classification to issues in terms of their associated importance or significance. Rather, our evaluation of the impact, knowledge gap and urgency associated with each issue topic is available in the equivalent text in the R&D Programme Overview Report for the majority of issues raised [5].

1.2 Our work to implement geological disposal

Work to implement geological disposal is currently at the preparation and planning phase as described in the document Geological Disposal - Steps towards implementation [6]. How we deliver the work programme to support the current generic stage of the programme is set out in our technical strategy [7] and is based on an established iterative development approach. The technical strategy describes how the major activities of our technical programme are integrated, and how they support an iterative, needs-driven work programme. It also describes how much of our work programme is generic reflecting that a site and a disposal concept has yet to be identified.

The technical basis for the current stage of the programme is also described in our technical strategy and includes the DSSC. This technical basis is updated as more work is undertaken, including work to address issues that we are responsible for managing.

RWMD has also produced a number of specific strategy and planning documents. These include our R&D strategy [8] and our R&D programme overview [5]. The R&D programme overview sets out the R&D needs in the current preparatory studies phase of the programme. This will be updated to take account of the outcomes of the issues management process.

1.3 How we are developing our process

We are developing our process for issues management by:

- Engaging with the regulators and stakeholders to ensure we are capturing their issues and inputs that affect our programme;
- Identifying best practice from issues management processes operating to support radioactive waste management programmes overseas;
- Identifying requirements and expectations from regulators and stakeholders on the desired features of an issues management process;
- Improving our developing issues management process to meet user requirements and expectations; and
Trialling features of the developing issues management process to identify further improvements to develop confidence in the approach.

1.3.1 Scope and source of issues that affect our programme

A range of activities can lead to issues being raised as illustrated in Figure 1. Issues are not always raised as issues, more often they are communicated as comments, suggestions of where work is needed (i.e. the solution to an issue), information needs, queries, or questions. Therefore during this early phase of developing our issues management process we have adopted a comprehensive and inclusive approach by considering all externally-raised issues and inputs. We have also included the internal issues that are evaluated as important in the 2010 generic DSSC and those raised through operating disposability assessments of waste packaging proposals.

Figure 1 Sources of issues that arise in our work to implement geological disposal
1.3.2 Requirements and user expectations for issues management

We have sought early engagement with a wide range of interested parties to ensure we understand the requirements and expectations of how an issues management process could operate. To date this has included engagement in the form of presentations together with question and answer sessions with regulators; CoRWM; DECC; the West Cumbria MRWS partnership; our contractors; NGOs (such as NWAA); sister waste management organisations (WMOs); waste producers; and our own staff. We plan to continue this engagement to support continuing development of the requirements and user expectations of our issues management process. This will be combined with formal feedback from scrutinisers of our work and from feedback received from a wider range of interested parties once the process is publicised further (for example feedback from this publication and our planned future publications on our issues management process as outlined in Section 4).

Based on the expectations and requirements from early engagement with the regulators and others we have established a set of principles that we have used and will continue to update to help support the ongoing development of our issues management process. These are:

- Simple and clear terminology and process description – by using plain English and avoiding the use of jargon to describe aspects of our issues management process;
- Comprehensive – by aiming to recognise and record all externally raised issues regardless of origin. This allows anyone to raise an issue, see how we have evaluated it, how it fits in with our work programme and how the issue is or will be managed;
- Evidence-based – by considering the range of information available on an issue in our evaluation of issues. This means providing the evidence on which our evaluation of issues is based;
- Openness and transparency – by publishing our issues process and issues register so that anyone can see the issues that have been raised and the work we have planned or ongoing in our programme to address issues;
- Manageable – by operating a process that is effective and manageable, such that it is seen as a helpful tool, rather than an overly onerous process;
- Accessible – by providing access to the issues and underlying evidence base at varying levels to suit a broad range of audiences;
- Clear objectives and boundaries – by making sure the scope of our process is understood by communicating how issues are considered within the context to which they relate. This provides clarity on the issues that are beyond the scope of our programme;
- Integration with other aspects of our programme – by making sure that our process works well along side other programme management processes and that we make these relationships clear;
- Success criteria for the process – by establishing success criteria\(^1\) we and others are able to gauge the value of an issues management process, and identify improvements to the process in meeting its set objectives;

\(^1\) Success criteria for the process have not yet been established. This is part of our plans of future work in developing our issues management process.
• Building confidence in our process – by building confidence in our process we want to support many stakeholders, who are not necessarily interested in particular aspects of individual issues, but want to see that we are managing issues appropriately. Gaining a sense that we have a robust and effective process for communicating and managing issues, with accepted governance and appropriate scrutiny arrangements, will help support wider confidence in our process;

• Proactive communication – by proactive we mean going out to stakeholders to engage them early in the process; and

• Addressing issues – by addressing issues we mean developing a sufficient understanding such that no more work on the issue is required. We recognise there may be a range of views on the work required to address an issue, hence it is important that we continue to engage with stakeholders and regulators in developing our issues management process.
2 Our issues management process

In this section, the ways in which we propose to manage issues are described, particularly focusing on how our issues management process integrates with other important processes used to deliver our technical strategy [7].

2.1 Framework

In order to frame issues within our issues management process we have, as much as possible, adopted the same structure as used in other areas of our programme (i.e. topic headings used in the R&D programme overview document [5]).

This enables us to manage issues in a way that maps easily into already established programme management processes, and also provides consistency for all stakeholders in how we communicate on each of the important aspects of our current programme. We recognise that due to the evolving nature of implementing geological disposal, this framework will need to be adapted for each phase of the programme. For example, as we move from the preparatory studies phase towards implementation, it is anticipated that the issues will be framed more by site-specific and concept-specific safety cases aligned to licensing submissions.

There are a number of external requirements / inputs, including the inventory, the MRWS White Paper, regulatory requirements, stakeholder views and interactions with the broader nuclear industry that also frame our programme. It is important to recognise these as part of our approach for managing issues.

Issues management will help ensure that we are prepared for key decisions in each phase of implementation. This will include supporting our inputs to the MRWS site selection process [7] and our regulatory submissions [9].

2.2 Terminology

We have updated the terminology used in previous communications [2] regarding our developing issues management process in response to feedback from stakeholders and regulators².

The term ‘issue’ is used in our process to mean any challenge, or concern that is raised internally or externally which could affect the implementation of a geological disposal system. Issues raised to date are mostly scientific, technical or environmental in their nature, although they may also be economic, social or ethical.

² Changes made to terminology from previous publications about our developing issues management process with a view to removing the use of jargon include: (i) ‘potential issue’ changed to ‘issue’; (ii) removal of terms ‘concept issue’ and ‘key issue’; (iii) ‘potential issues list’ changed to issues register; (iv) and removal of the terms concept issues register and key issues list.
2.3 Approach to managing issues

Our approach to managing issues comprises a number of steps, each closely linked with our overall process for identification and delivery of the technical strategy. Figure 2 illustrates each step, and a more detailed description of each step is provided in the following sections of the report.

Figure 2  Approach to managing issues relating to geological disposal

![Diagram showing steps 1 to 5: Capturing issues raised, Grouping issues into topics and recording on the issues register, Issue evaluation, Reporting and monitoring planned work to address issues, Periodic update of the issues register and evaluation responses.]

2.3.1 Step 1 – Capturing issues raised

We capture issues that originate from a wide range of sources including:

- Internal issues that are evaluated as important in the 2010 generic DSSC [4];
- Packaging assessments, self challenge, peer review;
- Regulators – as part of the regulators’ joint-issues resolution process (IRP) used by the Office for Nuclear Regulation (ONR) and the Environment Agency (EA)[10];
- CoRWM – through scrutiny of the Government’s and NDA’s proposals, plans and programmes to deliver geological disposal;
- MRWS Community Siting Partnerships – including issues raised during partnership meetings;
- Waste producers and potential “New Build” (i.e. new nuclear power station) operators; and
- Other stakeholders – this includes issues raised by NGOs and other organisations, or questions and queries.

3 Requests for readily available information (i.e. published reports) will not be recorded in our issues register as these are dealt with under our request for information policy.
2.3.2 Step 2 – Grouping issues into topics and recording on the issues register

Once raised, issues are assigned a unique ID number and recorded on our issues register. For each individual issue the following information is recorded:

- Description of the raised issue;
- Source of the issue (e.g. a publication, an email enquiry from an individual or organisation, programme of work etc); and
- Date raised.

In order to ensure the process for managing issues is coherent and practicable we then group issues into topics. We group identical or similar issues that would be addressed or partly-addressed by a piece of work or existing package of works, where possible, correlating to suitable topic titles of our work programme. The majority of issue topics contain multiple issues, however in a few instances there may be only one issue. Hereinafter, issue groups are referred to collectively as issue topics and specifically the remaining steps of the issues management process are applied to issues at the ‘topic level’.

The issue topics currently on the register are listed in Appendices A and B.

2.3.3 Step 3 – Issue evaluation

Once issues are grouped into topics and recorded on the issues register, each topic is then subject to an initial evaluation. As discussed in Section 1.3.1, issues raised externally are not always raised as problems or concerns (e.g. they are often raised as solutions to issues). Hence, the evaluation step is needed to ensure we have a clear understanding of what the issues are, if they are unclear we may engage with the issue raiser to ensure that we have interpreted the issue appropriately. The evaluation is focussed on determining whether the issues need to be addressed or have already been sufficiently addressed, by drawing from the information in our work programme and the knowledge of science, technology and engineering underpinning the development of a GDF. The evaluation step therefore interfaces with our established process for programme delivery as illustrated by Figure 3.

The evaluation is relatively brief, so as not to reproduce information that is available elsewhere. In each evaluation response we (usually) agree that the issues raised within the topic need to be taken into account in our work programme, specifically indicating for each:

- The current state of knowledge, against what we consider we need to know at this stage in our programme, including if they are issues managed by knowledge already available (and therefore could be effectively ‘closed’);
- Relevant references to more detailed information, including references to sections of the R&D Programme Overview document [5] where the relative significance and importance of issues is described for the current stage of the programme;
- Specific work activities either planned or ongoing in our programme to address the issues raised, often noting if they are issues that can only be managed (i.e. be solved or substantially better understood) once we progress to future phases of implementation (e.g. issues that are site-specific or concept-specific); and
Whether an issue needs to be managed by another process (e.g. an opportunity or a risk\(^4\)), is beyond our scope of work, or is considered to be addressed (and therefore effectively ‘closed’).

Figure 3  Diagram that illustrates the work flow for the evaluation step including integration with programme delivery

For some of the issues raised, we may not agree with some of the aspects of the wording of issues in terms of associated importance and significance, uncertainty with respect to our current knowledge or the implied urgency and scope of work required to address an issue \([11]\). Where this is the case, we have provided our judgement of its relative importance to a particular driver of our programme and provided reference to sections of our R&D Programme Overview Document where more details are provided \([5]\).

\(^4\) Our risk management procedure defines a risk as an uncertain event that, should it occur, may impact positively (opportunity) or negatively (threat/risk) on the outcome of defined objectives. Where raised issues meet this definition we manage the issue through our risk management procedure and record this on the issues register.
Each evaluation is undertaken by an issue owner, a member(s) of our staff most appropriately qualified to evaluate the issues. It is the responsibility of issue owners during the evaluation step to check the grouping of issues into respective topics for consistency with our work programme. If an issue has been wrongly assigned, it can be reassigned to another or new topic. It is also during this step that an issue may be evaluated as being needed to be managed by another process or is beyond our scope of work. Where this is the case, it is indicated within the evaluation response. Evaluation responses are prepared or updated (to reflect new issues that may be added to an existing topic) and recorded on the issues register (see Appendix B). Where relevant, evaluation responses subsume content from previous documents that we have produced in response to issues, including the response to the Nuclear Waste Advisory Associates’ issues register [12].

Following completion of each issue evaluation, we intend to engage with issue raisers (both regulators and stakeholders) in order to discuss and identify issues that have been addressed and therefore can be closed.

To-date we have completed the initial evaluation for all issue topics on the register. It is hoped that for the majority of cases, our evaluation response will provide enough information for those who raised an issue to be confident we have considered and are managing their issue appropriately. This will be discussed with issue raisers during engagement of each evaluation response when we will be able to establish those issues that are considered to be addressed and others that may need to be supported through further dialogue on the issue and ways for taking it forward (as described in Section 3.1.3).

2.3.4 Step 4 – Reporting and monitoring planned work activities to address issues

Processes for identifying, developing and delivering work to address issues are already well established within our iterative development process and project approach to programme delivery [7]. To avoid duplication across our processes we propose to integrate the reporting and monitoring step of issues management with future plans for reporting and monitoring of all planned work activities in our programme [7]. Integration of issues reporting and monitoring with the work programme is a strategy adopted by the majority of more advanced geological disposal programmes. This has been observed in our review of issues management processes in operation internationally and in our discussions of lessons learned with other waste management programmes.

Developing the exact approach and timing for integrating reporting and monitoring of planned work activities to address issues with the programme delivery process will be the focus of the next phase of developing our issues management process. This will include consideration of how we improve communication of our work programmes to address the more important issues.

We expect that this step will provide reference to the information that we currently use to deliver our work programme [6]. This information is based on the approach illustrated in Box 1 which uses seven structured questions to support an informed judgement of the need to do work by assessing the importance or significance of the topic area (the impact); how much more we need to know (the knowledge gap); and at what stage of the programme we need the results (the urgency). Upon the completion of work to address an issue we will re-evaluate the classification of the issue (by evaluating the impact, knowledge gap and urgency associated with an issue) and evaluate the need for further work. We will report on these aspects by updating our technical basis through publications and by including our evaluation when monitoring and reporting activities to address raised issues.
As part of our work programme we already undertake engagement activities surrounding both the plans for our work activities and the outputs of work activities [13]. This step of the issues process will provide input to the engagement activities planned by the work programme in particular areas.

2.3.5 Step 5 – Periodic update of our issues register and issue topic evaluation responses

As work is progressed to address issues we will undertake periodic updates of the issues register and issue topic evaluation responses. This will be to update the issues register and evaluation response to reflect the outcome of engagement activities with stakeholders regarding our evaluation responses to issues raised (in step 3) and our work planned and undertaken to address them (in step 4). It will also take into account new issues as they arise. The exact timing of the periodic updates will be dependant on the number and frequency of issues raised together with the timing and approach adopted for step 4 of the issues management process. At a minimum we expect to make an annual update to the issues register with additional periodic updates made on a needs-driven basis (i.e. if a large number of issues are raised that necessitate an update).

One of the most important aspects that we intend to focus on within step 5 of the issues management process is that of communicating the outcome of our engagement on issues that we believe we have addressed and are therefore could be effectively ‘closed’. For many issues, following the completion of work and as we progress through future phases of implementation, the answer to the ‘seven questions’ as described in Box 1 will change. Changes to such classifications will be a key aspect of evaluating outputs of work in step 5 and updating the issues register to reflect the current status of an issue, and ultimately addressing issues. In doing this we recognise that for some issues we will need to engage with a wide range of stakeholders and independent experts on issues we consider to be addressed. Section 3.1.3 provides more details on the methods and approaches we are investigating to help us with this aspect of step 5 of the issues management process.
Box 1 Overall process for identification and delivery of the technical programme [7]

In the development of the detailed technical programme of work, a structured list of seven questions is used, which includes an assessment of the importance or significance of a need (the impact), how much more is needed to be known (the knowledge gap), and at what stage of the programme the results are needed (the urgency).

The seven structured questions are as follows:

- What is the driver for the work?
- What does RWMD need to know by when?
- How important or significant is this topic?
- What is the ‘knowledge gap’?
- What is needed to be done to fill it?
- How long will it take?
- How urgent is the task?

The exact timing of individual activities will also depend on a number of additional factors including:

- Opportunities such as those for collaboration in joint international programmes;
- Development and maintenance of key skills in the supply chain;
- Reducing risk carried by the project by bringing forward some pieces of work;
- Available resource; and
- Available budget.
2.4 Governance and scrutiny of our approach

Governance and scrutiny of our issues management is provided in a number of ways. These include:

- Internal ownership of issues by a member of our staff most appropriate to assess the issue. Internal ownership of issues ensures that they are evaluated in light of the ‘bigger picture’, or context required, such as understanding the ‘current state of the art’ for a particular aspect of our programme;

- Internal review and approval of issue assessments and proposed work activities. Internal review and approval ensures that due process is followed to ensure our issues management process is carried out in a consistent manner across our organisation. It includes review, scrutiny and independent internal challenge provided by the Health, Safety, Security and Environment (HSSE) Function, together with expert scrutiny provided by our technical advisory committee which is an independent expert group who scrutinise the RWMD technical strategy, programme and activities. The issues process also provides senior management with regular visibility of the issues raised and review of the work being undertaken to address issues through approval of issue evaluation responses;

- Progress with issues management will be brought to the attention of the Geological Disposal Implementation Board (GDIB) which is chaired by a Government minister. We will, when the need arises, provide updates to GDIB by highlighting any important issues and indicating progress with the work developed to address these (for example by producing GDIB communications [14]);

- Scrutiny by the regulators on aspects of our work to address issues that are relevant to safety, security and environmental protection are subject to scrutiny by our regulators. Of particular importance will be our responsiveness and interface with scrutiny provided by the regulators’ joint-issues resolution process (IRP) as described in Section 2.5 [10]; and

- Scrutiny provided by the Committee on Radioactive Waste Management (CoRWM) which provides independent scrutiny and advice to UK Government and devolved administration Ministers on the long-term radioactive waste management programme, including storage and disposal [1]. To-date CoRWM has provided us with informal scrutiny of the issues management process as reported in NDA/RWMD/081 Issue 1. Comments received have provided valuable input to support some of the improvements reported herein both to the issues process and to the presentation of the issues register in Appendix B.

In addition to the above mentioned governance of our process, and scrutiny provided by the regulators and CoRWM, we aim to provide opportunities for wider scrutiny of our process by publishing our evaluation responses for each issue topic.
2.5 Current status of the ‘issues register’

The ‘issues register’ is included in Appendix B of this report. Its current status is Version 2. Since its last publication we have made a number of improvements to the presentation of the register and are continuing to make plans for its future development away from a paper-based document, to improve its functionality. Sections 2.5.1 and 2.5.2 respectively describe the sources of issues, and the current content and functionality of Version 2 of the issues register.

The issues register will be updated regularly (on a needs-driven basis, i.e. when new issues are added and evaluated) as described in Section 2.3.5.

2.5.1 Issues sources on the register

The issues currently included in the register originate from a number of sources. To-date these include issues that have been either raised specifically to us by stakeholders, many through engagement activities surrounding the West Cumbrian MRWS Partnership [15]. Others we have selected from a number of recognised state of the art reports or review documents on geological disposal, including our own generic DSSC [4]. Going forward we plan to improve the way in which issues are raised through engagement with the regulators and stakeholders. Specifically in 2012 we are engaging with the regulators to establish further the relationship between the issues register and the regulators joint-issues resolution process and associated register (described further below). We are also planning further engagement with waste producers to discuss how they can raise issues prior to the submission of waste packaging proposals for disposability assessment.

The sources of issues currently on the issues register includes:

- Peer review comments of the generic DSSC that are yet to be addressed, this includes some comments provided by the regulators from their early review of a number of specific documents in the DSSC suite5 [16,17,18];
- Issues raised by ourselves through operating our disposability assessment process [19];
- Information needs that are evaluated as important in the 2010 generic DSSC [4];
- Issues raised in a report produced for the Environment Agency’s Science Programme, titled ‘Technical issues associated with deep repositories for radioactive waste in different geological environments’ [20];
- Committee on Radioactive Waste Management (CoRWM) reports [21,22];
- The European Commission Joint Research Centre (JRC) report on geological disposal [23];
- The issues register produced by the Nuclear Waste Advisory Associates (NWAA) [12];
- The Greenpeace funded report titled ‘Rock Solid? A scientific review of geological disposal of high-level radioactive waste’ [24];
- Reply to the NDA response to MRWS paper 146 by Professor Stuart Haszeldine, University of Edinburgh [25]; and

5 Access to the 2010 generic DSSC was provided to the regulators to provide early visibility of a number of specific documents. This was not part of the formal review of the DSSC which the regulators have recently completed. Formal review comments from the regulators and CoRWM of the 2010 generic DSSC will be captured in the next version of the issues register.
The report titled ‘Why a deep nuclear waste repository should not be sited in Cumbria: a geological review’, authored by Professor David Smythe [26];

The individual issues from these sources are listed under the topics they have been allocated to in Appendix B. These have been presented as they were raised, i.e. minimal rephrasing or interpretation by RWMD.

We have also undertaken an exercise to evaluate approximately 400 internally raised information needs associated with our work programme that we previously referred to as issues [2]. In doing this we have considered if they are:

- Already identified as information needs in our R&D programme overview document and therefore effectively a duplication;
- Newly identified information needs to be added to our programme;
- Addressed by completed work that is documented in our technical baseline, and therefore effectively ‘closed’; or
- Risks or opportunities that should be managed by our risk management process.

Ensuring that we avoid duplication of work across separate processes, as exemplified above, is a part of our approach to continually improving our issues management process through iterations of using the process and talking to a range of stakeholders.

Since January 2011, the regulators (the Office for Nuclear Regulation (ONR) and the Environment Agency) are operating a joint-issues resolution process (IRP) to capture issues that the regulators consider may impact future regulatory decisions. This issues resolution process and the currently identified issues are published [10] as a database on the regulators’ joint website on regulating geological disposal. This database supersedes the Issues Resolution Process and associated technical issues database that the Environment Agency operated previously. At present the issues raised on the regulators’ database relate to our organisational structure and hence are not within the scope of our issues management process.

2.5.2 Contents and functionality of the ‘Issues Register’

The issues register in Appendix B of this report is a paper-based system and therefore has limited functionality. It currently totals almost 200 pages and is structured using the main areas of our work programme. Since its contents are wholly responsive to issues raised, it does not detail all of our work activities, since there are many areas of our work programme where no issues have been raised by the regulators or stakeholders. Therefore the issues register and its contents should not be considered a comprehensive description of our work programme.

The contents of the register reflect the fact that we have to-date developed and completed steps 1-3 of the issues management process, although we note that we have yet to undertake engagement activities in order to discuss and identify issues that have been addressed and therefore can be closed. In addition to beginning such engagement activities in support of step 3, we have yet to develop and complete steps 4 and 5 of the issues management process. Version 2 of the issues register therefore does not include:

- Indicators for issues that we consider to be addressed – this will be included in the next version of the issue register following engagement and discussion with issue raisers (as described in step 5 of the issues management process); or
- Indicators for the relative significance of an issue – this is already undertaken within our process of programme delivery and is documented in our R&D Programme.
Overview [5] and will be communicated in a future publication of our technical programme.

3 How you can use our issues management process

We have been encouraged by the constructive feedback we have received on our issues management process since publication of Version 1 of the issues register [3]. We welcome further engagement on the process or specific issues.

3.1.1 Raising issues

If you have an issue that you would like to raise that relates to implementing geological disposal in the UK, please contact NDA via email (rwmdfeedback@nda.gov.uk) or in writing, addressing your issue to:

Dr Elizabeth Atherton
Head of Stakeholder Engagement and Communications
Nuclear Decommissioning Authority
Radioactive Waste Management Directorate
Building 587
Curie Avenue
Harwell Oxford
Didcot
Oxfordshire OX11 0RH

If raising an issue, please state if you are an individual or representing the views of an organisation. If you are raising an issue on behalf of an organisation, please make it clear who the organisation represents and, where applicable, how you assembled the views of the members. Please also indicate if you agree to our publishing this information on our issues register or whether you prefer that your issue be recorded on our register as being raised by an anonymous individual or organisation.

3.1.2 Providing feedback on our developing issues management process

We are in the early phase of developing our issues management process and therefore welcome feedback and input. If you would like to provide feedback, please contact NDA as in Section 3.1.1 above.

3.1.3 Taking issues forward together

We recognise that for some issues there is a diversity of viewpoints which will require mechanisms for taking forward issues together. We will provide opportunities for further dialogue on such issues on a case-by-case basis. In preparation for this we are exploring the potential use of a number of mechanisms for addressing issues when there are differences of opinion about science and its implications. An introduction to some of these is given in Box 2. Taking issues forward together using such mechanisms enables open discussion of the issues and reaching a shared and balanced resolution. This open and transparent approach to managing issues will hopefully reassure interested parties that we are identifying, prioritising, managing and evaluating work appropriately to implement geological disposal.
Box 2 Potential mechanisms to support success of our issues management process

There are many tried and tested methods for supporting issue management and issue resolution when disagreements arise. Examples of these are summarised below:

- Using science appropriately - through engagement approaches that allow stakeholders to challenge our and each others’ views and evidence. The aim is to maximise confidence in the knowledge and understanding about an issue or a decision relating to an issue (for example, deciding if the work planned to address an issue is accepted). This may include taking a holistic, weight-of-evidence view of the underpinning knowledge base.

- Creating protected spaces in which a productive dialogue can take place. This can mean creating an atmosphere in which issues and questions can be explored in a process of honest enquiry.

- Building confidence in our process – ensuring that our issues management process fulfils stated aspirations:
  - open and transparent, with clarity about how the dialogue will inform the decision;
  - stakeholders who wish to be involved are enabled to do so, and can see that due account has been taken of their views;
  - realistic expectations of influence are established;
  - participants should have time to think issues through, and to become well-informed through reliable and balanced resources; and
  - explanations are provided of how eventual decisions are based on the evidence available.

- Joint fact-finding - forming a single fact-finding team comprised of a range of stakeholders representing a diversity of opinions on an issue to work together in an effort to come to agreement regarding relevant facts and a way forward.

- Using ‘honest brokers’ – to integrate scientific knowledge with stakeholder concerns to identify and inform decision options, to place scientific understanding in the context of decision options, and to seek and expand the scope of decision choice.

- Lessons learned from other organisations and successes of other issues management processes – to identify improvements to our process and to develop success criteria to monitor our process.
4 Work in progress

Through operating the developing issues management process, we can provide more visibility to how we are capturing and responding to challenges or concerns raised by regulators and stakeholders regarding aspects of our work. The issues management process has also led to some other positive influences on our work programme. One example is our plan to publish a document that communicates our technical programme, and hence improve the visibility of our work programme. The next steps planned for developing the reporting and monitoring of work to address issues (step 4) and periodic update of the issues register (step 5) will continue to improve the way we communicate and refine our work. Work is also planned to improve the relationship between issues management and our register of uncertainties\(^6\), and improve the functionality of the issues register together with engagement activities to support all steps of the issues process.

4.1 Improving our approach to issues management

In April 2011, we published and presented a briefing note to the West Cumbria MRWS Partnership on our developing issues management process [2]. We used this note as a basis for early engagement with regulators and many of our key stakeholders. Since this time we have published Version 1.0 of RWMD Approach to Issues Management [3].

The updated process as described in Section 2.3 reflects improvements identified through operating the issues management process and takes account of feedback from regulators and stakeholders. Improvements to the issues management process that have been implemented since the last publication are described below:

- Removing the management of opportunities from within the issues management process. However we will still use the process as a way of identifying opportunities (by allowing them to be raised as issues by regulators and stakeholders) but by managing them alongside management of risks within the NDA risk register [27];

- Focusing the process on issues raised externally by the regulators and stakeholders which fit with the definition of being challenges or concerns. For completeness we have also included the internal issues that are evaluated as important in the generic DSSC and those raised through operating disposability assessments of waste packaging proposals. Other internally raised issues which are often information needs are already documented and managed by our technical programme and therefore have not been reported herein [8];

- Removal of the term ‘key issue’ and removal of the screening of ‘key issues’ in the issues management process. Issues are already categorised in relation to how important or significant they are within our process for identification and delivery of the technical programme [8];

- Expanding the evaluation step of the process to address all issue topics. In previous communications we had proposed that this step would only apply to the more important issues in our programme;

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\(^6\) The register of uncertainties is the tool by which we record and manage the impact of different uncertainties on long-term safety of a geological disposal facility. We have already started this with a simple statement of the (largely generic at this stage) uncertainties in the 2010 generic Environmental Safety Case (ESC). As we develop and iteratively update a site-specific ESC, we will develop this register of uncertainties so that it is more specific and detailed.
Providing reference to specific sections of existing documentation where more information can be found on the current state of knowledge for a particular topic. We have also provided references to sections of our R&D programme document where the relative importance or significance of each topic area within our work programme is described to support the majority of the evaluation responses [5];

As part of our future plan to produce a technical programme document we will communicate our work to address externally raised issues together with the information needs identified internally. We expect this to form the basis of the reporting and monitoring for step 4 of the issues management process;

Addition of Section 4 to this report describing the status of our work programme to address issues raised, the expert review of Version 2 of the issues register, and a brief description of the more important issues in our programme; and

In response to commitments previously made, or in response to stakeholder feedback, we have made a number of improvements to the presentation of the issues register in Appendix B. These are described below:

- Addition of unique identification numbers for each individual issue raised;
- Symbols added to indicate: (i) new issues added to the register since the last publication (and are also listed in Section 2.5); (ii) issues that are assigned to more than one issue topic; and (iii) new issue topics created through either the addition of new issues that have been raised or by the re-assignment of issues to different topics following evaluation;
- Communication of issues for each topic within a single table. Previously we had separated externally-raised issues from those raised internally; and
- Adoption of informative titles for issue topics which replace the previously developed issue group titles, where appropriate, correlating to suitable topics and sub-topics of our work programme [5]. Feedback from a number of stakeholders indicated that the previously developed titles worded as issues were too long and difficult to understand.

We anticipate making further improvements as we continue to operate the process. We also anticipate that improvements and potentially substantial updates to the process might be required once we move into future phases of implementation, where many of the issues will become focused on what we need to do in order to meet regulatory licensing permissions.

4.2 Expert review

As part of the production of this document we issued a draft version of the issues register and description of the issues process to a review panel of technical experts commissioned by ourselves to help improve the issues process and register. Detailed review comments received have been addressed by updating the evaluation responses and/or by making the description of the issues management process clearer in a number of places. A number of high-level observations and recommendations were also made that will be addressed in future versions of the issues register and the development of steps 4 and 5 of the process. These are detailed below in italics together with how we plan to take the recommendations forward:

- The expert review noted that “the process of issue selection, description, classification and register management needs to be further developed (and documented in the report) in order to facilitate effective operation of the issues
“management process” - we plan to improve the process of issue identification and closure by discussing improvements with the regulators and stakeholders. Through engagement activities we will also establish if there are particular issue sources that we have not included in the register and add these issues to future versions. The functionally of the register will also be improved to aid its effective operation;

- The expert review noted that “the responses to issues, as documented in the report, should more directly address the specific technical points that have been raised” - grouping issues and preparing responses at the topic level enables a consistent and manageable approach. Since the expert review, we have endeavoured to update the responses so that they adequately cover each issue within a topic. We acknowledge that we have adopted the approach to produce evaluation responses that are relatively brief and high-level but have provided references to our technical programme where more detailed information can be accessed, including the relative importance or significance for each topic area to support the majority of the evaluation responses;

- The expert review noted that “on a longer timescale, there should be consideration of the opportunity to develop a comprehensive issues register in concert with the development of a wider approach to knowledge management” - we plan to use the issues register to assist with the development of knowledge and information management within our work programme. Our change control process and how it relates to our process for capturing updated knowledge will be integral to the way in which we close issues; and

- The expert review noted that “an overall integrated system that included external, all internal and regulatory issues would certainly provide a better overall basis for setting priorities and defining an optimised, goal-oriented technical programme” - as part of our future plan to produce a technical programme document we will communicate our work to address externally raised issues together with the information needs identified internally. This will form the basis of the reporting and monitoring step of the issues management process (step 4) and be used to inform the periodic update of the issues register (step 5).

4.3 Findings from our issues management process

In the period of August 2011 to March 2012 we have applied the methodology set out in Section 2.3 to evaluate all issue topics on the issues register. Of the now 82 topics, two of the more important issues relate to gaseous carbon-14 (issue topic 1.6.1) and long term risks that could arise from disposal of uranium stocks (issue topic 6.3.4). Both of these issues are being managed by our work programme through the establishment of two integrated project teams each focusing on the work we can complete during the preparatory studies phase to support addressing the issue.

In the generic Disposal System Safety Case we have explained why we have confidence in the safety of a geological disposal system and our approach to developing the necessary safety case to demonstrate that confidence [4]. After completing the evaluation step of the issues management process, we remain confident that we will be able to implement a GDF that will be able to meet with the required level of safety provided that a suitable site can be identified through the MRWS Site Assessment Process. We recognise that there remain issues that we continue to address through our work programme and that many of these

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7 Information is defined as something that is produced through processing, manipulating and organising data to answer questions, adding to the knowledge of the receiver. Knowledge is defined as what is known by a person or persons. Knowledge involves interpreting information received, adding relevance and context to clarify the insights the information contains.
can only be resolved once we have undertaken research and investigations at potential candidate sites.

The technical programme in the current generic stage is focussed on development of understanding of the disposal system in the context of generic geological environments and ensuring readiness for the site specific activities in future stages of the programme [7]. Once we enter the surface-based investigations phase, we will take account of the uncertainties that will remain, and undertake the necessary works identified at such time to support addressing all issue topics appropriately.

More details of our technical programme to address issues are provided in our R&D programme overview document [8]. This document provides a description of the relative importance or significance of each topic area (the impact) for the majority of issue topics, including the issues related to gaseous carbon-14 (Section 9.1 of [7]) and the long term risks that could arise from disposal of uranium stocks (Section 10.1 of [7]).

Operation of the issues management process has highlighted the need to bring forward a number of cross-cutting activities to support delivery of our programme. This illustrates the positive changes to our programme that have been influenced by the outputs of the issues management process. These include the observations relating to knowledge management and communication of our technical programme that were also highlighted by the expert review, together with the need for integrated project teams. The issues management process has highlighted that many of the more important issues in our work programme have many aspects that individually are being addressed through our work, but that for issue resolution need to be integrated within a single project. We have therefore initiated the development of integrated project teams for carbon-14, the long term risks that could arise from uranium stocks, and the disposal of spent fuel.

4.4 Next steps

We will continue to operate and improve our developing issues management process. As part of this development we will undertake periodic updates of the issues register and issue topic evaluation responses to take account of new issues raised by the regulators and stakeholders and those that are identified as closed. We will make this available on the NDA website (published in Appendix B of this document).

We have recently received formal review comments from the joint regulators from their scrutiny of the generic DSSC which we are currently reviewing. We anticipate that this will raise a number of issues that will be managed by our issues management process and will be published in an updated version of the issues register.

During 2012 we are also planning to continue engagement with stakeholders and begin the approach for developing step 4 of the issues process (reporting and monitoring of work programmes to address issues). This will be completed by integrating this step with future plans for reporting and monitoring of work activities for our technical programme [7].

In parallel with continuing to develop and gain experience of operating the issues management process we also intend to consider alternative formats for the issues register to improve its functionality (specifically considering both usability and ease of long-term maintenance). Alternatives that we will investigate include consideration of a database format.

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8 Integrated project teams are established for large projects that involve different technical and non-technical aspects of our work programme (for example, tasks on R&D are integrated with design and assessment tasks). Such project teams involve a core of NDA staff and specialist contractors together with input from external sources where important interfaces are identified (for example links with complementary academic research projects and industrial partners).
References
Many of the NDA report references below can be accessed directly by going to the section of the NDA website called 'our role in geological disposal' (www.nda.gov.uk). All NDA reports can also be requested through our bibliography at http://www.nda.gov.uk/documents/biblio/.

<table>
<thead>
<tr>
<th>Number</th>
<th>Reference</th>
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<tr>
<td>18</td>
<td>Extract from 4th NDA-RWMD R&amp;D Advisory Panel Meeting 20th October 2010, Atkins Offices, Bristol, Published by NDA, 2011.</td>
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<tr>
<td>25</td>
<td><em>Reply to the NDA response to MRWS paper 146 by Professor Stuart Haszeldine</em>, University of Edinburgh, 2011.</td>
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Appendix A  Issue Topics

Appendix A is a summary of the ‘issue topics’ currently in Version 2 of the issues register in Appendix B. These are structured by areas and align with topics of the RWMD work programme. Each topic has been evaluated, using the methodology described in 2.3.3. Evaluation responses are included in the issues register in Appendix B. In order to keep Appendix B to manageable proportions there is minimal context provided for each topic. The context can be established in more detail by reading the equivalent text in the R&D Programme Overview Report. New topics created through either the addition of new issues that have been raised and added to the register in the period August 2011 to March 2012, or re-assignment of issues to different topics following assessment, are indicated with a right point arrow (e.g. ▶).

A.1 Development of the underpinning science and technology through research and development activities

Wasteform evolution

1.1.1 - Evolution of vitrified high level waste
1.1.2 - Evolution of spent fuel
1.1.3 - Evolution of intermediate level waste
1.1.4 - Evolution of plutonium wasteforms

Container evolution

1.2.1 - Intermediate and low-level waste container evolution
1.2.2 - Evolution of waste containers for high level waste and spent fuel

Near-field evolution

1.3.1 - System interactions
1.3.2 - Engineered barrier resaturation
1.3.3 - Long-term cement backfill evolution
1.3.4 - Resaturation and long-term evolution of clay-based buffers

Geosphere and its evolution

1.4.1 - Characterisation of groundwater flow
1.4.2 - Impact of coupled thermal, hydrogeological, and chemical processes
1.4.3 - Evolution of the geosphere
▶ 1.4.4 - Rock spalling

Biosphere

1.5.1 - Biosphere assessment approach
1.5.2 - Non-human biota
1.5.3 - Radioactive methane gas
Gas

1.6.1 - Carbon-14 release from intermediate level waste
1.6.2 - Bulk gas generation from intermediate level waste
1.6.3 - Gas generation from high level waste and spent fuel
1.6.4 - Gas migration and reaction

Radionuclide behaviour

- 1.7.1 - Radionuclide migration in groundwater
- 1.7.2 - Radionuclide retardation and immobilisation mechanisms
- 1.7.3 - Other influences on radionuclide behaviour
- 1.7.4 - Data for radionuclide behaviour parameters
- 1.7.5 - Representation of radionuclide behaviour in assessment models

Waste package accidents

1.8.1 - Combined fault accidents
1.8.2 - Fire release fraction data.

Criticality

1.9.1 - Design for criticality safety
1.9.2 - Likelihood of criticality
1.9.3 - Consequences of hypothetical criticality
1.9.4 - Assessment of consequences of hypothetical criticality

A.2 Safety and environmental impact of a GDF

Environmental safety

2.1.1 - Treatment of uncertainty
2.1.2 - Representation of uncertainty in mathematical models
2.1.3 - Mathematical model development
2.1.4 - Assessment of the potential impact of gas
2.1.5 - Building confidence in the long-term safety
2.1.6 - Letter of Compliance – ensuring waste packages will be disposable
2.1.7 – Features, events and processes (FEPs) and scenario analysis
2.1.8 - Methodology for underpinning post-closure safety assessments

Operational safety

2.2.1 - Doses to GDF operators
2.2.2 - Scope of the Operational Safety Case
2.2.3 - Naturally occurring radon
2.2.4 - Consideration of the Office of Nuclear Regulation’s safety assessment principles in the Operational Safety Case

Transport safety
2.3.1 - Scope of the Transport Safety Case
2.3.2 - Transporting Magnox Encapsulation Plant (MEP) waste packages

Strategic environmental assessment
2.4.1 - Methodology for undertaking strategic environmental assessments

Site assessment methodology
2.4.1 - Use of assessments in the site selection process

A.3 Site characterisation

Data acquisition
3.1.1 - Surface-based data collection methods
3.1.2 - Underground investigation methods

Data interpretation
3.2.1 - Data and understanding of geology and hydrogeology for some parts of the UK

A.4 Designing and constructing a GDF

Design development
4.1.1 - Waste package design for high level waste and spent fuel
4.1.2 - Waste package design for intermediate level waste
4.1.3 - Disposal system design requirements
4.1.4 - Construction methodology
4.1.5 - Emplacement strategy
4.1.6 - R&D on repackaging
4.1.7 - Transport system

A.5 Stakeholder engagement

Consultations, stakeholder engagement and communications
5.1.1 - Documentation and stakeholder engagement material
5.1.2 - Assurance of contractors’ reports
A.6 Disposal system specification and derived inventory

Derived inventory
6.1.1 - Derived inventory data gaps, uncertainties and priorities
6.1.2 - Derived inventory methodology

Disposal system specification
6.2.1 - Disposal system requirements structure
6.2.2 - Disposal system requirements specification
6.2.3 - Management of thermal impacts
6.2.4 - Temperature target for intermediate level waste modules
6.2.5 - Barrier interactions in a co-located GDF
6.2.6 - Retrievability and the impacts of retrieval
6.2.7 - Safeguards
6.2.8 - Security

Concept Optioneering
6.3.1 - Disposal concept selection process
6.3.2 - Disposal options for metallic spent nuclear fuel
6.3.3 - Disposal concept optioneering
6.3.4 - Disposability of depleted, natural and low-enriched uranium wastes

A.7 Delivery of our programme

Delivery of our programme
7.1.1 - RWMD process for development of a geological disposal system for UK radioactive wastes
7.1.2 - RWMD process for information and knowledge management
7.1.3 - Research and development strategy

A.8 Policy, licensing and regulation

Policy
8.1.1 - UK Government policy for managing radioactive waste

Licensing
8.2.1 - International marine pollution control legislation

A.9 Cost
9.1.1 - GDF cost model
A.10 Working with waste producers

GWPS

10.1.1 - Strategy for development of the waste package specification and waste acceptance criteria

Upstream Optioneering¹

10.2.1 - Waste packaging grouting facilities at a GDF

¹ We use the phrase ‘upstream optioneering’ to describe the work we do to investigate and identify opportunities for the optimisation of a geological disposal facility for higher activity radioactive wastes in combination with earlier phases of the waste management lifecycle.
Appendix B  Issues Register Version 2

Appendix B is the full compilation of issues organised by their groupings together with each topic evaluation response as described in section 2.3.3. Each response represent a snapshot in time, i.e. they indicate our current state of knowledge, against what we consider we need to know or do at this stage in our programme (March 2012).

Figure 4 illustrates how issue topics are each given an informative title and are structured by areas of the RWMD work programme. New issues added to the register since the last publication, or re-assignment of issues to different topics following their evaluation, are indicated with a right point arrow (e.g. ▶).

Figure 4  Structure and content of the RWMD Issues Register

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<thead>
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<td>- B1.1: Topic of Work Programme</td>
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<td>- B1.1.1: Issue Group Title</td>
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<tbody>
<tr>
<td>B1.1.1</td>
<td>It is also recognised… that there are several key uncertainties (e.g. microbial effects,…) and that the magnitudes of these need to be explored through R&amp;D.</td>
<td>CoRWM Doc. 2545 Geol. disposal of higher activity radioactive wastes. July 2009 12.20, p44</td>
</tr>
<tr>
<td>B1.1.1</td>
<td>There are, however, a number of areas where generic (i.e. not site specific) research would be useful. Examples of these areas are: microbial interactions with wasteforms</td>
<td>CoRWM doc. 2543 Report on R&amp;D for interim storage and geological disposal .. 2.26, 22</td>
</tr>
<tr>
<td>B1.1.1</td>
<td>Microbial processes are poorly understood and may impact on the performance of a GDF. It is desirable to carry out generic research … develop UK capability in techniques for the sampling and characterisation of subsurface microbial communities…</td>
<td>CoRWM doc. 2543 Report on R&amp;D for interim storage and geological disposal .. 6.14, 91</td>
</tr>
</tbody>
</table>

- RWMD Response to group of issues indicating:
  - The current state of knowledge, against what we consider we need to know at this stage in our programme;
  - Relevant references to more detailed information;
  - Specific work activities either planned or ongoing in our programme to address the issues raised: and
  - Whether an issue needs to be managed by another process, is beyond our scope of work, or is considered to be addressed (and therefore effectively ‘closed’)
Unless otherwise stated, in our evaluation response to each issue topic we (usually) agree that the issues raised (either internally or externally) need to be taken into account in our work programme. We may not agree with some of the aspects of the wording of issues raised in terms of associated importance and significance, uncertainty with respect to our current knowledge or the implied urgency and scope of work required to address an issue. We have endeavoured to produce evaluation responses that are relatively brief and high-level but that adequately cover each issue within a topic. We have avoided reproducing information that is already available elsewhere. We have therefore extensively referenced to information available in our Research and Development Programme Overview (NDA/RWMD/073, 2011) and the suite of documents in our technical baseline as described in our Technical Strategy (NDA/RWMD/075, 2011). This includes providing relevant section numbers and including these in the reference.

B.1 Development of the underpinning science and technology through research and development activities

B.1.1 Wasteform evolution

B.1.1.1 Evolution of vitrified high-level waste

Raised issues:

<table>
<thead>
<tr>
<th>ID: 111-01</th>
<th>RWMD to consider the potential for, and implications of, de-vitrification on wasteform performance in the disposal system.</th>
<th>Disposability Assessment Database ID57 high level waste (Preliminary Assessment)</th>
<th>April 2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>ID: 111-02</td>
<td>RWMD to instigate research into the long-term durability of vitrified high level waste to support the disposability of UK high level waste products.</td>
<td>Disposability Assessment Database ID58 high level waste (Preliminary Assessment)</td>
<td>April 2009</td>
</tr>
<tr>
<td>ID: 111-04</td>
<td>There are uncertainties about the reactivity of borosilicate glasses in these circumstances … i.e. in presence of highly alkaline fluids.</td>
<td>CoRWM Doc. 2550. Geological disposal of higher activity radioactive wastes. July 2009 12.35, p47</td>
<td>July 2009</td>
</tr>
<tr>
<td>ID: 111-05</td>
<td>Co-Location of Various Types of Waste in a GDF - several issues on CoRWM doc 2543</td>
<td></td>
<td>October</td>
</tr>
</tbody>
</table>
which research is likely to be required... These issues include: the impact of highly alkaline waters on HLW

Report on R&D for interim storage and geological disposal...

6.10, 90

2009

RWMD response:

The evolution of vitrified high-level wastes under the range of potential geochemical conditions in the geological disposal facility (GDF) is a topic that we need to understand. The geochemical conditions considered are based on a range of circumstances including the consequences of a co-located facility utilising cementitious materials. A GDF would have to be designed to ensure that there would not be unacceptable detrimental interactions between materials forming part of the engineered barrier system such as vitrified waste and alkaline waters. In general there is a good understanding of the long-term evolution of HLW glasses under the expected environmental conditions in a GDF, including the presence of high pH fluids, as these have been studied extensively by a number of overseas Waste Management Organisations (see section 4.4 of the Package Evolution Status Report [1]). Our ongoing work programme to evaluate the behaviour of specific glass compositions used in the UK continues to provide more detailed understanding and input data to support our safety case, and to inform future decisions about what container and concept design is most appropriate for these wastes [2]. Once site-specific information becomes available, we plan to commission further experiments to measure the long-term or ‘residual’ glass dissolution rates for the envelope of UK HLW glass compositions in relevant site-specific geochemical conditions. The aim of these experiments and supporting model interpretation will be to allow us to determine the behaviour of UK HLW glasses in the event of failure of its disposal container over the required timescales.

We would expect in-situ temperatures in a GDF to be sufficiently low that the devitrification of the glass wasteform would not be possible.

B.1.1.2 Evolution of spent fuel

Raised issues:

<table>
<thead>
<tr>
<th>ID</th>
<th>Consider long-term integrity of AP1000 spent fuel and estimate time evolution of instant Release Fractions for high burn-up fuel. Investigate potential for pressurisation of high burn-up spent fuel canisters under fire conditions.</th>
<th>Disposability Assessment Database ID26 Generic Design Assessment of AP1000 Reactor</th>
<th>23rd Sept 2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>ID: 112-01</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ID: 112-02</td>
<td>Consider long-term integrity of EPR spent fuel and estimate time evolution of instant Release Fractions for high burn-up fuel. Investigate potential for pressurisation of high burn-up spent</td>
<td>Disposability Assessment Database ID20 Generic Design Assessment of</td>
<td>23rd Sept 2011</td>
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</table>


RWMD Response:

We plan to obtain further data to develop our understanding of the evolution of spent fuel to support future development of the Disposal System Safety Case. These data are also needed to inform future decisions about what container and concept designs would be most appropriate for these materials. As part of this work the release rate of radionuclides from spent fuel in the event of failure of its disposal container, under disposal conditions, will need to be sufficiently well understood.

At this stage of the programme, we are assessing the relevance of overseas data obtained for LWR spent fuels to UK AGR and Pressurised Water Reactors (PWR) fuels. This includes consideration of the results that will become available from the recently started 7th Euratom Framework (EC) collaborative project studying fission gas releases and instant release fraction (IRF) for light water reactor (LWR) and mixed-oxide (MOX) fuels [1]. This international collaboration project includes a number of objectives that will be met using both experimental and modelling techniques.

In addition to the work ongoing internationally, we have initiated experimental work to measure the matrix dissolution and radionuclide leaching rates for a range of UK AGR fuels under a range of geochemical conditions [2]. In the medium term, we plan to extend these studies to other UK specific fuel types for which we cannot easily extrapolate data from that obtained overseas for other types of spent fuel. Future work in the medium term might include further investigations of Magnox fuels, “new-build fuel” (arising from Generation III+ reactors such as AP1000 and EPR) and “exotic” fuels (those fuels that have not been generated through commercial power generation), if these fuels are declared as wastes and not reprocessed. Work planned to investigate the potential for pressurisation of waste containers for heat-generating wastes under fire conditions is described elsewhere (see for example, topic 1.8.1).

B.1.1.3 Evolution of intermediate level wastes

Raised issues:

| ID: 113-01 | Duration for which engineered barrier system materials may maintain their functions (durability): potential for relatively rapid degradation of packages that contain reactive metals (mainly Magnox swarf). | Environment Agency Science Programme Contractor Report: Technical issues associated with deep repositories for radioactive waste in different geological environments | August 2009 |


| ID: 113-02 | CoRWM is concerned about the level of R&D effort being devoted to determining the lifetimes of intermediate level waste wasteforms. | CoRWM doc 2543 Report on R&D for interim storage and geological disposal... 6.3, 89 | October 2009 |
| ID: 113-03 | Experience with encapsulation of relatively small amounts of reactive metals such as uranium has shown that existing cement formulations would not be suitable for uranium metal fuels. It would thus be necessary to carry out a substantial (and successful) programme of R&D into new encapsulants, such as polymers, glasses and alternative cements. | CoRWM doc 2543 Report on R&D for interim storage and geological disposal... A.21, 103 | October 2009 |
| ID: 113-05 | The relationship between waste form and repository design is a ‘major knowledge limitation’. | Nuclear Waste Advisory Associates’ Issues Register Issue - 33 | June 2010 |
| ID: 113-06 | The selection of appropriate treatment for reactive metals is required. | Nuclear Waste Advisory Associates’ Issues Register Issue - 34 | June 2010 |
| ID: 113-07 | A response to the ‘expansive fracturing’ that has taken place in waste packages in storage is required. | Nuclear Waste Advisory Associates’ Issues Register Issue - 36 | June 2010 |

**RWMD Response:**

Our understanding of the evolution of intermediate level wastes (ILW) is well developed. This is based on a substantial body of work from both national and international programmes over the last thirty years [2]. We continue to support focussed studies, for certain wasteforms, to ensure that ILW and/or low-level waste (LLW) is encapsulated in a suitably durable wasteform. The primary function of the ILW/LLW wasteform is to isolate and contain hazardous radioactive materials in a physically stable wasteform that is
suitable for storage and transport to a geological disposal facility (GDF). Furthermore the wasteform should continue to fulfil this function during the operational phase of a GDF. Once a GDF is backfilled [1], other barriers would also be in place to ensure safety of the system even if the wasteform were to degrade. Nonetheless it is desirable that the wasteform should continue to afford containment during the early part of the post-closure period when the hazard posed by the waste is higher.

Our current understanding suggests that most ILW wasteforms which make use of cement-based materials are suitable for the encapsulation of a variety of wastes and are likely to result in durable wasteforms. The evidence to support the claim is presented in the Package Evolution Status Report [2]. It is recognised more work is needed to understand the evolution of intermediate level waste in a small number of cases. For example, cement-based wasteforms containing Magnox alloy swarf wastes have shown signs of detrimental evolution, associated with the formation of expansive corrosion products generated by the relatively rapid reaction of waste metals with the alkaline porewater present in cementitious encapsulants. Similar concerns exist for other reactive metals present in ILW (mainly aluminium). We have an ongoing R&D programme investigating the potential for significant expansion of cement-based wasteforms containing reactive metals and evaluating the possibility of employing alternative encapsulation materials (e.g. glasses, polymers) for challenging wastes [3]. It is clearly important to understand the potential impact of such evolution processes on the disposability of resulting waste packages. However, we consider that reworking options (e.g. repackaging in suitable overpacks) could be employed in the unlikely event of significant premature degradation of the wasteform [4].

We are establishing an integrated project team to address the overall strategy and development of a corresponding work programme to address issues arising from uranium in the national inventory. This team will support the assessment of the uranium contribution to radiological risks arising from the groundwater pathways.

**B.1.1.4 Evolution of plutonium wasteforms**

**Raised issues:**

| ID: 114-01 | MRWS 146 stated that the NDA appears to be undertaking no specific research on plutonium or MOX fuel disposal. This NDA reply states that a desk study is underway, but agrees that no specific new research on magnesium oxide fuel is being undertaken. It is clear that plutonium dissolution and criticality remain poorly understood at present. Consequently, | Reply to the NDA response to MRWS paper 146 Professor Stuart Haszeldine University of Edinburgh | May 2011 |

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the NDA may need to generate a research program on an entirely new, and globally poorly known, research area of plutonium disposal, which other nations have not undertaken. Such a programme could take many years, or even decades. The realism of this proposition cannot be assessed with the minimal information provided by NDA, and remains an area of very serious doubt.

**RWMD Response:**

The Government has proposed [1] a preliminary policy view to pursue reuse of plutonium as mixed oxide fuel (MOX), converting a high proportion of UK civil separated plutonium into fuel for use in civil nuclear reactors. Any remaining plutonium whose condition is such that it cannot be converted into MOX, will be immobilised and treated as a waste for disposal. Regarding the latter some preliminary research has commenced. One of the main topics to be considered in relation to the geological disposal of plutonium is the selection and design of a wasteform that prevents or minimises the likelihood of a nuclear criticality. This is described in the criticality safety status report [2] and the research and development programme overview [3]. The objective of the preliminary research in this area is to inform RWMD on the performance requirements of the wasteform. Also, in preparation for starting an R&D programme, we commissioned a review of the durability of potential plutonium waste forms under conditions relevant to geological disposal [4]. Based on this work we have collated available dissolution rates for potential plutonium wasteforms for use in support of the NDA and RWMD programme at current generic phase.

We are not planning to undertake specific experimental work on plutonium wasteforms but this area of research will remain under review with respect to capturing knowledge that may become available within the scientific literature from work being undertaken internationally and through the NDA direct research portfolio. In the future, if geological disposal is chosen as the long-term waste management option for separated plutonium, we will develop further our R&D programme on the dissolution behaviour of potential plutonium wasteforms (applicable to the post-closure scenario of failure of the disposal container). Such long-term experiments would have a significant cost implication for our R&D programme but scheduling such experiments as part of future work would not be expected to impact on the permissioning schedule for license applications to the regulators.

**B.1.2 Container evolution**


## B.1.2.1 Intermediate and low-level waste container evolution

### Raised issues:

<p>| ID: 121-01 | In the context of a 500-year target lifetime for the waste container (CoRWM doc. 2389), both measurement of “store corrosivity” and quantitative assessment of “waste package degradation” are very challenging, not least because there is no current consensus on those parameters which need to be measured, and there will be a need to measure non-linear processes which give rise to very small changes and operate at very slow rates. A required element of the safety cases for storage and disposal will be a well-founded predictive model for waste package behaviour. Due to the long timescales, CoRWM believes that any such model will need to be derived from a process-based, mechanistic understanding; extrapolation from empirical data is unlikely to be sufficient. Currently, this required level of mechanistic understanding does not exist for UK waste packages. | CoRWM doc 2543 Report on R&amp;D for interim storage and geological disposal... A.8, 99 | October 2009 |
| ID: 121-02 | A specific concern is the ability of current steels to resist atmosphere assisted stress corrosion cracking (ASCC) which is exacerbated by the saline atmospheres prevalent at many UK storage locations. | CoRWM doc 2543 Report on R&amp;D for interim storage and geological disposal... A.13, 101 | October 2009 |
| ID: 121-03 | Failure criteria for the containers are not well established making it difficult to develop a safety case. | CoRWM doc 2543 Report on R&amp;D for interim storage and geological disposal... A.14, 101 | October 2009 |
| ID: 121-04 | Influence of different waste form types on the design of the engineered barrier system: intermediate level waste packages ...are vented to reduce the potential for overpressuring within the package. These vents mean that the packages | Environment Agency Science Programme Contractor Report: Technical issues associated with deep | August 2009 |</p>
<table>
<thead>
<tr>
<th>ID: 121-05</th>
<th>Influence of different waste form types on the design of the engineered barrier system: vents... provide an easy route by which substances released from other packages can enter the waste package.</th>
<th>Environment Agency Science Programme Contractor Report: Technical issues associated with deep repositories for radioactive waste in different geological environments Issue 1, 5.1.2, p90</th>
<th>August 2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>ID: 121-06</td>
<td>Duration for which engineered barrier system materials may maintain their functions (durability): been little UK-specific research to date into the durability of barrier materials for high level waste, spent fuel.</td>
<td>Environment Agency Science Programme Contractor Report: Technical issues associated with deep repositories for radioactive waste in different geological environments Issue 5, 5.5.2, p100</td>
<td>August 2009</td>
</tr>
<tr>
<td>ID: 121-07</td>
<td>Note that here no backfilling of the tunnels is assumed and the timing of vault sealing is not specified. Although the stacking specified is within package specifications, corrosion may be quite rapid under some conditions (if any brine is present) and hence collapse of stacks may be possible. How can this be prevented (MgO on top of the stack may not help at all).</td>
<td>Peer Review Outline Design Report - Evaporite Se 8.2</td>
<td>DSSC peer review 2010</td>
</tr>
<tr>
<td>ID: 121-08 (See also ID: 232-01)</td>
<td>Document the extent of acceptability of container failures during transport of Magnox Encapsulation Plant packages, addressing containment and operability of the transport system</td>
<td>Disposability Assessment Database ID46 Magnox Encapsulation</td>
<td>March 2010</td>
</tr>
</tbody>
</table>
RWMD Response:

We continue to be committed to ensure that intermediate level waste and/or low level waste (ILW/LLW) is packaged in waste containers able to achieve sufficient durability [1]. ILW/LLW waste containers need to provide sufficient durability during any period of interim storage and during the operational period of a GDF. For some designs (e.g. 500 litre drums) it may also be important to ensure sufficient durability of the drum stillages. Once a geological disposal facility (GDF) is backfilled, other barriers would also be in place to ensure safety of the system. Nonetheless it is expected that the waste container will continue to provide containment during the early part of the post-closure period when the hazard posed by the waste is higher. The engineered vents in waste packages ensure that any gas generated by the wasteform is released through the vent. While the overall container is intact, it is unlikely that a direct flow path through the waste package would be established until the waste container fails.

Regarding the potential for degradation during interim storage and the operational period of a GDF, an extensive R&D programme considering the long-term evolution of existing container designs (thin-walled, austenitic stainless steel) has been carried out by RWMD, in partnership with leading UK universities [2,3] and specialist suppliers [1]. To a lesser degree, this work considered also drum stillages, to address aspects of stability of the waste stack. Current understanding indicates that, in suitable environmental conditions, designs based on stainless steel will achieve sufficient durability [4]. In particular, extensive R&D has shown that atmospheric stress corrosion cracking does not occur below certain levels of chloride contamination and outside specific ranges of relative humidity and temperature [4,5]. Mechanistic models for pitting corrosion are being developed on the basis of in-situ, real time cutting-edge techniques [3].

Recently, a high level approach for the development of performance (i.e. failure) criteria for ILW Waste packages has been developed. The effect of radiation is not expected to significantly worsen the likely evolution of waste packages in suitably controlled environmental conditions. NDA is currently preparing industry guidance on interim storage.

Given the robust nature of the range of container designs currently considered in the UK (thick-walled, cast iron containers, thin-walled, stainless steel containers) and information available from other international programmes, we do not expect the durability of such containers to pose significant problems. Supporting studies on these materials and designs are planned in the future R&D programme [6]. In particular, we have recently

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commissioned a three year research programme aimed at strengthening our understanding in this area with focus on environmental conditions likely to exist in ILW stores. This work is an additional opportunity to use models to further develop mechanistic understanding of corrosion.

Regarding the potential for degradation of ILW containers during the post-closure period of a GDF, current understanding suggests that, for thin-walled, stainless steel designs the potential for rapid degradation would be site-specific. Relatively rapid degradation could occur if corrosive groundwaters (e.g. rich in chloride) were to come into contact with the packages while high redox potential (e.g. aerobic conditions) was still present in the engineered system. The potential for significant corrosion arising from other factors (e.g. presence of microbes) will also be evaluated in a later stage of the R&D programme, once site-specific information becomes available. The robust shielded containers that are being considered as alternatives for some wastes are expected to provide significant containment during the post closure period in many geological conditions.

B.1.2.2 Evolution of waste containers for high level waste and spent fuel

Raised issues:

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<tbody>
<tr>
<td>ID: 122-02</td>
<td>Research into mechanisms and probabilities of canister failure is required.</td>
<td>Nuclear Waste Advisory Associates’ Issues Register Issue - 38</td>
<td>June 2010</td>
</tr>
<tr>
<td>ID: 122-03</td>
<td>Particular problems due to new data on copper corrosion have arisen.</td>
<td>Nuclear Waste Advisory Associates’ Issues Register Issue - 39</td>
<td>June 2010</td>
</tr>
<tr>
<td>ID: 122-04</td>
<td>Operational risks favour backfilling of vaults as soon as possible. This reduces risk of stacks collapsing in an open vault – which will make recovery very much more difficult. In any case, estimates might be made of the time over which waste packages can be assumed to be intact and hence retrieval easier.</td>
<td>Peer Review - Geological Design Report - Evaporite Sec 11.2</td>
<td>DSSC Peer Review 2010</td>
</tr>
<tr>
<td>ID: 122-05</td>
<td>Corrosion mechanisms i) …there remains concern about the rate of corrosion of copper during the first 100 years or so, when oxygen and heat are both</td>
<td>Helen Wallace (for Greenpeace International) Rock Solid Sec 4.1.1</td>
<td>September 2010</td>
</tr>
</tbody>
</table>
likely to be present.

ii) ...it is presumed that the canisters will corrode in a uniform way, rather than through localised corrosion such as pitting. However, in reality, pitting may also occur and one of the scenarios that may result in early release of radioactivity is water flow into a defective canister.

Cu corrosion in pure water.

i) It has long been assumed that water alone does not corrode copper in an oxygen-free environment. If this assumption is wrong, the copper canisters used in the Swedish deep repository concept could corrode much more quickly than the current estimates suggest.

ii) If copper corrodes in water alone... hydrogen may also be produced by this reaction.

The pressure rise in a repository due to the formation of dissolved hydrogen, and the subsequent production of gas bubbles, might be sufficient to break or fracture the barriers... Hydrogen embrittlement of the corroding metal might also occur, with detrimental effects on the mechanical characteristics of the overpacks or canisters.

RWMD Response:

We are at an early stage in the development of concepts for the disposal of high level waste (HLW) and spent fuel (SF). Work is being planned in our programme to ensure that high level waste (HLW) and spent fuel (SF) (if deemed as waste for geological disposal) will be packaged in suitably durable waste containers.

Taking account of a recent review of the R&D programme on the long-term evolution of a variety of candidate container materials (for example, copper, carbon steel/cast iron, titanium, nickel alloys and stainless steel) [1], we have concluded a variety of materials are likely to offer the required durability in a range of geological conditions and waste management scenarios (e.g. prompt disposal in a geological disposal facility (GDF), interim storage preceding disposal). To support this, there is a large amount of information

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available from other, international programmes to inform the selection of preferred materials and designs once more information about candidate disposal site(s) becomes available.

Such information is likely to be relevant to package designs that may be considered in the future for disposal of HLW and spent fuel. In particular, much information exists on container designs based on the use of copper and carbon steel/cast iron. We understand that the interpretation of a recent research publication claiming that copper can corrode rapidly even in the absence of oxygen has been challenged by SKB (the organisation responsible for implementation of geological disposal in Sweden), who have submitted to the Swedish regulator a safety case for the disposal of spent fuel in higher strength host rock based on the use of a thick-walled copper design [2]. Further work is planned in our R&D programme to refine the treatment of container failure in the developing safety case and to identify a short-list of preferred designs for disposal in the UK [3]. This work is planned to take account of the impact of different waste management strategies and to inform any specific requirement on environmental control during the operational period of a GDF. Once site-specific information becomes available, additional work is planned to directly characterise the performance of candidate materials in UK-relevant conditions.

B.1.3 Near-field Evolution

B.1.3.1 System interactions

Raised issues:

| ID: 131-01 | Interactions between engineered components: little reported research into interactions that might occur if... intermediate level waste and long-lived LLW had a substantially different barrier system to... PGRC. | Environment Agency Science Programme Contractor Report: Technical issues associated with deep repositories for radioactive waste in different geological environments Issue 2, 5.2.2, p92 | August 2009 |
| ID: 131-02 | Prediction of whether immobilisation of radionuclides may occur under the conditions that evolve as a disposal facility and its wastes change over time is important for assessment of GDF performance. | CoRWM doc 2543 Report on R&D for interim storage and geological disposal... A.73, 118 | October 2009 |


| ID: 131-03 | Co-Location of Various Types of Waste in a GDF - several issues on which research is likely to be required... These issues include: the effects of thermally-driven circulation on performance of the intermediate level waste disposal system. | CoRWM doc 2543 Report on R&D for interim storage and geological disposal... 6.10, 90 | October 2009 |
| ID: 131-05 | The interaction of repository components and the resultant impact on the safety case requires further research. | Nuclear Waste Advisory Associates' Issues Register Issue - 41 | June 2010 |
| ID: 131-06 | The interaction of waste fuel with other repository components requires further research. | Nuclear Waste Advisory Associates' Issues Register Issue - 42 | June 2010 |
| ID: 131-07 | The assumption that the corrosion of iron would use up the available oxygen must be demonstrated. | Nuclear Waste Advisory Associates' Issues Register Issue - 64 | June 2010 |
| ID: 131-08 | Microbes could have a number of adverse effects on the safety of a nuclear waste repository, including causing corrosion of metal waste containers: | | |
| | i) Migration of micro-organisms through the bulk of the buffer appeared to be slow, but migration along the metallic holder–buffer interface was rapid, suggesting that cracks or interfaces may form preferred pathways for migration. | Helen Wallace (for Greenpeace International) Rock Solid Sec 4.1.3 | Sept 2010 |
| | ii) In concepts where the repository is to be kept open for a long period of time, to allow for monitoring and possible retrieval of wastes, there may be added difficulties with microbes due to the presence in the ventilated caverns of a humid, oxygen-filled | | |
| ID: 131-09 | Chemical disturbance due to corrosion:  
  i) chemical disturbance due to corrosion could change the properties of the backfill…  
  ii) The interactions between the corrosion products of steel, the surrounding groundwater and the bentonite are expected to create a chemical disturbance inside the engineered barrier system.  
  iii) the porosity of the bentonite will increase…  
  iv) there will be a feedback effect, involving the clogging of pores in the clay…  
  Helen Wallace (for Greenpeace International)  
  Rock Solid Sec 4.2.4  
  Sept 2010 |
| --- | --- |
| ID: 131-10 | The near-field evolution isn’t represented in much detail in the assessments so it is only possible to make qualitative statements.  
  Peer review Near Field Evolution status report  
  DSSC Peer Review 2010 |
| ID: 131-11  
 *(See also ID: 173-19)* | What are the effects of microbes introduced during repository construction?  
  Peer review Near Field Evolution status report  
  DSSC Peer Review 2010 |
| ID: 131-12 | Would the site characterisation process rule out sites which are oxidising?  
  Peer review Near Field Evolution status report  
  DSSC Peer Review 2010 |
| ID: 131-13 | An understanding of the near-field system behaviour of concepts in a co-located facility is required.  
  Peer review Near Field Evolution status report  
  DSSC Peer Review 2010 |
| ID: 131-14  
 *(See also ID: 162-03 and ID: 164-22)* | At present there are no relevant calculations to quantitatively present the kinetics of corrosion in different environments and the migration of hydrogen between intermediate level waste and high level waste.  
  Peer review Gas status report  
  DSSC Peer Review 2010 |
| ID: 131-15 | Consider whether capillary breaking (so-called ‘Richards’) barriers have any relevance.  
  Peer review Near Field Evolution status  
  DSSC Peer Review |
**RWMD Response:**

Our research and development programme on near-field evolution focuses on the key processes that impact on the performance of engineered barriers and/or on how these barriers evolve over the post-closure period of a GDF (for example, those processes covered by topics 1.3.2, 1.3.3 and 1.3.4). This is described in the Near-field Evolution Status Report [1]. To ensure that we remain comprehensive, and to build confidence that all relevant processes are considered, we use our scenario analysis work [1] which includes the development and use of features, events and processes (FEP) (see topic 2.1.7) to determine a more comprehensive range of processes. In our system interactions topic we consider this broader range of processes. System understanding considers how each of the engineered barriers will evolve through a combination of evolution processes (covering many of the issues raised above for different engineered barrier systems (EBS) and evolution scenarios). It includes understanding how these processes are coupled to each other and how these processes collectively impact on the engineered barrier system safety functions over various timeframes, including:

- Interactions between facility disposal areas (see also topic 6.2.5 on co-location);
- Interactions between engineered components;
- External influences in engineered barrier system performance (for example, host rock impacts and microbes);
- Coupled-thermal, mechanical, chemical and hydrogeological processes; and
- Treatment of near-field evolution in PA.

At present the information available from our own research programme, and from overseas waste management programmes, provides us with enough understanding to support the current generic stage of the programme. However, we recognise that increasing understanding will be required as the programme develops. With respect to processes in clay-based barriers, the impacts of thermal transients, steel corrosion products and groundwater chemistry are each summarised in the Near-field Evolution Status Report [1] and are described in further detail in the UK context in a report we have published [2]. We have also recently published a critical review of the international literature on microbial effects in and around a deep geological repository for higher activity wastes [3]. The conclusions of this demonstrated that internationally, considerable work has been carried

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out to understand and quantify microbial influences on many near-field processes, but that much of this work is site- or concept specific and that these investigations have shown the importance of considering microbial impacts in the context of a particular repository concept. Therefore we are not planning significant work on microbes until future stages of the programme.

We are continuing to keep up-to-date with research being conducted in this area by participating in a number of international collaboration projects that involve large-scale testing of evolution processes in underground research facilities [1]. In general we consider that internationally there has been a considerable amount of effort undertaken on demonstrating the required level of understanding for many of the known near-field evolution processes of importance to safety of a GDF for the range of concept options under consideration.

The model of the near field used in the generic Disposal System Safety Case Post Closure Safety Assessment report [4] is simplified and does not attempt to represent all of the engineered barriers and processes considered in the Near Field Status report (as stated by 131-10). However, over the next few years we will be developing a component numerical model of the near field/engineered barrier system of an intermediate level waste/low level waste (ILW/LLW) disposal area of a repository. It will build the links between detailed process understanding and the simplified representations of the important processes that affect performance in the total system model, as used in the probabilistic assessment of the performance of a GDF. Thus it will integrate the existing understanding of the physical and chemical evolution of the near field (e.g. cracking, carbonation, groundwater solute reactions, redox and pH) with physical parameters for a range of EBS materials and concept geometries. This will identify how the evolution of the near field impacts on the relevant safety functions (including immobilisation of radionuclides in the EBS) and will provide an opportunity to review and, if necessary, re-prioritise our research in this area to improve our process level understanding. It will also support the safety case to assess the suitability of specific sites for hosting a GDF, including the ability to determine the impacts of oxidising conditions at a site on near-field performance (see issue 131-12). When the concept options for high level waste and spent fuel disposal are more developed we will also consider the requirements of an appropriate component model for this disposal area drawing on our experience with the development of the ILW/LLW model.

Once site information becomes available, and appropriate disposal concepts have been selected, the respective site-specific safety cases will be focussed on the processes that are important. For example, it is during this time that detailed considerations of the impact of site-specific groundwater conditions (such as oxidising groundwaters) on EBS performance will be undertaken. This in turn will allow the research, development and demonstration activities needed to support further analysis of near-field evolution to be focused further, including the extent to which various issues raised will need to be considered [5].


B.1.3.2 Engineered barrier resaturation

Raised issues:

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<tbody>
<tr>
<td>ID: 132-02</td>
<td>NWAA Issues Register Issue - 53</td>
<td>June 2010</td>
</tr>
<tr>
<td>ID: 132-03</td>
<td>Helen Wallace (for Greenpeace International) Rock Solid Sec 5.1</td>
<td>Sept 2010</td>
</tr>
</tbody>
</table>

RWMD Response:

Resaturation can involve a small number of coupled processes, especially in low permeability materials such as typical clay-based and cement-based engineered barriers [1]. The rate of resaturation will be highly dependent upon the design of the disposal facility and the hydrogeological properties both of the rocks at candidate sites and of the materials used in the construction of a geological disposal facility (GDF) [2]. To support the current generic stage of the programme, our planned R&D on engineered barrier system resaturation and long-term buffer/backfill alteration processes in a range of host rock environments is focussed on developing a good understanding of barrier evolution to support the development of GDF concepts and of the Disposal System Safety Case. At present we consider a broad range of hydrogeological properties of host rocks by considering three general rock types focusing on mechanical strength properties and groundwater flow characteristics [3].


An overview of our planned research and development in the preparatory studies phase concerning resaturation is provided elsewhere (see reference [1]). Currently, we are developing the modelling of bentonite buffer resaturation in a fractured rock as part of our participation in the international collaborative Åspö Engineering Barrier System Task Force project [4]. We are also developing a component numerical model of the near field/engineered system of an ILW/LLW disposal area of a repository (see topic 1.3.1) which will be used to support our future treatment of resaturation, building on the work undertaken by United Kingdom Nirex Limited [5], as referred to by issue 132-01.

Once information on rock properties becomes available from site specific information we would model the resaturation process at an appropriate range of length scales and assess the significance of any uncertainties in the rate of resaturation. This work will take into account the possible knowledge limitations regarding resaturation as raised by the NWAA issue which we have previously responded to [2].

### B.1.3.3 Long-term cement backfill evolution

**Raised issues:**

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<tr>
<td>ID: 133-02</td>
<td>Interactions between engineered components: there have been no UK-specific research into the interactions between the barriers that might be employed in deep geological repositories for other kinds of waste (HLW, SF that might be declared as waste, and other wastes such as Plutonium/Uranium.</td>
<td>Environment Agency Science Programme Contractor Report: Technical issues associated with deep repositories for radioactive waste in different geological environments Issue 2, 5.2.2,</td>
<td>August 2009</td>
</tr>
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| ID: 133-03  | Impact of groundwater/porewater on engineered barrier system materials (including the impact of saline water): ... limited knowledge on the stability of these barrier materials in more saline waters... almost no UK-specific research to date on the effects of groundwater/porewater on barrier materials for high level waste, spent fuel... generic studies have not yet considered the very saline groundwaters that occur in parts of England and Wales, notably at depth within Mesozoic basins. Many of these brines are expected to have relatively high sulphate levels which could become an issue if an engineered barrier system used copper disposal canisters. | Environment Agency Science Programme Contractor Report: Technical issues associated with deep repositories for radioactive waste in different geological environments Issue 4, 5.4.2, p97-98 | August 2009 |
| ID: 133-04  | Duration for which engineered barrier system materials may maintain their functions (durability): likely that much of the knowledge developed for localised corrosion of stainless will be inapplicable to geological environments dissimilar to that at Sellafield, ... owing to differences in groundwater composition. | Environment Agency Science Programme Contractor Report: Technical issues associated with deep repositories for radioactive waste in different geological environments Issue 5, 5.5.2, p100 | August 2009 |
| ID: 133-05  | Investigate performance of Nirex Reference Vault Backfill (NRVB) as a chemical conditioning agent in the presence of large volumes of iron and iron corrosion products. Consider whether NRVB is optimised for use in the disposal of ductile cast iron containers. | Disposability Assessment Database ID49 Use of Ductile Cast Iron Containers (DCICs) for Disposal of intermediate level waste | May 2010 |
| ID: 133-06  | Proof is required that the ‘chemical containment’ approach put forward by nuclear industry would be effective in isolating waste. | Nuclear Waste Advisory Associates’ Issues Register Issue - 61 | June 2010 |
| ID: 133-07  | Large quantities of cement are also expected to be used in the repository for construction and sealing... | Helen Wallace (for Greenpeace International) | Sept 2010 |
| ID: 133-08 | Reaction rates and (experimental) evidence of the sequence of hydrogeochemical reactions in the near field, especially with respect to the reactions leading to the production of sulphides. | Helen Wallace (for Greenpeace International) Rock Solid Sec 5.1 | Sept 2010 |
| ID: 133-09 | The impact on the engineered barrier system of cementitious materials and other stray materials used in repository construction. | Helen Wallace (for Greenpeace International) Rock Solid Sec 5.1 | Sept 2010 |
| ID: 133-10 | ▶ Evaluate the impact on near-field performance that would arise from the disposal of large volumes of phosphate ceramic based wasteforms. | Disposability Assessment Database ID82 AWE Pyrochemical Ceramics | November 2011 |

**RWMD Response:**

We have evaluated this range of issues as requiring work in our programme. One of the high-level safety objectives of geological disposal of radioactive waste is containment of the radionuclides associated with the waste. A disposal concept might be selected that uses the chemical properties of an engineered barrier component to provide safety functions, such as limitation of solubility of radionuclides in groundwater and/or removal of radionuclides from aqueous solution by uptake onto the solid surface of the material. When we come to develop a safety case for a site-specific disposal system using such a barrier component we would provide the scientific and technical evidence that supports the fulfilment of the safety functions and we would analyse the consequences of any uncertainties about their fulfilment.

In the case of the use of cementitious barrier materials to contribute to containment there is an extensive UK generic knowledge base developed over more than two decades and our current understanding of their evolution is summarised in the Near-field Evolution Status Report [1]. We continue to add to the scientific and technical knowledge built up in the UK and internationally in radioactive waste, and also chemotoxic waste, programmes by long-term demonstration experiments that are designed to complement previous long-term experiments [2,3] and evidence from archaeological and natural analogues [4,5]. We will

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also undertake more detailed studies of the typical alteration of cements. This will provide us with the expertise to investigate site-specific issues, such as the effect of individual ground water compositions, in the future. As part of our ongoing research programme we are supporting disposability assessments by considering the impacts of new wastefoms (e.g. vitrified ILW and ceramics) and container materials (e.g. ductile cast-iron containers and multi-purpose containers) on the expected evolution of the near-field for a range of concept options, environmental conditions and post-closure scenarios. An overview of our planned research and development in the preparatory studies phase, based on our illustrative geological disposal concept examples, concerning cement backfill evolution is provided elsewhere (see, reference [6]). Since much of our work is this area has historically been focussed on understanding the behaviour of the Nirex Reference Vault Backfill (NRVB), we are currently reviewing the current state of the art with respect to the performance of cement as an engineered barrier (considering resaturation processes and long-term alteration and evolution processes). This will consider both UK specific historic research and work carried out overseas. It will also set out future research activities that can be undertaken in the current generic phase of our programme and identify work required to inform concept development activities in relation to UK candidate cement optioneering.

Once site specific information becomes available, we expect to be undertaking buffer/backfill experiments for a range of candidate cement engineered barrier materials. Future work will be influenced by changes to concepts, designs and packaging options as our programme develops.

### B.1.3.4 Resaturation and long-term evolution of clay-based buffers

**Raised issues:**

| ID: 134-01 | Investigate the influence of neutron dose rates on the performance of the bentonite buffer in the high level waste/spent fuel disposal system as part of the onward R&D programme for the high level waste/spent fuel disposal system. | Disposability Assessment Database ID56 high level waste (Preliminary Assessment) | 3rd April 2009 |
| ID: 134-02 | Duration for which engineered barrier system materials may maintain their functions (durability): been little UK-specific research to date into the durability of barrier materials for high level waste, and spent fuel. | Environment Agency Science Programme Contractor Report: Technical issues associated with deep repositories for radioactive waste in different geological | August 2009 |

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| ID: 134-03 | Interactions between engineered components: there have been no UK-specific research into the interactions between the barriers that might be employed in deep geological repositories for other kinds of waste (HLW, SF that might be declared as waste, and other wastes such as Plutonium/Uranium. | Environment Agency Science Programme Contractor Report: Technical issues associated with deep repositories for radioactive waste in different geological environments Issue 2, 5.2.2, p92 | August 2009 |
| ID: 134-04 | Impact of groundwater/porewater on engineered barrier system materials (including the impact of saline water).... limited knowledge on the stability of these barrier materials in more saline waters...almost no UK-specific research to date on the effects of groundwater/ porewater on barrier materials for high level waste, spent fuel...generic studies have not yet considered the very saline groundwaters that occur in parts of England and Wales, notably at depth within Mesozoic basins. Many of these brines are expected to have relatively high sulphate levels which could become an issue if an engineered barrier system used copper disposal canisters. | Environment Agency Science Programme Contractor Report: Technical issues associated with deep repositories for radioactive waste in different geological environments Issue 4, 5.4.2, p97-98 | August 2009 |
| ID: 134-05 | Significantly more and new experiments, and new coupled chemical diffusion–advection models, are required to understand and predict bentonite behaviour, including swelling and evolution of high gas pressures, dissolution, cementing and porosity reduction by precipitation of silica, cation and anion affinities under high pH, and overall barrier system performance. | CoRWM doc 2543 Report on R&D for interim storage and geological disposal... A.79, 119 | October 2009 |
| ID: 134-06 | Co-location of various types of waste in a GDF - several issues on which research is likely to be required... These issues include: the potential for and extent of cement-bentonite | CoRWM doc 2543 Report on R&D for interim storage and | October 2009 |
| ID: 134-07 | 52 | interactions. | geological disposal... 6.10, 90 | Helen Wallace (for Greenpeace International) Rock Solid Sec 4.2.1 | Sept 2010 |
| ID: 134-08 | 52 | The heat in a repository could have a significant negative impact on the properties of clay... | The interactions between the corrosion products of steel, the surrounding groundwater and the bentonite are expected to create a chemical disturbance inside the engineered barrier system. | Helen Wallace (for Greenpeace International) Rock Solid Sec 4.2.4 | Sept 2010 |
| ID: 134-09 | 52 | i) (smectite clay) could be transformed into other minerals with different physical and chemical properties. ii) the rate of conversion of montmorillonite to illite is in fact not yet known, and other mineralogical changes can also take place which are not yet well understood. | Chemical disturbance due to corrosion. | Helen Wallace (for Greenpeace International) Rock Solid Sec 4.2.2 | Sept 2010 |
| ID: 134-10 | 52 | The salinity of groundwater can also affect the properties of bentonite......mineral alteration in bentonite due to the accumulation of magnesium occurred in saline waters. | The thermal alteration of bentonite in saline water affects the caesium sorption capacity... | Helen Wallace (for Greenpeace International) Rock Solid Sec 4.2.2 | Sept 2010 |
| ID: 134-11 | 52 | The salinity of groundwater can also affect the properties of bentonite......the cation exchange capacity (CEC) decreased as the amounts of magnesium accumulation increased... | The porosity of the bentonite will increase... | Helen Wallace (for Greenpeace International) Rock Solid Sec 4.2.2 | Sept 2010 |
| ID: 134-12 | 52 | The salinity of groundwater can also affect the properties of bentonite.....the cation exchange capacity (CEC) decreased as the amounts of magnesium accumulation increased... | The thermal alteration of bentonite in saline water affects the caesium sorption capacity... | Helen Wallace (for Greenpeace International) Rock Solid Sec 4.2.2 | Sept 2010 |
| ID: 134-13 | Effects of gas on the clay barrier. i) hydrogen gas...could seriously affect repository safety if pressure build-up were to force fast routes through the bentonite or host rock or explosively damage their structure. | Helen Wallace (for Greenpeace International) Rock Solid Sec 4.2.5 | Sept 2010 |
| ID: 134-14 | Modelling has suggested that...that the gas problem is a key issue for the long-term performance of the clay barrier. | Helen Wallace (for Greenpeace International) Rock Solid Sec 4.2.5 | Sept 2010 |
| ID: 134-15 | It is difficult to predict the interaction of the glass of vitrified high level waste and clay. | Nuclear Waste Advisory Associates’ Issues Register Issue - 43 | June 2010 |
| ID: 134-16 | The chemical, mechanical and flow behaviour of clay would be affected by the high temperature of high level waste. | Nuclear Waste Advisory Associates’ Issues Register Issue - 44 | June 2010 |
| ID: 134-17 | Clay behaviour is difficult to quantify. | Nuclear Waste Advisory Associates’ Issues Register Issue - 45 | June 2010 |
| ID: 134-18 | The capacity of clay to retain radionuclides can be damaged by salty or alkaline water. | Nuclear Waste Advisory Associates’ Issues Register Issue - 46 | June 2010 |
| ID: 134-19 | Radionuclide retention by clay can also be damaged by corrosion products. | Nuclear Waste Advisory Associates’ Issues Register Issue - 47 | June 2010 |
| ID: 134-20 | The impact of salty groundwater on repository/rock interaction is difficult to predict. | Nuclear Waste Advisory Associates’ Issues Register Issue - 50 | June 2010 |
| ID: 134-21 | It is not clear what effects the chemicals in groundwater would have on the facility. | Nuclear Waste Advisory Associates’ Issues Register Issue - 54 | June 2010 |
RWMD Response:

These issues are managed by our work programme to develop understanding of the long term evolution of clay-based buffers within the near field evolution research topic. Work on resaturation of clay-based engineered barrier systems has been discussed above (see topic 1.3.2). There is uncertainty of the likelihood and extent of post-closure alteration processes (e.g. due to groundwater composition, thermal history and interaction with other components of an engineered barrier system) of clay-based buffers and backfills. These alteration processes will depend upon the design of the disposal facility, the materials used in the construction of the disposal facility and the geological environment at candidate sites.

At present we are investigating a range of alteration processes that need to be considered for the range of concepts currently under consideration. Our current understanding of clay alteration processes is summarised in the Near-field Evolution Status Report [1] and described in further detail in a review on bentonite that we have published [2]. This has included consideration of bentonite interactions as well as thermal alteration, and piping and erosion of clays. It identifies work that is likely to be taken forward in the near term including cementation and bentonite-iron interactions. It also provides information about processes that can be managed through appropriate engineering options, such as the fact that radiation effects on backfill are of negligible consequence provided a typical wall thickness is assumed for the disposal canisters. An overview of our planned research and development in the preparatory studies phase concerning clay-based backfill evolution is provided in our R&D Programme Overview [3]. Until site information becomes available, and we have progressed concept development, we will focus on developing the generic capability and understanding of bentonite interactions and alteration. This includes participation in international projects to further develop our expertise in a range of experimental and modelling activities relating to specific alteration processes and coupled processes of gas generation and multi-phase flow through clay barriers.

Once information on rock properties (and in particular the groundwater composition) becomes available from site investigations in Stage 5 of the MRWS site selection process and concepts have been selected we would demonstrate how the required safety functions would be met. This will include consideration of features, events and processes that relate to alteration of clay-based buffers and backfills if such materials are considered in the concepts selected, including consideration of the issue raised relating to alteration of clay-based buffers in saline groundwater conditions.

B.1.4 Geosphere and its evolution

B.1.4.1 Characterisation of groundwater flow

Raised issues:

<table>
<thead>
<tr>
<th>ID</th>
<th>The development of methodologies for establishing flow over geographical regions.</th>
<th>NWAA Issues Register Issue - 16</th>
<th>June 2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>ID: 141-01</td>
<td>Resolution of uncertainties in flow prediction.</td>
<td>NWAA Issues Register</td>
<td>June 2010</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ID: 141-03</th>
<th>The development of techniques for representing flow and transport in fractured rocks.</th>
<th>NWAA Issues Register Issue - 19</th>
<th>June 2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>ID: 141-04</td>
<td>The role of the 'excavated damage zone' (EDZ) as a pathway is under investigation.</td>
<td>NWAA Issues Register Issue - 27</td>
<td>June 2010</td>
</tr>
<tr>
<td>ID: 141-05</td>
<td>It is also recognised... that there are several key uncertainties (e.g. groundwater flow....) and that the magnitudes of these will need to be explored through R&amp;D.</td>
<td>CoRWM Doc. 2550. Geological disposal of higher activity radioactive wastes. July 2009 12.20, p44</td>
<td>July 2009</td>
</tr>
<tr>
<td>ID: 141-06</td>
<td>Geosphere characterisation - areas have been identified that, CoRWM considers, would benefit from R&amp;D. For example, R&amp;D may be required to define the chemical descriptions and models for the near field, geosphere and biosphere and in the definition of models of site-scale hydrology, hydrogeology and paleohydrogeology. ... It is unclear, to CoRWM, whether R&amp;D needs identified from this project are progressing or are being planned, or whether the skills and resources have been identified to undertake the work.</td>
<td>CoRWM doc 2543 Report on R&amp;D for interim storage and geological disposal... 6.13, 91</td>
<td>October 2009</td>
</tr>
<tr>
<td>ID: 141-07</td>
<td>CoRWM considers that through the adopted process information gaps will be identified that require R&amp;D. Among these will be the following issues: •naturally-occurring fractures - To understand the influence of these features fully it is considered that their genesis should be understood •Research into the relationship between fracture distribution and stress fields would aid in site characterisation •controls on identification and description of the distribution of permeability in low-permeability rock units •Research will be required in relation to understanding, in a fractured hard rock, the connectivity and transmissivity of the network of fractures. In addition research will be</td>
<td>CoRWM doc 2543 Report on R&amp;D for interim storage and geological disposal... A.94, 122</td>
<td>October 2009</td>
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</table>
required into any lithological and structural controls on permeability distribution.

• Research to understand the influence of fracture wall roughness and in situ stress would be useful in the characterisation process.

• Geophysical techniques - research into the use of these techniques in relation to possible GDF sites could inform geosphere characterisation and assist in GDF layout and the design.

| ID: 141-08 | Bedrock properties and hydrogeology.  
| i) Groundwater flow … through both fractures and porous rock needs to be considered in a safety assessment. This poses particular problems because of the very large degree of structural variation (known as heterogeneity) in the fracture systems… leading to very different thermo-hydro-mechanical properties at different points in space.  
| ii)... scaling up the measured properties of fractured rock to try to predict overall flows… is so complex that it has yet to be resolved.  
| Helen Wallace (for Greenpeace International)  
Rock Solid Sec 4.4.1 | Sept 2010 |

| ID: 141-09 | Flow paths to and from the repository (e.g. groundwater flows at canister scale, release paths for radionuclides).  
| Helen Wallace (for Greenpeace International)  
Rock Solid Sec 5.1 | Sept 2010 |

| ID: 141-10 | MRWS 146 stated that the heat produced by MOX and plutonium, and particularly by future disposal of spent fuel will be important. This heat causes the rocks to expand, and will lift the land surface, with important implications that many new fractures will be generated and re-opened. This will enable groundwater flow to circulate much more freely than at present, with greatly increased potential for leakage of radioactivity above and around a Repository site. The NDA cites an unpublished report, but agree that even on their best assumptions, heat effects will be very noticeable. NDA completely miss the scientific point that it is not the heat | Reply to the NDA response to MRWS paper 146  
Professor Stuart Haszeldine  
University of Edinburgh | May 2011 |

(See also ID: 142-25)
itself that is important, but the physical consequences for the rocks enclosing the Repository. No good reply has been given to this critical problem.

| ID: 141-11 | Understanding of the groundwater system at a site will be an important issue to the safety case once we have completed research and investigations at the selected site. | Generic DSSC NDA/RWMD/010 | Jan 2011 |

**RWMD Response:**

Understanding of the groundwater system at a site is an issue that was raised in our generic Disposal System Safety Case (DSSC) as being important to safety as it will be a significant undertaking within our programme in the future phases of the MRWS site selection process [1]. Our work programme at present is focussed on preparing for these phases.

Suitable methodologies exist to establish groundwater flow over geographical regions [2]. The requirements for a conceptual model of groundwater flow on a regional scale are strongly dependent upon site characteristics. We plan to set out our proposed approach to support permissioning by the Environment Agency at an early point in Stage 5 of the MRWS site selection process.

We recognise that, at a site-specific level, resolution of any uncertainties in groundwater flow characterisation will have to be achieved sufficiently to underpin confidence in the Environmental Safety Case. The degree to which uncertainties in groundwater flow characterisation will need to be resolved will be dependent on the sensitivity or importance of this issue in the safety case.

The impact of changes to the host rock resulting from the construction and operation of a geological disposal facility (GDF), e.g. the creation of an excavation damage zone (EDZ), on groundwater movement (and on the rate of any GDF-derived gas generation and subsequent migration) is a topic that we need to understand. This includes consideration of the consequences of heat generated by waste on the hydraulic and mechanical properties of the host rock and surrounding geosphere (and their subsequent evolution), and also includes consideration of how e.g. permeability is affected by the presence of a GDF. The significance of any impact will be dependent upon the design of the disposal facility and the properties of the host rock and surrounding geosphere. Ongoing studies in this area are building on developments in understanding progressed through international projects e.g. NF PRO [3].

Once information on e.g. rock properties and stresses become available from site investigations in Stage 5 of the MRWS site selection process, we will further develop the understanding of host rock and surrounding geosphere evolution, and assess its potential significance in relation to groundwater and gas movement.

On the basis of work conducted in the UK and internationally, we believe that suitable techniques are available to characterise groundwater movement and radionuclide transport in a range of rock types, e.g. fractured rocks, argillaceous rocks, and represent this derived understanding in numerical models [4]. We are continuing to conduct research to improve methodologies and capabilities in this area [5]. Predictive models relating to the host rock and surrounding geosphere could be tested against observations made when excavations are carried out in Stage 6 of the MRWS site selection process.

The actual methodology to establish the specific hydrogeological characteristics of a candidate site will take into account the lessons learnt in similar geological environments on other programmes. We consider that there is sufficient world-wide experience of the characterisation of important hydrogeological features and properties, and we have identified the techniques to quantify these in the Site Characterisation Status Report [2].

**B.1.4.2 Impact of coupled thermal, hydrogeological, and chemical processes**

**Raised issues:**

| ID: 142-01 | 'This is a salt dome – how would it apply to the reference bedded salt considered. Note also that higher temperatures cause migration of fluid inclusions towards the heat source – could this be of significance in the UK case? | Peer Review Outline Design Report - Evaporite Sec 10.3 | DSSC peer review 2010 |
| ID: 142-03 (also see ID: 143-01) | There are, however, a number of areas where generic (i.e. not site specific) research would be useful. Examples of these areas are: temporal changes (both transient and permanent) to the hydraulic, chemical and mechanical properties of a rock mass. | CoRWM doc 2543 Report on R&D for interim storage and geological disposal... 2.26, 22 | October 2009 |
| ID: 142-04 | Co-Location of Various Types of Waste in a GDF - several issues on which research is likely to be required... These issues include: the impact of highly alkaline waters on | CoRWM doc 2543 Report on R&D for interim storage and | October 2009 |

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| ID: 142-05 | high level waste, the effects of thermally-driven circulation on performance of the intermediate level waste disposal system, and the impact of gas generation in the intermediate and low-level waste part of a GDF on groundwater movement in the high level waste/spent fuel part. | geological disposal... 6.10, 90 |
| ID: 142-06 | There is at present no general model that can account for how coupled processes influence transport mechanisms and chemical reactions at grain surfaces and boundaries, in fluid films, and in pore throats and pores. This means that extensive experimentation is required. | CoRWM doc 2543 Report on R&D for interim storage and geological disposal... A.74, 118 |
| ID: 142-07 | Co-location of intermediate level waste, high level waste and Other HAW in One GDF - assumption that the geometry of the facility is such that there will be no significant adverse interactions...An important question for site selection and GDF design is how this can be achieved in various geological environments. A key question is whether it is possible to demonstrate that there will be sufficiently limited interaction between the two near-fields over sufficiently long time periods for a post-closure safety case to be developed. | CoRWM doc 2543 Report on R&D for interim storage and geological disposal... A.77, 118 |
| ID: 142-08 | Interactions between engineered components: potential interactions between the different barriers that might be employed in a repository for co-located LLW/intermediate level waste and higher-activity wastes, in the UK context, have not been investigated. | Environment Agency Science Programme Contractor Report: Technical issues associated with deep repositories for radioactive waste in different geological environments Issue 2, 5.2.2, p92 |
| ID: 142-09 | Engineered barrier system/host rock interactions: additional research... before employing a cementitious barrier in different host rocks at a future repository site. | Environment Agency Science Programme Contractor Report: Technical issues associated with deep |
| ID: 142-09 | Engineered barrier system/host rock interactions: no UK-specific research into the interactions between the different kinds of engineered barrier system that would need to be employed in a repository for high level waste and spent fuel. | Environment Agency Science Programme Contractor Report: Technical issues associated with deep repositories for radioactive waste in different geological environments Issue 3, 5.3.2, p94 | August 2009 |
| ID: 142-10 | Engineered barrier system/host rock interactions: UK understanding of EDZ development in hard fractured rocks may not be comparable to that in many other countries. | Environment Agency Science Programme Contractor Report: Technical issues associated with deep repositories for radioactive waste in different geological environments Issue 3, 5.3.2, p94 | August 2009 |
| ID: 142-11 | Engineered barrier system/host rock interactions: EDZ development in other lithologies besides hard fractured rocks appears to be based on reviews of literature published by other organisations. | Environment Agency Science Programme Contractor Report: Technical issues associated with deep repositories for radioactive waste in different geological environments Issue 3, 5.3.2, p94 | August 2009 |
| ID: 142-12 | …the heat could induce convective flow of groundwater in the surrounding rock… | Helen Wallace (for Greenpeace International) | Sept 2010 |
| ID: 142-13 | ...along with significant vaporisation of groundwater... | Helen Wallace (for Greenpeace International) Rock Solid Sec 4.2.1 | Sept 2010 |
| ID: 142-14 | Heating can also release gases from clay host rocks. | Helen Wallace (for Greenpeace International) Rock Solid Sec 4.2.1 | Sept 2010 |
| ID: 142-15 | Large quantities of cement are also expected to be used in the repository for construction and sealing... The creation of highly alkaline fluids is expected to degrade the clay rock at the interface with the barriers... and concrete engineered barriers may also be susceptible to attack by groundwater containing dissolved sulphates. | Helen Wallace (for Greenpeace International) Rock Solid Sec 4.2.4 | Sept 2010 |
| ID: 142-16 | The excavation-induced stresses form an EDZ in which hydromechanical and geochemical modifications induce significant changes in flow and transport properties. Strength degradation of the rock may occur over time due to micro-cracking or micro-fracturing. | Helen Wallace (for Greenpeace International) Rock Solid Sec 4.4.2 | Sept 2010 |
| ID: 142-17 | The impact of the EDZ and thermal spalling on the hydraulic evolution. | Helen Wallace (for Greenpeace International) Rock Solid Sec 5.1 | Sept 2010 |
| ID: 142-19 | The impact of 'weathering ' that would be caused by an 'open phase' is not understood. | Nuclear Waste Advisory Associates' Issues Register Issue - 29 | June 2010 |
| ID: 142-21 | The chemical database is inadequate to the task of predicting cement/clay interaction. | Nuclear Waste Advisory Associates’ Issues Register Issue - 49 | June 2010 |
| ID: 142-23 | The role of the ‘oxygen anomaly’ introduced by the excavation itself must be established. | Nuclear Waste Advisory Associates’ Issues Register Issue - 65 | June 2010 |
| ID: 142-24 | It is now recognised that cement would have a detrimental effect on clay. | Nuclear Waste Advisory Associates’ Issues Register Issue - 74 | June 2010 |
| ID: 142-25 | MRWS 146 stated that the heat produced by MOX and plutonium, and particularly by future disposal of spent fuel will be important. This heat causes the rocks to expand, and will lift the land surface, with important implications that many new fractures will be generated and re-opened. This will enable groundwater flow to circulate much more freely than at present, with greatly increased potential for leakage of radioactivity above and around a Repository site. The NDA cites an unpublished report, but agree that even on their best assumptions, heat effects will be very noticeable. NDA completely miss the scientific point that it is not the heat itself that is important, but the physical consequences for the rocks enclosing the Repository. No good reply has been given to this critical problem. | Reply to the NDA response to MRWS paper 146 Professor Stuart Haszeldine University of Edinburgh | May 2011 |

(See also ID: 141-10)
RWMD Response:

The thermal, hydraulic, mechanical and chemical properties of a host rock and surrounding geosphere will be affected, to a greater or lesser extent, by the construction and operation of a geological disposal facility (GDF). These properties could evolve once a GDF is closed. Evolving components of a GDF, e.g. waste, container, backfill/buffer material, could interact with other GDF components as well as the host rock and surrounding geosphere; the evolution of a GDF could be affected by the properties of the host rock and surrounding geosphere. There are therefore many coupled processes and GDF component-rock interactions that need to be systematically considered and prioritised as part of work in the MRWS site selection process; the (in)significance of such couplings and interactions are an artefact of a site and a disposal concept (the latter itself being an artefact of the disposal inventory).

The choice and selection of engineered barrier components, e.g. cementitious materials that might be used in a GDF must take account of the potential interactions between components and rock (both host rock and surrounding geosphere).

If a disposal concept includes the use of cementitious materials, the interaction of cement, or more specifically of the fluids derived from cement leaching by groundwater, with a host rock is a topic that requires the targeted development of further understanding (e.g. cement fluid interaction with clay materials). There is a considerable knowledge base that is available to support consideration of cement/rock interaction. In particular, participation in international projects involving the long-term evolution of cement/rock interactions in underground rock laboratories is ensuring that we maintain awareness of the state-of-the-art in this area [1]. We have recently commissioned a review of the work that has been conducted in the UK and internationally on cementitious engineered barrier system materials envisaged for use in a range of disposal concepts, including grouts and sealing materials.

We are also conducting research to provide further information on the behaviour of clay buffer and backfill materials, including participation in a number of international research collaboration projects. We are building on the outputs of the NF-PRO project, which was noted as addressing this area in the recent JRC report [2].

We believe that there is sufficient understanding of the effects of naturally-occurring saline groundwater and of alkaline waters (resulting from the possible use of cement in structural concretes), on clay materials such as bentonite to inform design decisions that will need to be made as part of future work during future phases of our programme. At a site-specific level, any GDF engineered barrier system materials will have to be selected so as to be appropriate for the natural conditions present, including the chemical composition of the groundwater. The design of a geological disposal facility shall ensure that interactions between one disposal area and another will not compromise the performance of the disposal system, this will include consideration of interactions between engineering materials themselves, and between engineering materials and the host rock and surrounding geosphere.

Understanding the perturbation to the evolution of the host rock and surrounding geosphere resulting from the construction and operation of a GDF, including in consideration of the properties of the disposed waste, is a topic that we are progressing within our programme and through involvement in international projects such as the now-

completed European Commission NF-PRO project [3], and the on-going DECOVALEX project [4].

We have recently initiated a project to consider how a range of natural transient processes (e.g. climate change, earthquakes) could affect a GDF, its host rock and the surrounding geosphere which will consider effects on coupled processes and GDF component-rock interactions.

Dependent on the MRWS programme, RWMD may in future access site-specific information and develop a site-specific facility design. The significance of coupled processes and GDF component-rock interactions will be a function of the host rock, surrounding geosphere, and the site-specific facility design. In the absence of site-specific information, detailed issues, such as the consequences of oxygen present in a GDF at closure on engineered components and the host rock and the significance, if any, of GDF-derived gases on safety functions, can only be studied at a generic (non site specific) level. Knowledge gained from RWMD’s current R&D studies will inform any subsequent site-specific work, ensuring national and international experience is reflected in its current and future programme and that future studies on coupled processes and GDF component-rock interactions are appropriately prioritised with regard to potential effects on GDF safety functions and the overall safety case.

B.1.4.3 Evolution of the geosphere

Raised issues:

| ID: 143-01 | There are, however, a number of areas where generic (i.e. not site specific) research would be useful. Examples of these areas are: temporal changes (both transient and permanent) to the hydraulic, chemical and mechanical properties of a rock mass. | CoRWM doc 2543 Report on R&D for interim storage and geological disposal... 2.26, 22 | October 2009 |
| ID: 143-02 | Geosphere evolution - there is a need for further research to develop fundamental process-based models. Further, to validate such models, new field analogues should be sought that illuminate the role of individual processes in geosphere evolution. | CoRWM doc 2543 Report on R&D for interim storage and geological disposal... 6.15, 91 | October 2009 |
| ID: 143-03 | Further work is needed to understand and model radionuclide migration... more understanding is required of: -the spatial variability, temporal evolution and reactivity of mineral surfaces. | CoRWM doc 2543 Report on R&D for interim storage and geological disposal... | October 2009 |


<table>
<thead>
<tr>
<th>ID: 143-04</th>
<th>CoRWM believes that a fundamental mechanistic understanding is required of the processes governing physical, chemical and microbiological evolution of the geosphere. Further, to validate such models, new field analogues should be sought.</th>
<th>CoRWM doc 2543 Report on R&amp;D for interim storage and geological disposal... A.100, 124</th>
<th>October 2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>ID: 143-05</td>
<td>Demonstrating long-term stability: In the UK, there has been relatively little experience in evaluating the stability of mud rocks.</td>
<td>Environment Agency Science Programme Contractor Report: Technical issues associated with deep repositories for radioactive waste in different geological environments Issue 8, 5.8.2, p109</td>
<td>August 2009</td>
</tr>
</tbody>
</table>

**RWMD Response:**

The geosphere is a key barrier in a geological disposal facility (GDF) concept. On the geological timescale it is continually evolving due to natural processes such as climate change, uplift / subsidence and tectonism (including earthquakes). These processes are all well-characterised and their potential impacts can be estimated. The geosphere at depths under consideration for a GDF, i.e. a depth between 200 m and 1,000 m, and having potentially suitable characteristics, is less dynamic (more stable) than shallow geological settings or surface environments. RWMD needs to demonstrate that geosphere evolution at a specific site would not compromise the site’s ability to provide a contribution to the safety functions of isolation and containment, which are fundamental to ensuring safety.

A safety case for the UK’s GDF will need to demonstrate an appropriate understanding of how the site evolved geologically to its present day state, and present reasoned arguments to demonstrate an appropriate understanding of how it is expected to evolve over timescales relevant to an Environmental safety case undertaken against UK regulations (which will typically consider times to 1 million years in the future, with the importance of demonstrating a qualitative understanding becoming prevalent over quantitative analyses of site evolution at longer times). Typical information that could be presented to demonstrate an understanding of the evolution of a site to present day could include palaeohydrogeological analyses such as fluid-rock interactions, mineral surfaces and their changes with time, weathering, and fracture fill mineralogy and its evolution in conjunction with e.g. fault activation, regional geological events. Consideration of groundwater chemistry could also be presented. It would be necessary to demonstrate an understanding of how such typical information varies across a site (spatial variability), as well as demonstrating site evolution (temporal variability).

The consideration of the evolution of the geosphere is therefore an issue justifying significant work in our work programme, and was the subject of much work by United...
Kingdom Nirex Limited in the 1990's when active site investigations were last undertaken in the UK for a GDF.

The natural evolution of the geosphere is widely studied nationally and internationally. At the current generic stage of our programme, we are not undertaking detailed R&D into the natural evolution of the geosphere, as this can only sensibly be undertaken at a specific site(s). We are therefore drawing on the experience and advice of experts, and making use of knowledge from the study of relevant natural analogues, to progress understanding of key natural processes and their significance [1]. We have recently initiated a project on a site-generic basis to consider how a range of natural transient processes (e.g. climate change, earthquakes) could affect a GDF, its host rock and the surrounding geosphere – this will consider effects on coupled processes (thermal, hydraulic, mechanical, chemical) and GDF component-rock interactions.

Working this way, we ensure that, at a future site-specific level, we can prioritise R&D towards geosphere evolution topics that can be demonstrated as important in the context of the safety case.

**B.1.4.4 Rock spalling**

**Raised issues:**

<table>
<thead>
<tr>
<th>ID: 144-01</th>
<th>How is the spalling of rock being considered?</th>
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<td></td>
<td>Peer review Near Field Evolution status report</td>
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</tbody>
</table>

**RWMD Response:**

Rock spalling, e.g. in a deposition hole for high level waste (HLW) or spent fuel canisters in higher strength host rock, may create a damaged zone that has higher conductivity or porosity than the intact rock. This could lead to increased flow of groundwater in the damaged zone. This issue is being considered by SKB [1] and is recognised in their safety analyses [2,3].

Spalling in open deposition holes, e.g. during construction and operation, could be addressed before or during placement of the bentonite buffer. Spalling could occur in the walls of a deposition hole after placement of HLW or spent fuel containers if the thermal stresses exceed the spalling strength of the rock. Spalling may be controlled by the swelling pressure of the bentonite due to partial water uptake and closure of the bentonite-rock gap would prevent disturbance of the bentonite buffer. The main concern has been identified as spalling induced by thermal stresses in deposition holes with initially open bentonite gaps [1]. As this issue depends both on the geological disposal concept and the strength of the rock in which a deposition hole is located, we consider it to be too early in our programme to undertake detailed studies of this issue. Instead we will maintain a watching brief on the progress of this issue in overseas disposal programmes.

**B.1.5 Biosphere**

**B.1.5.1 Biosphere assessment approach**

**Raised issues:**

<table>
<thead>
<tr>
<th>ID: 151-01</th>
<th>Prioritisation and iteration of the biosphere approach as the MRWS site selection process moves forwards.</th>
<th>Peer review Geological Disposal: Biosphere status report p.19</th>
<th>DSSC peer review 2010 (DSSC60)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ID: 151-02</td>
<td>Predicted doses to a ‘reference person’ living near the proposed repository are supposed to be calculated many generations into the future. The habits used as a basis</td>
<td>Helen Wallace (for Greenpeace International) Rock Solid Sept 2010</td>
<td></td>
</tr>
</tbody>
</table>


for this calculation (e.g. consumption of foodstuffs and use of local resources) should be typical of the small number of individuals expected to be most highly exposed. There are obviously considerable uncertainties in defining these habits, as well as disagreements regarding the impacts of radiation on vulnerable groups such as children, babies and developing embryos.

**RWMD Response:**

We have adopted an approach based on the guidance developed through international collaborative programmes together with specific national requirements (for example specific advice on habitat assessments are provided by the National Dose Assessment Working Group (NDAWG) [1,2]). A detailed review of potentially exposed group (PEG) characteristics and habit data has also been undertaken [3].

We believe that suitable methodologies for the assessment of potential impacts of radionuclides released from a geological disposal facility on the biosphere have been established through such programmes such as BIOMASS [4] and BIOCLIM [5].

We agree that as part of our ongoing work programme [6] we need to continue to develop further a robust biosphere assessment methodology as we move from a generic to a site-specific Environmental Safety Case. The methodology we develop will need to demonstrate the assessment of risk has taken proper account of a range of uncertainties.

**B.1.5.2 Non-human biota**

**Raised issues:**

| ID: 152-01 | Many data gaps also remain in factors governing the transfer of radionuclides in animal feedstuffs to domestic farm animals, … there are uncertainties | Helen Wallace (for Greenpeace International) Rock Solid | Sept 2010 |


| ID: 152-02 | Knowledge gaps with regard to wildlife species and ecosystems include a lack of knowledge concerning: key radionuclides. | Nuclear Waste Advisory Associates’ Issues Register Issue - 82 | June 2010 |
| ID: 152-03 | Knowledge gaps with regard to wildlife species and ecosystems include a lack of knowledge concerning: reference organisms. | Nuclear Waste Advisory Associates’ Issues Register Issue - 83 | June 2010 |
| ID: 152-04 | Knowledge gaps with regard to wildlife species and ecosystems include a lack of knowledge concerning: ecosystem impact. | Nuclear Waste Advisory Associates’ Issues Register Issue - 84 | June 2010 |
| ID: 152-05 | Knowledge gaps with regard to wildlife species and ecosystems include a lack of knowledge concerning: dosimetry – dose calculations in a variety of wildlife species. | Nuclear Waste Advisory Associates’ Issues Register Issue - 85 | June 2010 |
| ID: 152-07 | Relative Biological Effectiveness - the data is dominated by acute doses and by particular groups such as. | Nuclear Waste Advisory Associates’ Issues Register Issue - 87 | June 2010 |
| ID: 152-08 | Knowledge gaps with regard to wildlife species and ecosystems include a lack of knowledge concerning: fish and mammals. | Nuclear Waste Advisory Associates’ Issues Register Issue - 88 | June 2010 |
| ID: 152-09 | Knowledge gaps with regard to wildlife species and ecosystems include a lack of knowledge concerning: fish and shellfish... | Helen Wallace (for Greenpeace International) Rock Solid Sec 4.8 | Sept 2010 |
| ID: 152-10 | Knowledge gaps with regard to wildlife species and ecosystems include a lack | Nuclear Waste Advisory Associates’ Issues Register Issue - 89 | June 2010 |
### Knowledge Gaps with Regard to Wildlife Species and Ecosystems

| ID: 152-11 | Knowledge gaps with regard to wildlife species and ecosystems include a lack of knowledge concerning: biological uptake. | Nuclear Waste Advisory Associates’ Issues Register Issue - 90 | June 2010 |
| ID: 152-12 | Knowledge gaps with regard to wildlife species and ecosystems include a lack of knowledge concerning: natural background effects. | Nuclear Waste Advisory Associates’ Issues Register Issue - 91 | June 2010 |
| ID: 152-13 | Knowledge gaps with regard to wildlife species and ecosystems include a lack of knowledge concerning: dose effects. | Nuclear Waste Advisory Associates’ Issues Register Issue - 92 | June 2010 |
| ID: 152-14 | Knowledge gaps with regard to wildlife species and ecosystems include a lack of knowledge concerning: quantities and units. | Nuclear Waste Advisory Associates’ Issues Register Issue - 93 | June 2010 |
| ID: 152-15 | Knowledge gaps with regard to wildlife species and ecosystems include a lack of knowledge concerning: genotox techniques. | Nuclear Waste Advisory Associates’ Issues Register Issue - 94 | June 2010 |
| ID: 152-16 | Knowledge gaps with regard to wildlife species and ecosystems include a lack of knowledge concerning: field testing of models. | Nuclear Waste Advisory Associates’ Issues Register Issue - 95 | June 2010 |

### RWMD Response:

We agree that the potential impacts of radionuclides released from a geological disposal facility on living things are relevant and will be considered within the scope of the Environmental Safety Case. We set out our current understanding on this topic in the recently published Biosphere Status Report [1]. We will continue to refine our approach as necessary as we develop our programme in the future.

The regulatory framework within which assessments relating to non-human biota are undertaken reflects the evolving status of international recommendations in this area and is not, as yet, fully developed. Notwithstanding the developments in approaches and recommendations in relation to non-human biota, we have undertaken a preliminary assessment of potential impacts of releases of radionuclides from a GDF using the ERICA tool (The ERICA assessment tool was developed through a European Commission project

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which had strong regulatory involvement). The ERICA tool is based on models described in the IAEA report [2].

The relevance of any ‘knowledge gaps’ relating to the consideration of non-human biota in an Environmental Safety Case therefore needs to be assessed in the context of the range of human and non-human biota that might be present at a candidate site. Therefore we envisage reviewing the need for further work in this area when we have sufficient information on the biosphere characteristics of a candidate site, including its likely evolution over long timescales.

B.1.5.3 Radioactive methane gas

Raised issues:

| ID: 153-01 | Carbon dioxide and methane …are likely to contain radioactive carbon-14 and may pose a radiological hazard in themselves as they leak from the repository. | Helen Wallace (for Greenpeace International) Rock Solid Sec 4.3.4 | Sept 2010 |
| ID: 153-02 | The magnitude of the dose arising from this (CH4) exposure and over what timescale. | Nuclear Waste Advisory Associates’ Issues Register Issue - 11 | June 2010 |
| ID: 153-03 (See also ID: 161-02 and ID: 164-26) | MRWS 146 recognised the potential for leakage of radioactive gas as a critical safety performance factor, within a few years of a repository being closed. The NDA reply agrees with this problem and also states that the problem is long standing. This is contradictory to the statements made in item 15, where the implication is that all problems can be solved within 10 years, by spending small amounts of research money. There is no credible basis for the NDA to make this statement. Leakage of radioactive gas remains an intractable problem. | Reply to the NDA response to MRWS paper 146 Professor Stuart Haszeldine University of Edinburgh | May 2011 |
| ID: 153-04 (See also ID: 161-04 and ID: 164-24) | Conclude generic research into the fate of C-14 in the gas phase from a geological repository. | Disposability Assessment Database ID44 Magnox Encapsulation Plant Periodic Review | 30th March 2010 |

RWMD Response:

We agree that the calculation of radiological dose from potential exposure to carbon-14 bearing methane gas and the timescale over which it might occur needs to be addressed. However we will only be able to review the significance of this when we have site information, a specific engineered design for the disposal system and understand fully the outputs from safety assessment calculations based on specific information on the geology and hydrogeology of a candidate site and based a specific design.

Previously, NDA and United Kingdom Nirex Limited published the results of initial assessments that covered the range of possibilities that gas released from a hypothetical disposal facility for intermediate-level waste (the most significant potential source of radioactive methane). This work studied the consequences of gas release in two cases: either all the gas dissolves in groundwater and eventually reach the biosphere in solution (e.g. after about 10,000 years for the illustrative flow conditions assumed), or, in a second case the gas was cautiously assumed to remain wholly in the gas phase and start to emerge in the biosphere as a gas shortly after closure of the facility, when the gas generation rate is high (see e.g., [1]). For the case of release in solution the calculated radiological risk was about six orders of magnitude below (one millionth) the regulatory guidance level; for the case of retention in the form of gas the calculated radiological risk was more than two orders of magnitude above (x100) the guidance level. In the light of uncertainties about the formation of radioactive methane from irradiated graphite and irradiated metals, these assessments were based on the cautious assumption that all carbon-14 present in these materials that might conceivably react to form radioactive methane would do so. It can be seen from this summary that to make a realistic assessment we would require additional information that would allow us to determine the extent to which gas would dissolve in groundwater before reaching the biosphere and a better understanding of the extent of any formation of radioactive methane.

We are currently undertaking a multi-year, combined experimental and modelling programme concerned with understanding the uptake of carbon-14 bearing gases by plants [2].

We have recently established an Integrated Project Team to address the overall strategy and development of a corresponding work programme to address issues arising from carbon-14 in the national inventory. This team will support the assessment of the carbon-14 contribution to radiological risks arising from both the groundwater and gas pathways. The aims of this project are to:

- improve our understanding of the processes controlling the release of carbon-14 from waste
- manage the consideration of waste disposal options in terms of concept, design and waste treatment and packaging advances; and
- improve our modelling approach for the assessment of gas.

B.1.6 Gas


### B.1.6.1 Carbon-14 release from intermediate level wastes

**Raised issues:**

| ID: 161-02 | MRWS 146 recognised the potential for leakage of radioactive gas as a critical safety performance factor, within a few years of a repository being closed. The NDA reply agrees with this problem and also states that the problem is long standing. This is contradictory to the statements made in item 15, where the implication is that all problems can be solved within 10 years, by spending small amounts of research money. There is no credible basis for the NDA to make this statement. Leakage of radioactive gas remains an intractable problem. | Reply to the NDA response to MRWS paper 146 Professor Stuart Haszeldine University of Edinburgh | May 2011 |
| ID: 161-03 | Investigate the rate at which methane containing the radionuclide carbon-14 might be produced from the waste, and the potential for this gas to migrate through the surrounding and overlying rock formations. | Generic DSSC NDA/RWMD/011 | Jan 2011 |
| ID: 161-04 | Conclude generic research into the fate of C-14 in the gas phase from a geological repository. | Disposability Assessment Database ID44 Magnox Encapsulation Plant Periodic Review | 30th March 2010 |
| ID: 161-05 | With Sellafield Ltd develop a dataset on the fate of C-14 from corrosion of irradiated magnox and uranium (note: SDP project have identified a useable source of irradiated uranium). | Disposability Assessment Database ID45 Magnox Encapsulation Plant Periodic Review | 30th March 2010 |
| ID: 161-06 | Work to reduce conservatisms in C-14 'risk threshold' release rate (2.4E-3TBq/y). | Disposability Assessment Database ID35 Windscale Piles Aluminium Nitride cartridges | 20th Nov 2009 |

**RWMD Response:**
The potential for carbon-14 release from intermediate level waste has been identified as requiring work in our programme [1]. Gaseous radioactive species form a small proportion of the total volume of gas generated in a geological disposal facility (GDF). Carbon-14 labelled gas species may be radiologically the most important of these, if the gas migrates rapidly from a GDF after closure, because of the radionuclide’s relatively long half-life (5730 years). The major sources of carbon-14 in intermediate-level wastes in the UK are irradiated metals, irradiated graphite and some organic materials. There is uncertainty about the rates of release of gases containing carbon-14 from the wastes and the chemical form in which they are released (e.g. carbon dioxide, carbon monoxide, and hydrocarbons, such as methane), therefore this uncertainty is addressed in the safety assessment calculations (an example of which is described in the response to Issue Group B.1.5.3). Their rate of generation may depend upon water availability, and hence on the rate of resaturation of waste packages during backfilling and after closure (and may thus be site-dependent), temperature (e.g. during backfilling) and the previous history of the wastes (e.g. how much corrosion has occurred during storage prior to backfilling and closure of a GDF). The form in which carbon-14 would be released is dependent upon the chemical form of the carbon-14 in the wastes. Thus we need to better understand the source term for carbon-14 labelled gases. Carbonation of the backfill and other cementitious materials in the near field may be an important sink for carbon-14 labelled carbon dioxide and we need to better understand these reactions in the context of package grouts.

The potential release of gaseous carbon-14 from a GDF has been identified previously as an important uncertainty in the post-closure safety assessment requiring further work [2]. The recently published Operational Environmental Safety Assessment (OESA) has shown that it also represents an important uncertainty in relation to possible gas release from ventilation systems during backfilling of vaults at the end of the operational phase [3]. In respect of the post-closure phase the migration of carbon-14 in a distinct gas phase (if formed) and the persistence of a distinct gas phase is dependent on the nature of the host geology and can only be addressed once a candidate site or sites are being investigated [4].

As illustrated in our response to Issue Group 1.5.3 we have recently established an Integrated Project Team to address the overall strategy and development of a corresponding work programme to address issues arising from carbon-14 in the national inventory.

B.1.6.2 Bulk gas generation from intermediate level waste

Raised issues:

<table>
<thead>
<tr>
<th>ID: 162-01</th>
<th>There are, however, a number of areas where generic (i.e. not site specific) research would be useful. Examples of these areas are: microbial interactions with wasteforms.</th>
<th>CoRWM doc 2543 Report on R&amp;D for interim storage and geological disposal... 2.26, 22</th>
<th>October 2009</th>
</tr>
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<tbody>
<tr>
<td>(also see ID: 173-03)</td>
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| ID: 162-02 | We don’t have calculations for the total amounts of gas produced from all wastes (including spent fuel and high level waste). | Peer review Gas status report | DSSC peer review 2010 |
| ID: 162-03 | At present there are no relevant calculations to quantitatively present the kinetics of corrosion in different environments and the migration of hydrogen between intermediate level waste and high level waste. | Peer review Gas status report | DSSC peer review 2010 |
| ID: 162-04 | Uncertainty in rate of corrosion of Magnox with temperature in the disposal environment, most significant to effects of backfilling. Determine rate of gas and chemical heat generation. | Disposability Assessment Database ID38 Magnox Encapsulation Plant Periodic Review | 30th March 2010 |
| ID: 162-05 | The interaction of processes that would lead to hydrogen release is not understood. | Nuclear Waste Advisory Associates’ Issues Register Issue - 8 | June 2010 |
| ID: 162-06 | Investigate the rate at which methane containing the radionuclide carbon-14 might be produced from the waste, and the potential for this gas to migrate through the surrounding and overlying rock formations. | Generic DSSC NDA/RWMD/011 | January 2011 |

**RWMD Response:**

Understanding bulk gas generation arising from a geological disposal facility (GDF) during operations and closure is important. Corrosion of metals in intermediate level waste (ILW) packages is a significant contributor to bulk gas generation. The research we have undertaken found that for ILW the peak in hydrogen production can be early in the post-closure period and is associated with the reaction of water and dissolved salts with metals [1]. The mechanisms and rates of corrosion (and hence hydrogen generation) from steels, Zircaloy, Magnox, uranium and aluminium have been reviewed for high pH conditions. Therefore, we recognise bulk gas will be generated from metal corrosion, and we have developed a good understanding of the generation processes. To supplement this understanding our approach is to carry out periodic reviews of data and mechanisms to ensure that our understanding remains up-to-date and is applicable to concepts and GDF designs under consideration. Gas generation from the microbial degradation of cellulose is also an important contributor to the overall bulk gas generation from ILW. Recently, we have held a workshop, engaging domain experts, to inform the development of a needs driven research in the microbial degradation of cellulose. We propose to undertake

experiments and modelling on rates of gas generation from degradation of cellulose and organic wastes under a range of conditions [1]. In the longer-term this area of the programme would develop to take account of site-specific information.

We have made calculations previously for gas generation from ILW based on an update of the 2004 UK Radioactive Waste Inventory [2]. We are currently undertaking similar calculations for the operational and early post-closure periods based on the 2007 Derived Inventory [3]. Our gas generation calculations will be updated at appropriate intervals to take account of new information on the inventory of gas-generating materials in ILW, improved understanding (e.g. metal corrosion rates under relevant conditions, rates of resaturation) and the development of a concept.

In respect of bulk gas generation we need to maintain understanding of gas generation processes as the concept for a GDF develops to be in a position to support calculations of rates and volumes of gas generation from materials in a GDF in the future.

B.1.6.3 Gas generation from high level waste and spent fuel

Raised issues:

| ID: 163-01 | We don’t have calculations for the total amounts of gas produced from all wastes (including spent fuel and high level waste). | Peer review | DSSC peer review 2010 |
| ID: 163-02 | There is a lack of understanding of the potential gas generation for packages containing high level waste and spent fuel which is not considered within the current scope of the generic Waste Package Specification documents. | Disposability Assessment Database ID32 Disposability of Technological high level waste (Preliminary Assessment) | May 2010 |
| ID: 163-03 | If however corrosion of copper by water can occur in the absence of oxygen...the hydrogen generated by this reaction might also have significant implications for the safety case...Additional steel may be introduced... e.g. as structural support... Hydrogen generation from the corrosion of this steel also needs to be considered in the safety case. | Helen Wallace (for Greenpeace International) Rock Solid Sec 4.2.5 | Sept 2010 |


RWMD Response:
It is important to minimise any potential for significant pressurisation within high level waste (HLW) and spent fuel waste containers and ensure that any gas does not affect the overall safety of the system.

Our current understanding is that, for package designs based on copper and thin-walled, corrosion resistant designs (stainless steel, nickel alloys, titanium), the potential for significant gas generation is low [1]. For less corrosion-resistant designs (e.g. those based on carbon steel/cast iron) some quantities of hydrogen gas are likely to be generated upon contact with groundwater once anoxic conditions are established. The ability of such gas to be transported through the surrounding rocks is concept and site specific. However, disposal concepts based on geological disposal of HLW and spent fuel in carbon steel/cast iron container are, or have been, considered in many countries (for example in Switzerland, France, and Germany). Based on the research data and understanding available internationally and work we have recently completed [2], we expect to be able either to show that gas generation is unlikely to be a problem, or that we would be able to propose alternative designs to mitigate any potential problem arising from gas generation in HLW and spent fuel.

Work is continuing is our programme to support the concept selection process by developing our understanding of the corrosion behaviour of candidate container materials under a range of geological disposal conditions. In particular we are participating in a number of the international projects, including the Decovalex project referred to in the JRC report [3], which has an objective of improving understanding of this technical issue.

B.1.6.4 Gas migration and reaction

Raised issues:

| ID: 164-01 | It is also recognised... that there are several key uncertainties (e.g. 14C transport as gas or dissolved species…) and that the magnitudes of these will need to be explored through R&D. | CoRWM Doc. 2550. Geological disposal of higher activity radioactive wastes. July 2009 12.20, p44 | July 2009 |
| ID: 164-02 | Gas/groundwater (or porewater) interactions: Gas migration in the geosphere is strongly influenced by the detailed structure of the site itself, so the absence of a UK site for study has limited progress in this area. | Environment Agency Science Programme Contractor Report: Technical issues associated with deep repositories | August 2009 |


### An issue of whether gas generated in the intermediate and low-level waste part of a facility could affect groundwater movement in the high level waste/spent fuel part of a facility.

- **CoRWM doc 2543**
- Report on R&D for interim storage and geological disposal...
- A.82, 120
- **October 2009**

### There are, however, a number of areas where generic (i.e. not site specific) research would be useful. Examples of these areas are the fate of waste-emitted gases in the geosphere (including from chemical and microbial reactions).

- **CoRWM doc 2543**
- Report on R&D for interim storage and geological disposal...
- 2.26, 22
- **October 2009**

### The need to allow the release of hydrogen gas which is contrary to the need for ‘barriers’.

- **Nuclear Waste Advisory Associates’ Issues Register Issue - 6**
- **June 2010**

### Lack of clarity as to whether hydrogen pressure will open fractures and result in ‘fast pathways’.

- **Nuclear Waste Advisory Associates’ Issues Register Issue - 7**
- **June 2010**

### The extent of the ‘carbonation’ reaction between carbon-14 and cement.

- **Nuclear Waste Advisory Associates’ Issues Register Issue - 9**
- **June 2010**

### Gas generation and its interaction with groundwater: in particular the implications for the reliability of the risk predictions.

- **Nuclear Waste Advisory Associates’ Issues Register Issue - 20**
- **June 2010**

### The impact of groundwater chemistry on gas solubility is poorly known.

- **Nuclear Waste Advisory Associates’ Issues Register Issue - 21**
- **June 2010**

### Current predictions of gas/groundwater flow may not be adequate.

- **Nuclear Waste Advisory Associates’**
- **June 2010**
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<tr>
<td>ID: 164-12</td>
<td>..a sudden release of pressure (or explosion) could damage the repository. Alternatively, slow release of gas could open up fractures in the backfill or rock, and speed up the release of some radionuclides…</td>
<td>Helen Wallace (for Greenpeace International) Rock Solid Sec 4.1</td>
<td>September 2010</td>
</tr>
<tr>
<td>(see also ID: 122-07)</td>
<td></td>
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<tr>
<td>ID: 164-13</td>
<td>The pressure rise in a repository due to the formation of dissolved hydrogen, and the subsequent production of gas bubbles, might be sufficient to break or fracture the barriers... Hydrogen embrittlement of the corroding metal might also occur, with detrimental effects on the mechanical characteristics of the overpacks or canisters.</td>
<td>Helen Wallace (for Greenpeace International) Rock Solid Sec 4.1.4</td>
<td>September 2010</td>
</tr>
<tr>
<td>ID: 164-14</td>
<td>Gas breakthrough… could permanently damage the engineered barriers and surrounding rock.</td>
<td>Helen Wallace (for Greenpeace International) Rock Solid Sec 4.2.5</td>
<td>September 2010</td>
</tr>
<tr>
<td>ID: 164-15</td>
<td>Release of radioactive gas. … concerns relate to any damage to containment that might be caused by pressure build-up … and to the potential role of the gas in pushing radioactively contaminated water upwards out of the repository.</td>
<td>Helen Wallace (for Greenpeace International) Rock Solid Sec 4.3.4</td>
<td>September 2010</td>
</tr>
<tr>
<td>ID: 164-16</td>
<td>…effects of water vapour as well as liquid water need to be considered.</td>
<td>Helen Wallace (for Greenpeace International) Rock Solid Sec 4.2.1</td>
<td>September 2010</td>
</tr>
<tr>
<td>ID: 164-17</td>
<td>Advective flow could also have safety consequences because water would be pushed through the clay ahead of the gas.</td>
<td>Helen Wallace (for Greenpeace International) Rock Solid Sec 4.2.5</td>
<td>September 2010</td>
</tr>
<tr>
<td>ID: 164-18</td>
<td>Gas flow. i) the ability to understand and predict underground gas migration is</td>
<td>Helen Wallace (for Greenpeace International) Rock Solid Sec</td>
<td>September 2010</td>
</tr>
<tr>
<td>ID: 164-19</td>
<td>Points for consideration in future gas assessments: (i) which pathways are important for gas; (ii) what scenarios should be considered in the assessment? (iii) What approach should be used to account for gas generation and migration in the safety assessment?</td>
<td>Peer review</td>
<td>DSSC peer review 2010</td>
</tr>
<tr>
<td>ID: 164-20</td>
<td>Determination of methodology for gas pressurisation calculations.</td>
<td>Peer review</td>
<td>DSSC peer review 2010</td>
</tr>
<tr>
<td>ID: 164-21</td>
<td>Determination of methodology for performing gas calculations is required (across departments).</td>
<td>Peer review</td>
<td>DSSC peer review 2010</td>
</tr>
<tr>
<td>ID: 164-22</td>
<td>At present there are no relevant calculations to quantitatively present the kinetics of corrosion in different environments and the migration of hydrogen between intermediate level waste and high level waste.</td>
<td>Peer review</td>
<td>DSSC peer review 2010</td>
</tr>
<tr>
<td>ID: 164-23</td>
<td>Develop Gas migration text for each illustrative concept example within the Disposal System Technical Specification.</td>
<td>Peer review</td>
<td>DSSC peer review 2010</td>
</tr>
<tr>
<td>ID: 164-24</td>
<td>Conclude generic research into the fate of C-14 in the gas phase from a geological repository.</td>
<td>Disposability Assessment Database ID44 Magnox Encapsulation Plant Periodic Review</td>
<td>30th March 2010</td>
</tr>
<tr>
<td>ID: 164-25</td>
<td>Investigate the rate at which methane containing the radionuclide carbon-14 might be produced from the waste, and the potential for this gas to migrate through the surrounding and overlying rock formations.</td>
<td>Generic DSSC NDA/RWMD/011</td>
<td>Jan 2011</td>
</tr>
<tr>
<td>ID: 164-26</td>
<td>▶ MRWS 146 recognised the potential for leakage of radioactive gas as a critical safety performance factor, within a few years of a repository being closed. The NDA Reply to the NDA response to MRWS paper 146 Professor Stuart</td>
<td>May 2011</td>
<td></td>
</tr>
</tbody>
</table>
reply agrees with this problem and also states that the problem is long standing. This is contradictory to the statements made in item 15, where the implication is that all problems can be solved within 10 years, by spending small amounts of research money. There is no credible basis for the NDA to make this statement. Leakage of radioactive gas remains an intractable problem.

Haszeldine
University of Edinburgh

RWMD Response:

NDA has published the results of assessments that considered gas generation (bulk and radioactive) in a geological disposal facility (GDF) situated in a range of host rock media, and subsequent gas migration [1]. These studies consider, for example, how gas is generated from waste in the presence of water availability in a GDF, which depends on the host rock type and properties, and the desaturation / resaturation behaviour exhibited in the GDF operational and post-closure periods. If a free gas phase were to form, its subsequent migration from a GDF would be dependent on the properties of the host rock, properties of the surrounding rock, and the extent of dissolution in groundwater. In the absence of a migrating free gas phase the only transport of trace radioactive gases, e.g. carbon-14 labelled methane (as discussed in Issue Group B.1.5.3), would be as dissolved species.

We would agree that the potential over-pressurisation of the disposal facility due to a build up of gas, which is likely to be mainly hydrogen, needs to be considered. The potential for over-pressurisation is highly dependent upon the design of the engineered system, including the waste containers, engineered barrier, and the characteristics of the surrounding host rock (in particular in relation to the availability of water for gas generation processes).

Over-pressurisation is unlikely to be an issue in a strong, fractured rock where gas is expected to be able to enter the fracture network and migrate away from the disposal facility without causing mechanical damage to the rock. In addition this is unlikely to be an issue in evaporites due to the self-healing properties of the rock and the high pressure required for the gas to enter the host rock (hence why salt caverns are utilised as gas storage facilities).

In very low permeability clay rocks, which are most likely to prevent the release of gas from a disposal facility and so result in a build up of pressure, there may be an insufficient supply of groundwater to react with materials in a facility and generate gas at a rate where such a pressure build-up would occur [2]. If the rate of gas generation were to become sufficiently high there would be a potential for over-pressurisation of very low permeability rocks, with no significant natural fractures that would allow gas to escape. Work carried out on such rock types in other countries’ waste management programmes [3,4] has shown


that a gas over-pressure can be relieved by the formation of micro-fissures in the rock. In the cases studied, the micro-fissures “heal” after the pressure is relieved because of the rock’s intrinsic properties and the compressive forces acting on the rocks at depth. In addition, there are also international studies to assess the potential for gas to be transported along the Engineered Disturbed Zone at the tunnel/rock interface.

We would expect to assess any potential for over-pressurisation at a later stage in the programme when we would have sufficient information on the host rock properties and would have developed an engineered design for the disposal system.

As these post-closure issues are site–specific, they can only be addressed in detail during site selection. Therefore, this area of our programme is currently focusing on providing information and data to develop our generic understanding including:

- bulk gas migration and reaction through clay-based materials; and
- bulk gas migration and reaction through cement-based materials, focusing on the carbonation of cements.

We are incorporating into our ongoing work a number of the recommendations from the peer review of the generic Disposal System Safety Case relating to gas assessment methodology (which are further described in the response for topic 2.1.4). We are also participating in the EC international collaboration FORGE (Fate Of Repository GasEs) project [5] to progress the international state of the art understanding of repository-derived gas in the context of the safety case.


## B.1.7 Radionuclide behaviour

### B.1.7.1 Radionuclide migration in groundwater

#### Raised issues:

| ID: 171-01 | There are, however, a number of areas where generic (i.e. not site specific) research would be useful. Examples of these areas are: sorption processes on likely surfaces and the transport ... in the geosphere (including from chemical and microbial reactions). | CoRWM doc 2543 Report on R&D for interim storage and geological disposal... 2.26, 22 | October 2009 |
| ID: 171-02 | If predictions of radionuclide migration with groundwater are to be reliable they need to be based on a good understanding of the mechanisms involved. This requires, for the key radionuclides, advances in knowledge of: the physico-chemical forms of the radionuclides the spatial variability, temporal evolution and reactivity of mineral surfaces upscaling molecular level models to estimate bulk chemical properties and predict transport over hundreds of metres. | CoRWM doc 2543 Report on R&D for interim storage and geological disposal... 6.7, 90 | October 2009 |
| ID: 171-03 | Further work is needed to understand and model radionuclide migration... more understanding is required of: radionuclide physico-chemical form (speciation) | CoRWM doc 2543 Report on R&D for interim storage and geological disposal... A.57, 112 | October 2009 |
| ID: 171-04 | Need for R&D to improve predictions of radionuclide movement through the geosphere-biosphere interface (for example, movement from rocks to soils and sediments). | CoRWM doc 2543 Report on R&D for interim storage and geological disposal... A103, 125 | October 2009 |
| ID: 171-05 | Are the impacts/effects of mobile radionuclides (e.g. Cl-36, I-129) understood? | Peer review Near Field Evolution status report | DSSC peer review 2010 |
RWMD Response:

We believe that there is a substantial knowledge base available on the general behaviour of radionuclides under the conditions implied by post-closure scenarios of relevance to concepts considered for the three generic rock-types in the generic Disposal System Safety Case. The current understanding of radionuclide transport processes is summarised in the Radionuclide Behaviour Status Report [6]. This includes understanding the impacts of the likely chemical environment of the near field and potential chemical environments of the geosphere and how these would influence radionuclide migration processes. It also includes understanding of physical processes such as diffusion, advection and dispersion transport, and chemical interactions with material surfaces such as sorption, and interactions with colloids and microbes (as discussed in the responses to issue groups 1.7.3 and 1.7.4). We are starting to address issues relating to representing transport processes at varying levels of detail through engaging with the BIGRAD project [7] and the recently funded NDA/EPSRC project investigating atomic and macro-scale studies of surface processes [8]. This project will be producing new empirical data and developing further mechanistic understanding of transport processes at the molecular level. We are also addressing the up-scaling of molecular level understanding and small-scale experimental data through participation in a number of large scale demonstration activities [9].

Once site-specific samples and data become available, we will use tracers to measure their transport through candidate backfill and buffer materials that have been conditioned with site-specific waters. Work will also be undertaken to measure radionuclide transport properties in groundwater flowing or diffusing through the engineered disturbed zone and various rocks between a geological disposal facility (GDF) and the surface (including consideration of the geosphere-biosphere interface). This work will be essential to support the safety case.


[7] Biogeochemical Gradients and RADionuclide transport (BIGRAD), Project BIGRAD is a UK NERC funded consortium aimed at developing a better understanding of the geochemical and microbiological evolution of the subsurface environment surrounding a radioactive waste geological disposal facility (GDF), http://www.bigradnerc.com/ accessed February 2012.

[8] Atomic and macro-scale studies of surface processes: towards a mechanistic understand of surface reactivity and radionuclide binding mechanisms (led by Imperial College London), GeoWaste NDA-EPSRC funded research project investigating (i) how the surfaces of candidate materials in an engineered barrier system behave in a typical disposal environment; and, (ii) the effect of any alteration processes on radionuclide/surface interactions.

B.1.7.2 Radionuclide retardation and immobilisation mechanisms

Raised issues:

| ID: 172-01 | It is also recognised... that there are several key uncertainties: e.g. radionuclide sorption and that the magnitudes of these will need to be explored through R&D. | CoRWM Doc. 2550. Geological disposal of higher activity radioactive wastes. July 2009 12.20, p44 | July 2009 |
| ID: 172-02 | Experiments in Sweden suggest that some actinides are retarded in the rock, while others (e.g. neptunium) may break through with hardly any retardation. | Helen Wallace (for Greenpeace International) Rock Solid Sec 4.4.1 | Sept 2010 |
| ID: 172-03 | Similarly, reaction rate information is also largely unavailable. | Nuclear Waste Advisory Associates’ Issues Register Issue - 59 | June 2010 |
| ID: 172-04 | The retention time within fractured rock and the possibility that radionuclides would not be retained for a sufficient time to adopt the 'oxidised' form must be addressed. | Nuclear Waste Advisory Associates’ Issues Register Issue - 66 | Jun-10 |
| ID: 172-05 | The capacity of clay to retain radionuclides may be affected by other repository components. | Nuclear Waste Advisory Associates’ Issues Register Issue - 78 | June 2010 |

RWMD Response:

The uptake of radionuclides on the rocks around a geological disposal facility (GDF) or on the materials selected for use in the engineered barriers provides a safety function in many geological disposal concepts and will depend on the composition of the rock or barrier materials and on the local chemical environment. The current understanding of radionuclide behaviour focussing on the groundwater system is summarised in the Radionuclide Behaviour Status Report [1] which represents the main retardation and immobilisation processes that we consider are important to the range of illustrative disposal concepts used in the Disposal System Safety Case.

At present the information available from our own research programme, or from overseas waste management programmes that are mature, provide us with enough understanding to support the current phase of implementation. The chemical form of a radioelement and its influence on processes such as sorption that retard radionuclide migration in groundwater is an issue (see also issue group 1.7.6). At present we do not make a priori assumptions about the chemical state of radioelements. We determine by experimental and

thermodynamic modelling research which chemical forms of a radionuclide would exist under a range of possible conditions both within the engineered part of the disposal facility and in the groundwater system between the disposal facility and the surface environment and what the associated retardation of the radioelement would be. Where there is uncertainty in the chemical form of the radioelement and therefore in the associated level of retardation, we reflect this by using a range of chemical parameter values in safety assessments.

Once site information becomes available, and concepts for the sites have been selected, the respective site-specific safety cases will demonstrate how the required safety functions would be met. Understanding of specific radionuclide retardation and immobilisation processes at this stage will become more focussed. This will allow us to address remaining knowledge gaps with regard to the chemical properties for some radioelements and the treatment of radionuclide retardation and immobilisation processes that are of interest and of relevance to our work programme at this time (i.e. specific to UK wastes and site-specific concepts under consideration) [2].

B.1.7.3 Other influences on radionuclide behaviour

Raised issues:

| ID: 173-01 (see also ID: 172-01) | It is also recognised... that there are several key uncertainties: e.g. radionuclide sorption ...... and that the magnitudes of these will need to be explored through R&D. | CoRWM Doc. 2550. Geological disposal of higher activity radioactive wastes. July 2009 12.20, p44 | July 2009 |
| ID: 173-02 | Duration for which engineered barrier system materials may maintain their functions (durability): impact of modern superplasticisers on very long term durability and on radionuclide mobility is not well understood. | Environment Agency Science Programme Contractor Report: Technical issues associated with deep repositories for radioactive waste in different geological environments Issue 5, 5.5.2, p100 | August 2009 |
| ID: 173-03 (see also ID:162-01) | There are, however, a number of areas where generic (i.e. not site specific) research would be useful. Examples of these areas are: microbial interactions with wasteforms. | CoRWM doc 2543 Report on R&D for interim storage and geological disposal... 2.26, 22 | October 2009 |

<p>| ID: 173-04 | Microbial processes are poorly understood and may impact on the performance of a GDF. ... it is desirable to carry out generic research ... | CoRWM doc 2543 Report on R&amp;D for interim storage and geological disposal... 6.14, 91 | October 2009 |
| ID: 173-05 | It is also recognised... that there are several key uncertainties (e.g..... microbial effects.....) and that the magnitudes of these will need to be explored through R&amp;D. | CoRWM Doc. 2550. Geological disposal of higher activity radioactive wastes. July 2009 12.20, p44 | June 2010 |
| ID: 173-06 | Microbial processes are poorly understood and may impact on the performance of a GDF. ... it is desirable to carry out generic research ... develop UK capability in techniques for the sampling and characterisation of subsurface microbial communities... | CoRWM doc 2543 Report on R&amp;D for interim storage and geological disposal... 6.14, 91 | June 2010 |
| ID: 173-07 | There remains a requirement to conduct generic research and build essential capability, for example in techniques for the sampling and characterisation of subsurface microbial communities. | CoRWM doc 2543 Report on R&amp;D for interim storage and geological disposal... A.97, 124 | June 2010 |
| ID: 173-09 | Much colloid work has been restricted to experimentation with uranium resulting in considerable research gaps as far as other radionuclides are concerned. | Nuclear Waste Advisory Associates’ Issues Register Issue - 68 | June 2010 |
| ID: 173-10 | The interaction between colloids, microbes and radionuclides has not been well researched. | Nuclear Waste Advisory Associates’ Issues Register Issue - 69 | June 2010 |
| ID: 173-11 | The effect of colloid ‘size exclusion’ – (i.e. the role of colloids in preventing radionuclides becoming trapped in pores due to the size of the colloid) – on the speed of radionuclide travel. | Nuclear Waste Advisory Associates’ Issues Register Issue - 70 | June 2010 |</p>
<table>
<thead>
<tr>
<th>ID: 173-12</th>
<th>Decomposition products of paper can cause a significant increase in radionuclide solubility.</th>
<th>Nuclear Waste Advisory Associates' Issues Register Issue - 76</th>
<th>June 2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>ID: 173-13</td>
<td>Knowledge gaps with regard to wildlife species and ecosystems include a lack of knowledge concerning: the role and effect of microbes in proposed disposal systems is not fully understood.</td>
<td>Nuclear Waste Advisory Associates' Issues Register Issue - 96</td>
<td>June 2010</td>
</tr>
</tbody>
</table>
| ID: 173-14 | Microbes could have a number of adverse effects on the safety of a nuclear waste repository, including causing corrosion of metal waste containers.  
n  i) Migration of micro-organisms through the bulk of the buffer appeared to be slow, but migration along the metallic holder–buffer interface was rapid, suggesting that cracks or interfaces may form preferred pathways for migration.  
n  ii) In concepts where the repository is to be kept open for a long period of time, to allow for monitoring and possible retrieval of wastes, there may be added difficulties with microbes due to the presence in the ventilated caverns of a humid, oxygen-filled environment. This could provide many potential niches for microbial growth, which could then affect the integrity of the storage canisters | Helen Wallace (for Greenpeace International) Rock Solid Sec 4.1.3 | Sept 2010 |
| ID: 173-15 | Role of microbes.  
n  i) Microbiological processes must be taken into account when modelling groundwater hydrogeochemistry:  
n  ii) Microbes... can enhance radionuclide migration by sorption, or reduce it by immobilising radionuclides in biofilms. They can also influence the release of radionuclides by altering bulk water chemistry (especially pH and redox)...  
n  iii) These complex biological effects on radionuclide transport are poorly understood but must be considered in a repository safety case | Helen Wallace (for Greenpeace International) Rock Solid Sec 4.3.3 | Sept 2010 |
| ID: 173-16 | ▶ the concentration of plutonium by plants could be an issue of concern if it is transported to an aquifer faster than expected, perhaps in the form of colloids...
Helen Wallace (for Greenpeace International) Rock Solid Sec 4.8 | Sept 2010 |
| ID: 173-17 | ▶ Colloids and complexation.
  i) Migration on colloids is of particular concern in the case of actinides, such as plutonium, which can be transported large distances in groundwater as colloids...
  ii) There are still significant gaps in the understanding of the transport of actinides bound to minerals and colloids. However, experiments suggest that actinide speciation may be dominated by colloid forms.
  iii) ...these colloids are very stable in low saline and alkaline waters, and could facilitate radionuclide transport in the fracture network of the excavation disturbed zone (EDZ) in the granite around a repository.
  iv) The presence of oxidants can also enhance actinide transport significantly.
  v) Cementitious materials are commonly used to stabilise some radioactive wastes, such as long-lived intermediate-level wastes, which may be co-disposed with high-level wastes in some countries... cellulosic materials present in the wastes (tissues, cotton or paper) can exacerbate the above difficulties by forming organic compounds, which may then form complexes with actinides.
Helen Wallace (for Greenpeace International) Rock Solid Sec 4.3.2 | Sept 2010 |
| ID: 173-18 | ▶ Findings that micro-organisms can dissolve smectite at room temperature (by reducing Fe(III)) have been described as a major challenge in the context of deep geological disposal, since they suggest that this process may happen much faster than predicted, even in the absence of significant heat.
Helen Wallace (for Greenpeace International) Rock Solid Sec 4.2.6 | Sept 2010 |
| ID: 173-19 | ▶ What are the effects of microbes introduced during repository construction?
Peer review Near Field Evolution status | DSSC peer review |
Further research into metal solubility (other than Uranium and Plutonium) in cement pore water containing comb superplasticisers is required to support the generic use of these materials in waste packaging operations.

ID: 173-20

Disposability Assessment Database ID34 Comb Superplasticisers 13th April 2010

RWMD Response:

There are areas of our understanding of radionuclide behaviour in both the near field of a geological disposal facility (GDF) and in the geosphere which is less mature than that for transport, retardation and immobilisation processes (as described in evaluation response for 1.7.1). Our research programme is currently focussed on developing further understanding of the complexants in cellulose degradation products under a range of conditions of relevance to intermediate level waste and low level waste (ILW/LLW) disposal and to assess their influence on radionuclide behaviour. We are also progressing work to understand the influence of other potential complexants that may be generated or present in the wastes that could give rise to enhanced radionuclide transport. This understanding is important to support the safety case and includes consideration of non-aqueous phase liquids (NAPLs), superplasticisers, anthropogenic decontamination agents such as citrate and ethylenediaminetetraacetic acid (EDTA), and naturally occurring complexants in the geosphere.

With respect to colloids and microbes, we have participated in a number of international collaborative projects [1] and have also recently commissioned substantive reviews of the international literature on both topics [2]. We have previously responded to the individual issues raised by the NWAA on colloids and microbes and consider that these issues are adequately covered in the review documents cited in reference [2]. We recently held a colloid strategy review [3], which was independently facilitated and observed by a member of CoRWM and the Chairman of our R&D advisory panel. The meeting discussed a wide range of colloid related process and issues and identified areas that it would be useful to address over the next five years. A similar exercise is planned to review our programme on microbes. Both these areas will continue to be managed by our research and development programme to support understanding that is required for the safety case and developing colloid and microbe sampling methodologies to support site characterisation [4].

The interaction between colloids, microbes and radionuclides will also be an issue for consideration within the safety case. Given that the concentrations and properties of both colloids and microbes will be site-specific we envisage that this issue will not be addressed in detail until later in our programme.


## B.1.7.4 Data for radionuclide behaviour parameters

### Raised issues:

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<tr>
<td>ID: 174-02</td>
<td>A better understanding of the heavier chemical elements (uranium and heavier) is required.</td>
<td>Nuclear Waste Advisory Associates’ Issues Register Issue - 60</td>
<td>June 2010</td>
</tr>
<tr>
<td>ID: 174-03</td>
<td>The lack of knowledge concerning the basic chemical behaviour of important radionuclides led to a programme of fundamental research. However, the majority of this research has not been carried out under natural conditions.</td>
<td>Nuclear Waste Advisory Associates’ Issues Register Issue - 71</td>
<td>Jun-10</td>
</tr>
<tr>
<td>ID: 174-04</td>
<td>There are gaps in the chemical data for common major elements.</td>
<td>Nuclear Waste Advisory Associates’ Issues Register Issue – 73</td>
<td>June 2010</td>
</tr>
<tr>
<td>ID: 174-05</td>
<td>The impact of salty water on chemical reactions is difficult to predict.</td>
<td>Nuclear Waste Advisory Associates’ Issues Register Issue – 75</td>
<td>June 2010</td>
</tr>
<tr>
<td>ID: 174-06</td>
<td>The data used to predict radionuclide take up by solid surfaces is known to be wrong.</td>
<td>Nuclear Waste Advisory Associates’ Issues Register Issue – 77</td>
<td>June 2010</td>
</tr>
</tbody>
</table>
RWMD Response:

Data for radionuclide behaviour parameters are used in our safety assessment models (see a separate response for topic 1.7.5) but are also used to plan or interpret experiments to provide or test understanding at the mechanistic level and the development of conceptual models, for key components of disposal concepts. Thermodynamic modelling of environmental chemical conditions and radionuclide behaviour is complex, however it is a well-established scientific discipline. It is an area of ongoing active research for a wide range of applications. With respect to geological disposal we believe that there is a substantial knowledge base to support the data that are used in a disposal system safety case. The information used in the UK programme is maintained in the HATCHES database which includes descriptions of the protocols used to select data. We also part-fund a multinational effort under the auspices of the NEA to produce high-quality, peer reviewed, internally consistent datasets of elements of interest in the geological disposal of radioactive waste [1]. This work also provides guidance on how data should be corrected to account for changes in temperature and salinity for a range of chemical environments which we incorporate into the HATCHES thermodynamic database data selection procedures. A more detailed description of HATCHES, how to access it and the underpinning references for its data are available on our bibliography.

In preparation for future updates of the generic Disposal System Safety Case we are reviewing our approach to data selection, focussing especially on data to support concept selection and disposability assessments for high level waste and spent fuel. Once site-specific information is available, we will further refine the datasets for both the intermediate level waste and high level waste/spent fuel concepts under consideration and geochemical conditions at a potential candidate site(s) [2].

B.1.7.5 Representation of radionuclide behaviour in assessment models

Raised issues:

| ID: 175-01 | The incorporation of corroded iron into clay can in theory act as a pump to accelerate corrosion. A UK model again shows slowing of corrosion after time due to clogging of pores in the clay, but the chemical reactions assumed to take place differ significantly from the model developed in France. The authors conclude that meaningful application of the model requires key missing data, such as solubilities and free energies at the mineral–fluid interface. | Helen Wallace (for Greenpeace International) Rock Solid Sec 4.2.4 | Sept 2010 |
| ID: 175-02 | It must be demonstrated that | Nuclear Waste | June |

[1] Nuclear Energy Authority (NEA) chemical thermodynamics series comprises review reports dealing with data selection for particular elements or groups of elements and state-of-the-art reports focusing on the application chemical thermodynamics to particular systems of interest in radioactive waste management, http://www.oecd-nea.org/dbtdb/info/publications/, accessed February 2012.

<table>
<thead>
<tr>
<th>Issue</th>
<th>Description</th>
<th>Source</th>
<th>Date</th>
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<tbody>
<tr>
<td>ID: 175-03</td>
<td>Soluble compounds which have only more recently received attention would not result in an undue risk.</td>
<td>Advisory Associates’ Issues Register Issue – 62</td>
<td>2010</td>
</tr>
<tr>
<td>ID: 175-04</td>
<td>The validity of the assumption that the ‘oxidised’ form of the radionuclides is the more soluble form, must be demonstrated.</td>
<td>Nuclear Waste Advisory Associates’ Issues Register Issue – 63</td>
<td>June 2010</td>
</tr>
<tr>
<td>ID: 175-05</td>
<td>Many radionuclides do not occur in nature and therefore cannot be studied in natural systems.</td>
<td>Nuclear Waste Advisory Associates’ Issues Register Issue - 72</td>
<td>June 2010</td>
</tr>
<tr>
<td>ID: 175-05</td>
<td>To add to the level of complexity, multiphase fluid systems are likely to prevail in engineered systems designed for geological disposal of nuclear waste. However, current understanding of such multiphase systems at 40-110°C and 2-10 MPa is very limited, and generally confined to macroscopic thermodynamic models for H2O-CO2 and H2O-CO2-NaCl-KCl at low salinities.</td>
<td>CoRWM doc 2543 Report on R&amp;D for interim storage and geological disposal... A.75, 118</td>
<td>October 2009</td>
</tr>
</tbody>
</table>
RWMD Response:
An important objective of our R&D programme on radionuclide behaviour is the provision of data for post-closure safety assessment calculations [1]. Data used in our assessment calculations are often experimentally measured data in conditions representative of a geological disposal facility (GDF) and natural environmental conditions. Alternatively data may also be mathematically derived using chemical thermodynamic modelling. These data when selected are subject to rigorous quality considerations as to whether they correspond with international literature and peer reviewed data compilations carried out internationally (such as those undertaken by the NEA [2]). Aspects such as missing data, lack of knowledge regarding newly identified species, and the up-scaling of laboratory-scale, and thermodynamic data, to real and more complex environmental systems are each managed within our treatment of uncertainty, as explained in reports dealing with data selection [3]. The treatment of uncertainty associated with the data and its representation in the safety assessment calculations considers the general knowledge of the radionuclide speciation (that is, the chemical form in which the radionuclide would exist when dissolved in groundwater) under a range of possible disposal conditions and what the associated solubility of the radionuclide would be. Where there is uncertainty in the chemical form of the radionuclide and therefore in the associated solubility, we reflect this by using a range of solubility values in safety assessments. In the preparatory studies phase of our programme, we plan to review the data for key radionuclides and our treatment of uncertainty. Once site-specific information is available, we will further refine our datasets for specific concept and geochemical conditions of a potential candidate site(s).

B.1.8 Waste package accidents

B.1.8.1 Combined fault accidents

Raised issues:

| ID: 181-01 | Investigate the potential for failure of the spent fuel/high level waste disposal canister under combined fire and impact accident as a result of elevated temperature. | Disposability Assessment Database70 AGR Spent Fuel | October 2010 |
| ID: 181-02 | Determine more realistic way of assessing consequences of transport scenario of impact followed by fire. Current approach does not adequately represent potential changes to Release Fractions as a result of this combined accident. | Disposability Assessment Database ID53 Use of Ductile Cast Iron Containers for Disposal of | May 2010 |


[2] Nuclear Energy Authority (NEA) chemical thermodynamics Series comprises review reports dealing with data selection for particular elements or groups of elements and state-of-the-art reports focusing on the application chemical thermodynamics to particular systems of interest in radioactive waste management, http://www.oecd-nea.org/dbtdb/info/publications/, accessed February 2012

RWMD Response:

The current approach for assessing combined impact and fire performance is to assume that the two events are independent and can be assessed separately. Following the completion of the generic Disposal System Safety Case (DSSC) we are developing combined impact and fire accident methodologies and criteria, and updating the suite of models for calculating release fractions from combined impact and fire accidents for a range of facility design and fuel transport options [1]. The outputs of this ongoing work programme will be important to support transport assessments for proposed high level waste and spent fuel waste containers and existing intermediate level waste containers at candidate sites and support future updates of the DSSC.

B.1.8.2 Fire release fraction data

Raised issues:

| ID: 182-01 | Consider the challenge posed by pressurisation of waste packages under fire conditions as a result of significant voidage in high level waste packages. | Disposability Assessment Database ID33 Disposability of Technological high level waste (Preliminary Assessment) | Jan 2010 |
| ID: 182-02 | Consider long-term integrity of EPR spent fuel and estimate time evolution of Release Fractions for high burn-up fuel. Investigate potential for pressurisation of high burn-up spent fuel canisters under fire conditions. | Disposability Assessment Database ID20 Generic Design Assessment of EPR | Sept 2009 |
| ID: 182-03 | Consider long-term integrity of AP1000 spent fuel and estimate time evolution of Release Fractions for high burn-up fuel. Investigate potential for pressurisation of high burn-up spent fuel canisters under fire conditions. | Disposability Assessment Database ID26 Generic Design Assessment of AP1000 Reactor | Sept 2009 |

RWMD Response:

At present release fraction data for fire accidents have been calculated for the main types of intermediate level waste (ILW) waste package, including consideration of ductile cast iron containers. Once container designs have been further developed, we will calculate release fraction data for fire accidents for high level waste, spent fuel, plutonium and highly enriched uranium wastes [1]. As this work progresses we will need to consider the treatment of uncertainty associated with the model predictions and will provide fire accident release fraction data for accident scenarios applicable to a range of waste package pressurisation scenarios to support the range of concept and waste packaging options under consideration.

B.1.9 Criticality safety

B.1.9.1 Design for criticality safety

Raised issues:

| ID: 191-01 | Previous UK work on criticality in a closed GDF has focused on intermediate level waste, for which the criticality hazard appears to be low. The hazard for spent fuel and/or CoRWM doc 2543 Report on R&D for interim storage and | CoRWM doc 2543 Report on R&D for interim storage and | October 2009 |

plutonium is higher and requires rigorous assessment...primary need for research into criticality is to preserve and develop UK capability and make the most use of work carried out in countries that have been working on geological disposal of spent fuel for many years.

If fresh, rather than irradiated, nuclear fuel were buried, it could undergo a nuclear chain reaction (criticality) while underground, potentially causing significant damage to the engineered barriers and the surrounding rock.

Undertake a detailed criticality safety assessment to demonstrate criticality compliance for packages containing vitrified high level waste for all phases of GDF operation.

RWMD Response:
To date most of our criticality safety assessment studies have been made for transport and disposal of intermediate level waste (ILW) to a geological disposal facility [1]. An important requirement will be to assess the safety of operations on spent fuel and separated uranium and plutonium, which will be disposed of if declared as waste. Well-established methodologies for criticality safety assessment of higher activity materials exist elsewhere in the nuclear industry, in the UK and internationally. These will be applied to GDF transport, operations and post-closure as the concepts and designs are developed. Currently (2011/12) criticality safety solutions for transport of higher activity materials are being evaluated.

B.1.9.2 Likelihood of criticality

Raised issues:

An improved discussion of scenarios is required in the next version of the Criticality Status report.

Peer review questions whether it can be further inferred that similar host geologies will have broadly similar characteristics of groundwater flow and chemistry to allow a wider comparison to be made for the

[ID: 191-02] If fresh, rather than irradiated, nuclear fuel were buried, it could undergo a nuclear chain reaction (criticality) while underground, potentially causing significant damage to the engineered barriers and the surrounding rock.

Helen Wallace (for Greenpeace International)
Rock Solid Sec 4.5
Sept 2010

ID: 191-03
Undertake a detailed criticality safety assessment to demonstrate criticality compliance for packages containing vitrified high level waste for all phases of GDF operation.

Disposability Assessment Database ID63 high level waste (Preliminary Assessment)
3rd April 2009

[ID: 192-01] An improved discussion of scenarios is required in the next version of the Criticality Status report.

Peer review Criticality Status Report
DSSC peer review 2010

ID: 192-02
Peer review questions whether it can be further inferred that similar host geologies will have broadly similar characteristics of groundwater flow and chemistry to allow a wider comparison to be made for the

Peer review Criticality Status Report
DSSC peer review 2010

| ID: 192-03 | The development of alternative spent fuel concepts needs to note the potential for adverse effects on post-closure criticality safety associated with horizontal deposition tunnels. The potential for accumulation of fissile material on extended timescales may be more significant where fissile material from multiple packages could accumulate. This is not believed to be an issue for packages emplaced singly in vertical deposition holes. | Disposability Assessment Database ID79 Preconceptual LoC for PFR Irradiated Carbide Fuel | February 2011 |
RWMD Response:

We agree there is a need to define and analyse a wider range of scenarios and processes, for post-closure criticality, to assess the likelihood of criticality for all higher activity materials. The requirement was emphasised during peer review of the Criticality Safety Status Report [1]. This is important to support the Disposal System Safety Case and is being addressed by our work programme [2].

We have good understanding of the processes that contribute to the low likelihood of fissile material in a geological disposal facility (GDF) accumulating to give a critical configuration at some time after the closure of the intermediate level waste (ILW) disposal area [1]. Work has begun to initiate the review, extension and evaluation of scenarios for the relocation of fissile material, for the full range of higher activity materials and illustrative concepts, as our work to date has focused on ILW and higher strength rocks.

Work has also recently started to develop, document and communicate the qualitative and quantitative arguments to analyse the probability of post-closure criticality.

B.1.9.3  Consequences of hypothetical criticality

Raised issues:

| ID: 193-01 | Consideration of whether a rapid homogenization of a heterogeneous accumulation of Plutonium would be subject to a pre-initiation from Plutonium-240 spontaneous fission that would minimise the effects of a rapid transient. | Peer review Criticality Status Report | DSSC peer review 2010 |

RWMD Response:

Our approach is to complement our work on the likelihood of criticality (as described in issue group 1.9.2) with work to evaluate the consequences of a criticality in the unlikely event that one were to occur. We describe this work as examining the consequences of a hypothetical criticality [1]. This work supports the Disposal System Safety Case.

Our work on the consequences of a hypothetical criticality has identified two distinctly different types of hypothetical criticality event. These events can be described as either in quasi-steady state, or the event develops as a rapid transient. Our approach to modelling these events is well developed:

- There is a good fundamental understanding of quasi-steady state criticalities. This understanding is supported by observations from the Oklo natural reactors [2].
- There is significant coupling between the rapid release of energy from the criticality and the response of the immediate environment (e.g. the host rock) for a rapid transient criticality. We plan to evaluate the consequences of this form of criticality using a bounding approach, which may be sufficient to demonstrate that a rapid transient has limited consequences.

Work has also recently started to apply the criticality models and bounding approach to scope the consequences of criticality.

B.1.9.4  Assessment of consequences of hypothetical criticality

Raised issues:

| ID: 194-01 | The probability and the impact of a chain release of nuclear energy within a repository remain to be established. | Nuclear Waste Advisory Associates’ Issues Register Issue - 79 | June 2010 |
| ID: 194-02 | The implications of the 100 tonne stockpile of plutonium must be factored in to this consideration. | Nuclear Waste Advisory Associates’ | June 2010 |


RWMD Response:

We have conducted a considerable amount of work in the absence of a site-specific disposal facility design to generically study probability and impact of nuclear criticality. We believe that we have sufficient information to understand the bounds on the possible impacts of a wide range of hypothetical situations which would have the potential to lead to a nuclear chain reaction. The Criticality Safety Status Report [3] sets out our current understanding, at least qualitatively, that the likelihood and consequences of any nuclear chain reaction is low, particularly given the controls on fissile nuclear material in waste packages exercised through our Letter of Compliance disposability assessments. The current research programme includes work intended to improve, if possible, our ability to quantify the low probability of the occurrence of a nuclear chain reaction in a disposal facility. The implications of the civil stockpile of separated plutonium being declared a waste and consigned to geological disposal have been considered already in coming to the conclusions above. The generic Disposal System Safety Case (DSSC) explicitly considered the safety and environmental implications of the civil plutonium stockpile being declared as waste. Since production of the 2010 generic DSSC, the Government has proposed [4] a preliminary policy view to pursue reuse of plutonium as mixed oxide fuel (MOX), converting a high proportion of UK civil separated plutonium into fuel for use in civil nuclear reactors. Any remaining plutonium whose condition is such that it cannot be converted into MOX, will be immobilised and treated as a waste for disposal. We expect to do further work to assess specific waste packaging proposals through the Letter of Compliance disposability assessment process.


B.2 Safety and environmental impact of a GDF

B.2.1 Environmental safety

B.2.1.1 Treatment of uncertainty

Raised issues:

| ID: 211-01 | Need to recognise that the uncertainty in model outputs might be less than the uncertainties in defining scenarios. | Peer review Criticality Status Report | DSSC peer review 2010 |
| ID: 211-02 | Register of uncertainties - Peer review panel considers that further work would be required to develop a detailed register of uncertainties that can serve as a useful tool for uncertainty management. | TerraSalus Peer Review Summary report 3.10 | DSSC peer review 2010 |

RWMD Response:

There will inevitably be uncertainties associated with processes operating in a geological disposal system extending over an area of square kilometres on a timescale of hundreds of thousands of years. Such uncertainties may relate to our conceptual understanding of the system (and hence the way in which it is modelled, including the choice of scenarios to consider), the future evolution of the disposal system in space and time, and the data that describe the system. All these uncertainties require appropriate treatment in safety cases in support of a geological disposal facility (GDF). Our overall strategy for managing uncertainty and the different approaches we use within the environmental safety case are set out in our generic Environmental Safety Case (ESC) [1] and are being further developed as part of ongoing work to develop a strategy for how the ESC will evolve from a generic stage to site-specific stages. It is worth noting that not all uncertainties have a significant impact on long-term safety. Many can be easily managed by appropriate bounding assumptions, or are insignificant compared to other uncertainties, or can be addressed by considering different scenarios for the system evolution. We have published a report that discusses our strategy for handling uncertainty in model and scenario development [2]. Identifying which uncertainties are important, so that we can ensure they are addressed appropriately to provide confidence in long-term safety, is an important component of our programme.

For this reason, and because it is a regulatory expectation [3], we will include a register of uncertainties in our ESC. We have already started this with a simple statement of the (largely generic at this stage) uncertainties in the generic ESC [1]. As we develop and iteratively update a site-specific ESC, we will develop this register of uncertainties so that it

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is more specific and detailed. We expect this register to become the tool by which we record and manage the impact of different uncertainties on long-term safety. When an issue is raised that relates to an uncertainty in the safety case, this will be referred to the register of uncertainties and analysed in the context of the ESC. Thus the register of uncertainties will identify which uncertainties have the potential to make a significant impact on the ESC. It will also be helpful in identifying those areas of research and site characterisation where we most need to focus our efforts in order to reduce the most significant uncertainties, and also the appropriate time in the programme to undertake the work. Our recently published R&D Programme Overview [4], which sets out the work we believe is appropriate for the current preparatory studies phase of the programme prior to a site or sites being identified for characterisation, takes into account the uncertainties identified in the generic ESC and underlying documents.

B.2.1.2 Representation of uncertainty in mathematical models

Raised issues:


RWMD Response:

Mathematical modelling is one of a range of techniques we use to demonstrate confidence in the safety case. It is important that any mathematical model that contributes to our safety arguments includes an appropriate representation of the uncertainty in the parameters that are used to describe the behaviour of radionuclides in the waste packages and their containment in the engineered barriers of a geological disposal facility (GDF) and the geosphere.

A probability density function (PDF) is a mathematically robust, and well accepted, way of expressing uncertainty in a way that can be quantified. It can signify that we are uncertain about the value of a parameter, but at the same time indicate that some parts of the possible range of values to be more likely than others. The process of ‘data elicitation’ – the encoding of expert judgement in the form of, for example, probability density functions – is a standard method for determining appropriate data for use in models in cases where there are not sufficient data available for us to be confident that basing the value of a model parameter solely on the available data would capture the full range of uncertainty in the parameter. However, the process needs to be done with care to avoid bias and ensure that the full range of uncertainty is captured in an appropriate manner. We are confident that the data elicitation techniques we use are appropriate and that we are able to avoid bias through the use of a formal structured approach to the elicitation process [1].

Monte-Carlo simulations are a widely accepted and mathematically robust method for exploring the impact of uncertainty in the input parameters of a model in an unbiased manner. The technique enables both the most likely outcome and the probability of obtaining an extreme result to be determined.

We believe that the relevant issue is to ensure that these techniques for representing uncertainties in a safety assessment are applied in an appropriate manner, and that the inherent uncertainties and limitations of the techniques are recognised when drawing conclusions from the results of calculations. We describe our approach to using these techniques as part of the wider process of building confidence in the long-term safety of a GDF in the 2010 generic Environmental Safety Case (ESC) [2] and generic Post-closure Safety Assessment [3]. We will support our probabilistic analyses with deterministic analyses in which we specify, rather than sample, the values of the parameters to allow us to better explore particular cases of interest, and with studies of the sensitivity of the


models to particular parameters or assumptions. Furthermore, these numerical analyses are only one component of the structured collection of qualitative and quantitative arguments and evidence we will use to support the claims we make about long-term environmental safety in the ESC [2].

B.2.1.3 Mathematical model development

Raised issues:

| ID: 213-01 | Further work is needed to understand and model radionuclide migration... more understanding is required of:  
- upscaling molecular level models to estimate bulk chemical properties, both thermodynamic and kinetic, and transport over spatial scales from nanometres to hundreds of metres. | CoRWM doc 2543 Report on R&D for interim storage and geological disposal... A.57, 112 | October 2009 |
| ID: 213-02 | The relationship of scientific research to the safety assessment and the use of simplified models in the safety assessment are not adequately explained. | Geological Disposal: Radionuclide behaviour status report | DSSC peer review 2010 |
| ID: 213-03 | Peer review panel considers that further work would be needed to resolve several issues concerning the PCSA model: the approach taken to the PCSA calculations, the inclusion and exclusion of processes in the PCSA models, the representation of the barriers in the disposal system, the traceability of data used, and the presentation and use of PCSA results. | TerraSalus Peer Review Summary report TerraSalus 3.6 | January 2010 |

RWMD Response:

We have adopted a hierarchical approach to modelling, which is documented in the 2010 generic Environmental Safety Case (ESC) [1] and will be described in more detail in our ESC Strategy, which is planned for publication in the near-term. In this approach, we propose that our understanding from data and research will be used to develop process understanding, which is captured in process-level conceptual and numerical models. These process-level models feed into models of key geological disposal facility (GDF) system components, namely the engineered barrier system, the geosphere and biosphere. In turn, the component models are represented in a top level, total system model. It is the total system model that is used to calculate radiological risks from a GDF for comparison with the regulatory risk guidance level. It is therefore important that the total system model appropriately represents the behaviour of the system, including any uncertainty associated

with that behaviour. While we intend to explore at all levels in the model hierarchy the effect of uncertainty on our confidence that barriers will perform the safety functions assigned to them, a key function of the total system model is quantifying the impact of uncertainty on our overall confidence in long-term safety. It therefore needs to be at a suitable level of detail to allow us to run the model probabilistically to explore the combined impact of uncertainty in all parameters.

The features, events and processes (FEPs) included in the models at the different levels in the modelling hierarchy are informed by our FEP analysis (see Topic 2.1.7), which ensures completeness. At the lower levels of the hierarchy the majority of the FEPs are represented explicitly. The topics considered in Section B.1 describe our work to understand and represent processes at this detailed level. At higher levels in the hierarchy, the selection of FEPs to include in a particular model is based on the understanding gained from the models lower in the hierarchy, and only the most significant FEPs are represented explicitly.

For the generic ESC we did not have a site or design and so were working with illustrative concepts only. We felt we had an insufficient basis to develop meaningful component models for the engineered barrier system and geosphere, but we do have a stylised component model that underpins our total system model representation of the biosphere. Therefore we developed a total system model that used four key parameters to represent a generic groundwater flow field and a single containment parameter to represent the performance of a generic engineered barrier system. This is clearly a very simplified model, and we based the values of these parameters on a combination of previous work and expert judgement. However, our view is that this simple model was able to provide information about the performance of generic disposal systems in a range of geological environments that could support the safety arguments in the generic ESC. We believe that at the current stage this is an appropriate approach to demonstrating that the regulatory requirements could be satisfied in a range of geological environments.

As we move forward with the MRWS Site Selection Process, we will start to develop a site-specific ESC that includes a total system model that directly represents our understanding of the site, the site-specific GDF design, and the different ways in which radiological exposure to the disposed inventory might occur. Rather than being based on assigned parameters, this total system model will be derived from site-specific component models of the engineered barrier system, geosphere and biosphere, which in turn represent the detailed site descriptive models of the system developed from our research, design and site characterisation programmes, in line with our hierarchical modelling approach. These models will include representations of the way in which the system may evolve over time. It will be possible to trace assumptions and parameter values in the total system model back to information in the underlying models and finally to the site-specific information gathered in our site characterisation and research programmes. The way in which we build confidence in our models is considered in topic 2.1.5. Development of a site-specific total system model is an important aspect of our forward programme.

B.2.1.4 Assessment of the potential impact of gas

Raised issues:

<table>
<thead>
<tr>
<th>ID: 214-01</th>
<th>Points for consideration in future gas assessments: (i) which pathways are important for gas; (ii) what scenarios should be considered in the assessment? (iii) What approach should be used to account for gas generation and migration in the</th>
<th>Peer review</th>
<th>DSSC peer review 2010</th>
</tr>
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<tbody>
<tr>
<td>(See also ID: 164-19)</td>
<td></td>
<td>Gas status report</td>
<td></td>
</tr>
<tr>
<td>ID: 214-02 (See also ID: 251-01)</td>
<td>Resolution of gas issues and their incorporation into site selection considerations. <em>Issue refers to the conflict between the requirement to provide a barrier to radionuclide release and the requirement to allow bulk gas to escape to prevent pressure build-up.</em></td>
<td>Nuclear Waste Advisory Associates’ Issues Register - 12</td>
<td>June 2010</td>
</tr>
</tbody>
</table>

**RWMD Response:**

Gas, a very small fraction of which is radioactive, is generated from the slow degradation of the wastes and their packaging materials both before and after final closure of a geological disposal facility (GDF). We have undertaken, and continue to undertake, research on the mechanisms of gas generation from waste packages, and there is much international experience with disposal concepts and geological settings that we can draw upon to develop our understanding of gas migration and safety case impacts (see, for example, the EU FORGE project [1]).

Our current understanding of the generation of gas within waste packages and of its migration and impact on the safety case is set out in the gas status report [2] and the generic Environmental Safety Case (ESC) [3]. These reports also identify areas for further research, which is part of our future work programme [4]. Over the next few years our programme in this area can be divided into four broad topics: studies of gas generation and release from wasteforms and waste packages; studies of gas migration and reaction within the EBS and in the host rock; studies of the consequences of the release of gases containing carbon-14 into the biosphere and development of modelling and assessment methods so that we can determine the safety impacts of any such gas generation and migration.

The generic ESC [2] sets out our strategy for ensuring that all the relevant processes, pathways and exposure scenarios associated with gas generated in a geological disposal facility (GDF) are identified and included in our assessments. It describes the approaches we use to assess the impact of gas before and after closure of a GDF [5], and sets out a series of qualitative and quantitative safety arguments that explain why we believe the disposal system will be able to both provide sufficient containment for disposed radionuclides and at the same time prevent potentially damaging gas over-pressures from developing [6]. Some of these safety arguments are summarised in the response to topic 1.6.4.

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### B.2.1.5 Building confidence in long-term safety

#### Raised issues:

| ID: 215-01 | There is limited evidence to demonstrate long-term mechanical stability or stability of groundwater conditions at GDF depths. | Nuclear Waste Advisory Associates’ Issues Register Issue - 26 | June 2010 |
| ID: 215-02 | The high likelihood of interpretative bias in the safety assessment process because of the lack of validation of models, the role of commercial interests and the pressure to implement existing road maps despite important gaps in knowledge. Lack of (funding for) independent scrutiny of data and assumptions can strongly influence the safety case.  
   i) other problems may remain unidentified due to lack of sufficient independent scrutiny.  
   ii) Reliance on industry-funded research… is likely to introduce interpretative bias in repository safety assessments.  
   iii) overconfidence in a particular computer model or the assumptions that underpin it. | Helen Wallace (for Greenpeace International) Rock Solid Exec summary & 5.1.1 | September 2010 |
| ID: 215-03 | Significant challenges in demonstrating the validity and predictive value of complex computer models over long timescales.  
   i) Safety assessment requires the post-closure behaviour of the radioactive wastes in a repository to be predicted hundreds of thousands to millions of years into the future. The limitations of the computer models that are used to make these predictions and the difficulties of validating them – i.e. of confirming that they will give sufficiently reliable predictions over such long timescales – are among the key issues for safety assessment.  
   ii) The release of radioactive water and gas through the rock also calls | Helen Wallace (for Greenpeace International) Rock Solid Exec summary & 3.1 | September 2010 |
| ID: 215-04 | Most safety assessment programmes remain wedded to the idea that there is a single ‘best fit’ model, rather than focusing on exploring possible alternative models of the site… | Helen Wallace (for Greenpeace International) Rock Solid Sec 5.1.1 | September 2010 |
| ID: 215-05 | Suggested that much faster groundwater return flow times than those calculated by Nirex were more consistent with its borehole measurements, implying that Nirex’s risk calculations might be two orders of magnitude in error. (note that this is a comment about a specific site) | Helen Wallace (for Greenpeace International) Rock Solid Sec 5.1.2 | September 2010 |
| ID: 215-06 | Geosphere evolution - there is a need for further research to develop fundamental process-based models. Further, to validate such models, new field analogues should be sought that illuminate the role of individual processes in geosphere evolution… | CoRWM doc 2543 Report on R&D for interim storage and geological disposal... 6.15, 91 | October 2009 |
| ID: 215-07 | CoRWM believes that a fundamental mechanistic understanding is required of the processes governing physical, chemical and microbiological evolution of the geosphere. Further, to validate such models, new field analogues should be sought… | CoRWM doc 2543 Report on R&D for interim storage and geological disposal... A.100, 124 | October 2009 |
| ID: 215-08 | MRWS 146 stated that computational models of the natural world do not have simple answers on which to build a safety case for a repository. This NDA reply agrees with that, but maintains the fiction that computer models with uncertain outcomes can be used to | Reply to the NDA response to MRWS paper 146 Professor Stuart Haszeldine University of Edinburgh | May 2011 |
build and conclude range of numerical values for a safety assessment to be precise (note this is a direct quotation from the source report).

RWMD Response:

We recognise that building confidence in our understanding of the long-term behaviour of a disposal system and representing that understanding in models is a challenging process. In cases where we use models to provide evidence for safety, we need to demonstrate why we have confidence in the results. Particular concerns that have been raised include:

- the "validity and predictive power of complex computer models over long timescales", with the suggestion that many of the complex processes are poorly understood and many model assumptions impossible to validate;
- the range of variant models and evolution scenarios that it is appropriate to consider;
- the level of detail at which it is necessary to understand processes and represent them in models to support a safety case; and
- a challenge that "there is limited evidence to demonstrate long-term stability".

First, it is important to understand that numerical modelling only constitutes one strand of our overall safety case. Indeed, it is a regulatory requirement that we present multiple lines of reasoning to build confidence in our overall understanding of the performance of a geological disposal facility (GDF). In addition to numerical calculations, these multiple lines of reasoning include direct research results, the use of tried and tested materials for the waste packages and other engineered barriers, large-scale demonstration experiments, natural indicators (such as groundwater ages) and comparisons with natural and archaeological analogues. We acknowledge that integrating these multiple lines of evidence from different disciplines will be challenging, and we have ongoing work to develop integration strategies.

Second, our assessment models are not aiming to "predict" the future, but rather to represent our understanding of the GDF system and potential scenarios for its evolution. Our understanding of the GDF system will be developed from our existing knowledge and experience, our on-going research and site characterisation activities and international collaboration projects. This understanding will be continually tested and challenged through independent peer review and regulatory and stakeholder scrutiny of our work.

Nevertheless, numerical models have an important part to play in demonstrating whether we expect the long-term performance of a GDF to be consistent with the regulatory risk guidance level, in building confidence in the performance of the different barriers and in guiding design and site characterisation activities. In our safety assessment calculations our aim is to take account of all relevant uncertainties. Therefore, rather than make assumptions about uncertain properties, we will explicitly incorporate the range of uncertainty for all uncertain parameters in our total system model. We then use the model to make a large number of calculations in each of which we randomly sample a different set of values for each of the uncertain parameters. This enables us to explore how different potential uncertainties may interact with each other and hence identify any situations that may be detrimental to safety. We can also identify the parameters to which overall safety is most sensitive and hence identify where there is the greatest need to reduce uncertainty (or increase understanding) and hence focus our research and site characterisation activities accordingly. Modelling should therefore be viewed as a powerful tool for testing
our system understanding and identifying areas where that understanding needs to be improved.

We have a systematic approach to identifying all the features, events and processes that need to be considered in our models and the scenarios that need to be addressed (see response to topic 2.1.7), and we aim to validate our models against independent data wherever practicable. During the site characterisation stage we will develop our understanding and consequent modelling in an iterative manner. This will include using our more detailed process models to make predictive testing of the next iteration of site data to build confidence in our models, and demonstrating that we understand how and why the conditions currently observed at the site developed. If the information we obtain from the site suggests there is more than one model that is consistent with the observations, we will progress several alternative conceptual models for the site until such time as we obtain evidence that confirms that one or more of the models are no longer plausible.

We believe that we have a sound approach to modelling and that its use in iteration with research and site characterisation activities contributes to developing our understanding of GDF performance. We understand the need to use a range of independently constructed, models created using different modelling tools to build confidence that we have removed any bias resulting from a particular numerical technique (or software package). This is especially important in cases where it is difficult to validate the models against real data. However, it will be neither possible, nor necessary to validate all of the different models we use. In particular, it is often only possible to collect data, for example from experiments in boreholes, on relatively short length and/or time scales and/or for conditions that are different to those we expect to prevail post closure. Such data are valuable for building confidence, but we must take into account that they may not provide a full validation of the model for the conditions we wish to simulate. Our assessment models sit at the top of the modelling hierarchy (topic 2.1.3) and build on the results of the more detailed and fundamental models below them, including any validation. When we use our total system model to calculate radiological risks from a GDF we explicitly take account of uncertainties and the range of potential scenarios for the GDF system evolution. The results of such calculations indicate the range of potential outcomes but should not be taken as predictive of the future. Our approach to building confidence in the post-closure safety case, and the models used to support it, is set out in the 2010 generic Environmental Safety Case [1].

The most effective and robust safety arguments are the simplest ones. They are often qualitative or use simple mass balance type arguments or demonstrate that readily verifiable bounding cases will ensure safety. In many cases, they draw on evidence from natural analogues to demonstrate that the processes being relied on to provide safety are effective over the very long timescales that must be considered in the post-closure safety case. Our approach to developing our technical programme is to understand how much we need to know about each topic in order to ensure that we can develop robust safety arguments and design and construct a GDF that can be operated and closed safely and have an acceptable long-term environmental performance. This approach is described in our Technical Strategy [2] and our R&D Programme Overview [3], which describe how we develop our needs-driven technical programme to meet the GDF project objectives in an optimised manner. In a few cases, it may be necessary to obtain a detailed mechanistic understanding of a particular process, but this is the generally the exception rather than the rule. In many cases, it is possible to demonstrate that a process or group of processes

does not influence safety, or that a relatively simple empirical understanding of the impact is sufficient for our needs.

It is a common misconception that it is necessary to demonstrate long-term stability in conditions at the GDF site (i.e. that the system is not changing) in order to demonstrate long-term safety. Few, if any, sites anywhere in the world would meet this criterion. Instead we need to demonstrate that we understand how the system is evolving and how it will respond to changes in the natural driving forces such as climate, and that the likely evolution will not compromise long-term safety; indeed in some cases the predicted changes may improve our confidence. We will do this by a combination of demonstrating that we understand the long term past evolution of the site (i.e. how it has responded in the past to events such as glaciation) and exploring the range of future driving forces and their expected impact. For example, the long term evolution of the climate will result in major changes in conditions at the ground surface but our understanding of the physical processes involved and observations from depth provides confidence that changes, and hence impacts, at GDF depths will be both smaller and slower than at the surface.

We are therefore confident that we have a programme in place that will allow us to build confidence in the long-term performance of the GDF system. Our forward programme includes activities to gather a range of different types of evidence to support our claims about long-term safety.
B.2.1.6 Letter of Compliance – ensuring waste packages will be disposable

Raised issues:

| ID: 216-01 | Peer review panel considers that further information is required to document the Letter of Compliance (LoC) process in detail within the DSSC, to justify the approaches being followed and, in particular, to explain and justify how calculation results from the Post-Closure Safety Assessment (PCSA) are, or may be, used to inform the LoC process in a quantitative sense, taking account of uncertainties in disposal system performance. | TerraSalus 2.6 TerraSalus Peer Review Summary report | January 2010 |

RWMD Response:

We have applied our disposability assessment process [1] to waste packages containing cemented intermediate level waste (ILW) or low level waste (LLW) for a number of years, and, as waste producers submit their proposals to us for assessment, we are starting to apply it to waste packages that include more robust containers and potentially more robust wasteforms, for example packages containing vitrified high level waste (HLW).

The post-closure performance assessment component of our Letter of Compliance (LoC) disposability assessment process considers a range of characteristics of the proposed waste package that might affect the post-closure performance. These include characteristics such as inventory (radionuclide and chemically toxic species), chemical form, the presence of substances that might enhance radionuclide mobility, the potential to generate gas and the general nature of the proposed waste packages. An important part of the LoC disposability assessment is to compare the properties of the proposed waste package with the properties of the “average” waste package for that waste type (for example, ILW) assumed in the total system model used in the 2010 generic Post-closure Safety Assessment (PCSA) [2]. In this way we can test whether the characteristics of the real waste package (e.g. actual radionuclide inventory, chemical form, conditioned wasteform) will lead to a significant deviation from the results of the generic assessment. We believe that the very simple representation of the waste package and the engineered barrier system in the total system model and the assumption of a higher strength host rock for our disposability assessment are appropriate at the current stage in the programme because they are bounding with regard to post-closure performance. We, and the waste producers, need to be confident that the proposed waste package will be disposable whatever geological environment and disposal concept are selected for a geological disposal facility.


In many cases, we can gain confidence that the proposed waste package would be disposable from the post-closure point of view from a simple comparison against the assumptions included in the PCSA. In other cases, it may be necessary to carry out a more detailed assessment, including use of the total system model to provide quantitative information. The total system model is constructed in a way that allows it to be enhanced relatively easily so that it can include more detail of a particular part of the system than is considered in the main PCSA. For example, our total system model includes a parameter that represents the containment provided by a robust container but the model could readily be enhanced to provide a more realistic description of container failure and the release of inventory from a proposed waste package type to allow a more detailed assessment of the expected behaviour of the proposed waste package to be made were this considered to be justified for the particular assessment being undertaken. To consider every waste package type in the GDF in this way would not be practicable, which is why we consider an average package in the main safety assessment calculations [2].

We are therefore confident that the post-closure component of the disposability assessment process is fit for purpose. The generic Disposal System Safety Case suite of documents includes a report that describes how we assess the disposability of waste packages [1]. We will strengthen the description of how we use the PCSA to inform the disposability assessment process in future issues of this report and provide a more comprehensive description in the top level safety case documents. We will also improve the clarity of the documentation of this process as part of the updated Waste Package Specification Guidance documents, to be produced during 2011/12.

### B.2.1.7 Features, events and processes (FEPs) and scenario analysis

#### Raised issues:

| ID: 217-01 | Uncertainties about the issues at each stage of the staged authorisation process: tendency ... to give greater weight to 'known unknowns' rather than 'unknown unknowns'. | Environment Agency Science Programme Contractor Report: Technical issues associated with deep repositories for radioactive waste in different geological environments 5.10, p110 | August 2009 |
| ID: 217-02 | It is not clear which outcomes would lead to unacceptable safety hazards. *Specific review comment made on POSIVA report 2006-05 [3].* | Nuclear Waste Advisory Associates’ Issues Register Issue - 57 | June 2010 |
| ID: 217-03 | The Environment Agency argues that future mining at the repository site would be 'highly unlikely. However, their reasoning for this is | Nuclear Waste Advisory Associates’ Issues Register | June 2010 |

| ID: 217-04 | Potential for significant radiological releases through a variety of mechanisms, involving the release of radioactive gas and/or water due to the failure of the near-field or far-field barriers, or both. | Helen Wallace (for Greenpeace International) Rock Solid Exec summary | September 2010 |
| ID: 217-05 | The long-term effects of glaciation on repository safety could be very serious, potentially involving a large release of radionuclides due to glacial flushing from a damaged repository zone. Future glaciations could cause faulting of the rock, rupture of containers and penetration of surface and/or saline waters to the repository depth… | Helen Wallace (for Greenpeace International) Rock Solid Sec 4.6 | September 2010 |
| ID: 217-06 | Inactive faults may be reactivated during the lifetime of a repository and earthquakes could severely damage the containment system, including the canisters, backfill and the rock. | Helen Wallace (for Greenpeace International) Rock Solid Sec 4.7 | September 2010 |
| ID: 217-07 | Climate states are considered in safety assessments, but not the transitions between them: this means that some scenarios that might result in higher releases …are not included in the models. Processes at the biosphere/geosphere transition zone… are also neglected, although they may be essential for modelling radionuclide mobility during climate transition phases. | Helen Wallace (for Greenpeace International) Rock Solid Sec 4.8 | September 2010 |
| ID: 217-08 | There are significant social uncertainties regarding future human behaviour… | Helen Wallace (for Greenpeace International) Rock Solid Sec 4.8 | September 2010 |
| ID: 217-09 | The impact of external conditions related to glaciations – e.g. taliks (unfrozen layers of ground in regions of permafrost) and glacial meltwater intrusion – on the long-term performance of the engineered barrier system. | Helen Wallace (for Greenpeace International) Rock Solid Sec 5.1 | September 2010 |
Do we intend to include climate change, including glaciation, in the baseline evolution scenario?

Peer review
Near Field Evolution status report
DSSC peer review 2010

**RWMD Response:**

The Environmental Safety Case (ESC) needs to consider potential impacts from a geological disposal facility (GDF) over future timescales that span to hundreds of thousands of years or more. In order to do this we need to identify what features, events and processes (FEPs) are relevant to the safety of a GDF, both at the time of its closure and over its future evolution. FEP analysis is an important step in identifying how the different aspects of disposal system evolution will be addressed in the safety case and starting to understand the potential impact of simplifications (i.e. not including certain FEPs explicitly) (see also topics 2.1.3 and 2.1.8). It is a challenge to build confidence that all relevant FEPs have been identified, not least because of the fundamental impossibility of identifying "unknown unknowns" and the ways in which society might evolve in the future. It is well recognised internationally that it is not possible to provide a formal demonstration of 'completeness' for a long-term safety assessment. This applies to any large-scale project with long term hazards and has to be accepted by society and recognised in regulations. The documented consensus, however, is that the current state of the art is sufficient to demonstrate safety of a well designed GDF in a suitable geological setting.

An international FEP database was established under the auspices of the Nuclear Energy Agency (NEA) in the early 1990s. United Kingdom Nirex Limited developed a systematic approach to the identification of FEPs and their subsequent use in constructing assessment scenarios to represent the potential evolutions of a GDF. This approach is presented in a United Kingdom Nirex Limited Science Report [1] and elsewhere [2 - 5], and received a favourable peer review from an independent, international Nuclear Energy Agency (NEA) expert group [6]. This confidence is further reinforced by the fact that the approach of using FEPs as a tool in safety case development has been broadly adopted internationally over the last decade or more. Since its creation, the international FEP database has been revised periodically but there have been no new significant FEPs identified in recent years, giving confidence that the database is comprehensive at the level of FEPs that might be significant for long-term safety. We believe our systematic approach, involving experts from all relevant disciplines and repeatedly asking them 'what else?', and reviewing the FEPs considered by partner programmes (overseas and near-surface disposal programmes within the UK) at their major documentation milestones,

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means that we can have confidence that the process is comprehensive, at least in terms of identifying all the FEPs that are likely to be significant for long-term safety.

Having identified the relevant FEPs, and documented why the FEPs that are not being taken forward have been excluded from further consideration, a base scenario is defined to represent the expected, or normal, evolution of a GDF system in the absence of inadvertent human intrusion. It is our strategy to define the base scenario as broadly as possible, including all FEPs that are more likely than not to occur during the assessment period, so it will include events such as glaciation and minor earthquakes if it is considered that these events are more likely than not to occur for the site being assessed. Having defined the base scenario, we then consider those FEPs that could lead to scenarios with potentially higher consequences than the base scenario, including scenarios in which there is inadvertent human intrusion. These are each specifically addressed as variant scenarios. (In some cases, a bounding variant scenario may be considered as representative of a group of similar scenarios.) For the generic ESC [7], we used our existing knowledge of generic FEPs and the scenarios most likely to lead to releases from a GDF to represent and assess illustrative conceptual examples. Once we have a site and a preferred disposal concept we will review our FEP database to identify specific FEPs and scenarios that need to be considered. The approach to doing this is subject to ongoing work and is part of our developing ESC Strategy. Variant scenarios that we expect to need to address in future site-specific ESCs include:

- Glaciation, if it is not included in the base scenario, or variations in the timing of the next glaciation if it is; such scenarios would take account of all of the potential impacts of glaciation on the barriers in the disposal system;
- Early failure of waste containers, including shear failure or potential rupture from stresses or seismicity caused by glaciation;
- Climate change and the transitions between different climate states, insofar as they could result in increased releases; and
- A fuller treatment of inadvertent human intrusion or interference in the disposal system (i.e. without full knowledge of the existence of the GDF or any potential hazard it might pose); a stylised treatment that captures a range of possible future human behaviour is often adopted because the inherent uncertainties are greater here than for other scenarios.

For each of these, and other identified variant scenarios, our strategy is first to scope the likely consequences of the scenario. This enables us to consider a broad range of scenarios to understand which could lead to high consequences and then focus our resources on addressing those, including the situations under which the scenario could occur and hence its likelihood. Any scenario that we are confident after a careful assessment of the associated uncertainties (see also topics 2.1.1 and 2.1.2) does not lead to higher consequences than the base scenario can effectively be subsumed into the base scenario and will not require separate consideration.

We therefore consider that we have a well established and peer reviewed approach for dealing with FEPs and scenarios that is in line with international best practice. It nevertheless remains an important part of our forward programme to identify and address relevant scenarios as we move forward with the MRWS process.

### B.2.1.8 Methodology underpinning post-closure safety assessments

#### Raised issues:

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<td>i) A 2007 review by the NEA found that dose constraints set by individual countries span a range of 0.1–0.3 mSv per year, while risk constraints are set at one in 100,000 or one in a million per year. A major issue in the case of deep underground repositories is whether these limits can be met in practice, due to the difficulties of predicting the radiation exposures that will actually be experienced by future generations.</td>
<td>Helen Wallace (for Greenpeace International) Rock Solid Sec 3.1 Sept 2010</td>
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<td>ii) the environmental impact of radionuclides has only recently begun to be considered.</td>
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<td>A number of low- and intermediate-level radioactive waste disposal sites have operated over the last 50 years. However, many of these supposedly final disposal sites have already caused unexpected environmental contamination, highlighting how difficult it is to predict what will happen to buried wastes, even over short timescales.</td>
<td>Helen Wallace (for Greenpeace International) Rock Solid Sec 3.3 Sept 2010</td>
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<td></td>
<td>The definition of repository safety functions is vague. Specific review comment made on POSIVA report 2006-05 [1].</td>
<td>Nuclear Waste Advisory Associates’ Issues Register Issue - 56 June 2010</td>
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<td></td>
<td>The impact of the timescales involved – and in particular the way that relevant processes will change over time - is not understood.</td>
<td>Nuclear Waste Advisory Associates’ Issues Register June 2010</td>
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Risk predictions over one million years are intrinsically questionable.

Any mention of ‘timescales’ ought to also discuss the role of the independent regulator in determining the time frame to be considered for each aspect of the safety case.

Further work would be required to include more evidence in the top level safety case reports to support the safety arguments being presented.

RWMD Response:

We are currently developing (and expect to publish later this year) a strategy for developing the Environmental Safety Case (ESC) for a geological disposal facility (GDF). This report sets out our strategy for developing the necessary site-specific ESC from the foundations provided by our recently published generic ESC [2]. It explains that our focus is on developing and testing our understanding of the components of a GDF, and how they interact and evolve over time. This understanding will be acquired from information from our research, site characterisation activities and design development work, our analysis of that information using computer models, and participation in international projects. We will also keep under review developments in areas such as approaches for representing uncertainty in our developing safety case, and will continue to seek to build on experience and good practice from other disposal programmes. This includes further developing the way in which we present our safety case to ensure it is accessible to all interested stakeholders, and as noted in topic 2.1.5 it should be remembered that numerical assessment is just one strand of an overall safety case.

As our understanding develops, we will be able to develop the methodological aspects of our ESC strategy, including our modelling strategy for any particular GDF site and design under consideration. A key aspect of our ESC Strategy is that we will start to develop the site-specific ESC as a parallel work-stream to the existing generic ESC [1]. We will continue to use and maintain the generic ESC as a living suite of documents as we progress through the Managing Radioactive Waste Safely (MRWS) site selection process, until such time as we have sufficient confidence in the site-specific ESC and it is judged that a generic ESC is no longer required. This strategy enables us to allow for the possibility of additional, alternative sites being put forward for consideration and to continue to undertake disposability assessments that encompass a broad range of potential disposal facility designs until such time as a site-specific ESC is sufficiently well-established.

The concept of safety functions (physico-chemical characteristics and processes that contribute to achieving the objectives of isolation and containment) is important in our programme, and is commonly adopted in advanced programmes overseas. We have recently reviewed our approach to the definition and use of safety functions across the Disposal System Safety Case suite of safety assessments. Safety functions will be dependent on the GDF setting and disposal concepts chosen. However, we know that we

will need to demonstrate how the various GDF components work together to provide the overall generic safety functions of isolation and containment of the waste materials. As we move forward in the MRWS process, we expect that the Disposal System Specification will define site- and concept-specific safety functions in increasing levels of detail. Our research, engineering design and site characterisation activities will focus on building our knowledge and understanding of how the different components of a GDF will provide these safety functions and how they interact and evolve over time. We will represent this understanding in our post-closure safety assessment models, together with appropriate representation of any associated uncertainty, in order to evaluate whether or not a proposed GDF system would be compliant with regulatory risk guidance levels set out by the regulators [3].

We will need to demonstrate safety on extremely long timescales; the current regulatory guidance [3], in common with that in several other countries (for example Switzerland), does not specify a time beyond which we no longer need to demonstrate continuing safety. We recognise the uncertainties inherent in radiological risk calculations covering very long periods, such as one million years, and that information gained from such calculations needs to be used appropriately in the safety case. As we noted in the response to topic 2.1.5, we are not aiming to “predict” the future, but rather to demonstrate our understanding of a GDF system and potential scenarios for its evolution. A site-specific safety case would include a range of scenarios and calculation cases corresponding to the range of possibilities for the evolution of the assessed disposal system. Thus the calculation of radiological risk for each of the cases would provide a comparative measure to enable the significance of different situations or processes to be understood. Particularly at very long times after the closure of a disposal facility we envisage that the safety case would be built more on the evidence for the persistence of barrier safety functions (reflecting the quality of the facility design and its exploitation of favourable site characteristics, and evidence from alternative safety indicators such as natural analogues) combined with analysis of the reduced hazard presented by the residual radionuclides in the wastes; rather than risk calculations.

Whilst we are continually seeking to develop and improve our post-closure assessment methodology, we believe that, especially with the production of the ESC Strategy, we have a clear understanding of what is required to produce a post-closure safety case that, subject to a suitable site for a GDF being identified, will satisfy the relevant regulatory requirements. It is also worth noting that more advanced GDF programmes overseas (such as in the USA, Canada, Sweden and elsewhere) have successfully produced post-closure safety cases. We collaborate with such agencies through various international fora and learn from their experience where it can be applied to the UK situation. Developing the methodology for post-closure assessments is a vital part of our forward work programme [4].

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B.2.2 Operational safety

B.2.2.1 Doses to GDF operators

Raised issues:

| ID: 221-01 | It is possible that worker doses would be unacceptable. In the context of worker doses arising from the work involved with emplacing waste in the repository. | Nuclear Waste Advisory Associates’ Issues Register Issue - 31 | June 2010 |

RWMD Response:

Geological Disposal Facility (GDF) workers will be exposed to radiological dose from normal receipt, handling, emplacement, and maintenance operations. However, we would not operate a facility where worker doses were unacceptable, nor would the regulators support such a situation under the nuclear licensing arrangements that apply to such operations. The potential for radiological doses to be incurred during GDF construction as a result of exposure to naturally-occurring radon are considered in topic 2.2.3.

The design of the GDF and the development of operating procedures for it are currently at an early stage. Workers will be protected by a combination of shielding and operational procedures, for example remote handling, that will ensure that doses are a) as low as reasonably practicable (ALARP) for normal GDF operations and b) below the targets set by our regulators for the range of scenarios (e.g. foreseeable faults) our regulators expect us to consider. Monitoring of the GDF environment and of the doses received by workers will allow us to demonstrate compliance with the regulatory requirements and build confidence that our procedures and safety measures (e.g. shielding) are performing as we expect.

We have published a generic Operational Safety Case [1], which deals with the subject of doses to workers in relation to the disposal of the Baseline Inventory of wastes in a range of illustrative disposal concepts, taking account of the relevant characteristics of the wastes. This safety case gives us confidence that we will be able to operate the GDF in a manner that provides an appropriate level of protection for the work force. In our forward programme we will refine our approach to the radiological protection of workers as facility designs are developed when site-specific information is available.

B.2.2.2 Scope of the Operational Safety Case

Raised issues:

| ID: 222-01 | Human error during the process of disposal is one of the hardest scenarios to identify and evaluate… | Helen Wallace (for Greenpeace International) Rock Solid Sec 4.5 | September 2010 |

| ID: 222-02 | There does not appear to be any recognition that the surface dose rate/shielding requirements for Plutonium/Uranium packages will be | Health and Safety Executive Operational Safety Case - | DSSC peer review |

The Operational Safety Case (OSC) for a Geological Disposal Facility (GDF) will need to clearly set out that we understand and can demonstrate operational safety where this can affect workers and members of the public. Achieving this objective will require us to identify all of the operations that will be carried out within a GDF for the full range of waste types that are planned to be emplaced, and all of the foreseeable fault conditions (accidents) that might occur.

The development of a comprehensive OSC that will meet the requirements of our Regulators will require knowledge of the detailed design, the characteristics of the different types of waste packages that will be emplaced and the proposed operating procedures for a GDF. We are currently developing a Nuclear Operations Safety Manual (NOSM), which will identify the operational safety cases (construction, commissioning, decommissioning and closure, in addition to waste emplacement operations) that will need to be submitted to regulators at various stages of the GDF project in order to demonstrate that associated risks are ‘as low as reasonably practicable’ (ALARP), provide guidance on the scope, structure and contents of these safety cases and provide the procedures, methodologies, guidance and base data required to undertake the assessments in a standardised and traceable manner. We have published our generic OSC [1], which sets out how we intend to structure and present the OSC. The generic OSC demonstrates our approach using the information we currently have available, which relates to the generic illustrative example designs used in our generic Disposal System Safety Case. The Hazard and Operability (HAZOP) study for the generic OSC noted that neutron radiation would potentially comprise a more significant contribution to external exposure from highly enriched uranium (HEU) and plutonium (Pu) packages than from other waste packages [2]. However, the waste packaging options for HEU and Pu are still being investigated, and the packaging solution that is finally selected for these waste types will be designed to ensure that packages containing these wastes can be handled safely in a GDF. We consider the current scope of the assessment to be appropriate for this stage of the MRWS process. We will further develop the OSC in line with the developing NOSM as information about the GDF site and detailed designs become available.

We have on-going work to develop an Operational Safety Strategy and a Human Factors Integration Plan for operational activities associated with a GDF. The latter will describe how all aspects of human behaviour, including human error, will be taken into account during the development of the design for a GDF.

B.2.2.3 Naturally occurring radon

Raised issues:

| ID: 223-01 | The potential implications of natural radon should be considered as part of safety assessments. | Peer review Disposal System Technical Specification | DSSC peer review 2010 |
| ID: 223-02 | Further work would be required to assess the impact of radon from the host rocks on ventilation, GDF operations, and worker dose. | TerraSalus 2.5 TerraSalus Peer Review Summary report | DSSC peer review 2010 |

RWMD Response:

Radon gas (Rn-222) is generated by decay of radium (Ra-226), which is a member of the Uranium-238 decay chain; uranium-238 makes up 99.3% by weight of the uranium found naturally in rocks. Rn-222 is therefore generated in, and may be released from, all rocks that contain uranium, which includes the host rock for a geological disposal facility (GDF) and the rocks that overlie the host rock.

Exposure to radon gas will result in a dose to workers if radon is released into areas of a GDF that are accessed by workers or to the public if radon is released via the GDF ventilation system or to the surface post closure. Rn-222 present in the disposal vaults of a GDF may either be generated in the vault by decay of Ra-226 present within the disposed wastes or it may be released into the vault from the host rock. Rn-222 has a short half life (3.8 days) and, as a result, much of the radon generated in the GDF will decay to solid daughter products before it is able to escape from the waste packages or the host rock in which it is generated. Therefore, not all of the radon generated within the GDF will be released to contribute to the dose received by workers or the public.

The safe management of radon released from the walls of underground excavations, such as tunnels and mines, is standard practice within the mining and underground construction industries. We have no reason to believe that the conditions at a GDF site (uranium/radium content and rate at which radon is released from the walls of the excavation) would be significantly different to those encountered in those industries. In addition, a range of engineering measures such as appropriate ventilation and lining the walls of excavations are available to ensure that radon concentrations and discharges remain as low as reasonably practicable.

Our generic Operational Safety Case [1] and our generic Operational Environmental Safety Assessment [2] both recognise the release of naturally occurring radon from a GDF host rock as one of the pathways by which workers or the public might receive a radiological dose during the GDF operational period. Our generic Environmental Safety Case [3] and

our generic Post-closure Safety Assessment [4] identify the stripping of naturally generated Rn-222 from near-surface rocks by a gas stream that originated in a GDF and its transport to the ground surface as the post-closure pathway most likely to result in a dose due to naturally occurring Rn-222. Our assessments currently only present quantitative estimates for the potential release of radon from the disposed wastes. However, we recognise that once site specific information becomes available it will be appropriate to also include quantitative estimates of releases of naturally occurring radon. We consider the current scope of the assessment to be appropriate for this stage of the MRWS site selection process.

B.2.2.4 Consideration of the Office of Nuclear Regulation's safety assessment principles in the Operational Safety Case

Raised issues:

| ID: 224-01 | Accident safety assessment - peer review panel considers that more detail may need to be provided to demonstrate compliance with HSE SAPs. | TerraSalus 2.4.2 TerraSalus Peer Review Summary report | Jan 2010 |

RWMD Response:

The Office for Nuclear Regulation (ONR) Safety Assessment Principles (SAPs) provide inspectors with a framework for making consistent regulatory judgements on nuclear safety cases. Although there is no legal requirement to demonstrate compliance with most of the ONR SAPs, the ONR encourage Site Licence Companies to develop their own safety principles against which compliance is demonstrated. We are currently developing our own safety principles against which will demonstrate compliance in collaboration with the regulators.

The ONR SAPs provide a framework for what is expected of an accident safety assessment, which is in line with the approach used in the Disposal System Safety Case and to be used in future OSC submissions. The basic requirement of an accident safety assessment is to analyse all potential faults using the complementary approaches of design basis and probabilistic analyses, and severe accident analysis as appropriate, demonstrating that control of hazards and risks are as low as reasonably practicable (ALARP). In doing so the assessment should also demonstrate that the design provides sufficient 'defence in depth' with adequate safety margins.

Our approach to development of our Operational Safety Case (OSC) [1] is to fully meet our safety principles and follow good practice as set out in ONR SAPs and associated technical assessment guides. A key part of our generic Operational Safety Case (OSC) is the accident safety assessment, where potential fault scenarios involving radioactive material are identified and assessed. At the current stage of our programme, we have not developed our GDF design to the level of detail that will be required at a later stage to demonstrate compliance with our safety principles to the satisfaction of the ONR. We will be revising and providing more detail to the accident safety assessment in future OSC submissions as the GDF design is developed in line with the MRWS site selection process.

B.2.3 Transport safety

B.2.3.1 Scope of the Transport safety case

Raised issues:

| ID: 231-01 | Peer review panel considers that further work would be required to assess the potential risks associated with faults and accidents in the waste transport system. | TerraSalus 1.1 TerraSalus Peer Review Summary report | January 2010 |

Assessing accident risks and doses to the public - Peer review panel considers that further work would be required to assess potential doses to workers from accidents, and potential doses to the public from routine operations and accidents.

RWMD Response:

The transport of nuclear materials has an extremely good safety record and a very large international knowledge base exists on the transport of nuclear materials by road, rail, sea (waterways) and air. The Transport Safety Case (TSC) for a geological disposal facility (GDF) will need to set out clearly that we understand and can demonstrate why we believe that the transport of higher activity waste and materials will be accomplished safely and in accordance with IAEA Transport Regulations [1]. A site-specific TSC will require detailed information on the proposed transport routes and modes of transport and all of the different types of waste packages that will be transported. Once we have sufficient information in these areas, we will be able to develop the Radiation Protection Programme (RPP) required under [1] to demonstrate that measures and controls are in place to ensure the safety of workers and the public.

We are currently developing, and intend to publish, our TSC Strategy. This document is intended to set out the scope of TSC, how we expect this scope to develop as we proceed through the different stages of the MRWS site selection process and develop our RPPs, and the underpinning methodologies that will be used to demonstrate safety, including that the safety case is sufficiently comprehensive. We have recently published our generic TSC [2], which sets out how we intend to structure and present the TSC. At this stage of the MRWS site selection process when we do not have a site for a GDF we have produced a generic assessment that reflects uncertainties in transport route and mode, and have made what we believe are appropriate assumptions. We have at this stage restricted our assessment to the impact this transport operation would have on workers, but do consider other potential exposure pathways elsewhere in our programme. For example, our current understanding of the way in which waste packages would behave in transport accidents is set out in our waste package accident performance status report [3]. We recognise that this generic assessment is just the first step in a series of assessments that we will undertake to support licensing and planning of a future GDF and our TSC Strategy will set out our plans for future development in this area.


B.2.3.2 Transporting Magnox Encapsulation Plant (MEP) waste packages

Raised Issues:

<table>
<thead>
<tr>
<th>ID: 232-01</th>
<th>Document the extent of acceptability of container failures during transport of Magnox Encapsulation Plant packages, addressing containment and operability of the transport system (i.e. could this be a real driver for additional packaging measures).</th>
<th>Disposability Assessment Database ID46 Magnox Encapsulation Plant Periodic Review</th>
<th>March 2010</th>
</tr>
</thead>
</table>

RWMD Response:

Our disposability assessment process considers whether a proposed waste package type can be transported, handled and disposed safely and perform adequately over the long term once a geological disposal facility (GDF) has been closed. Such assessments may lead to the issue of a Letter of Compliance confirming disposability which the waste producer may use in discussions with regulators and stakeholders. Once waste packages have been produced, we periodically review them via the Letter of Compliance process to ensure that existing waste packages are evolving in the manner that was expected when the original Letter of Compliance was issued and remain disposable. Magnox Encapsulation Plant (MEP) waste packages first received a Letter of Compliance in 1990.

Inspection of MEP waste packages in store at Sellafield has revealed that some packages exhibit surface bulges. The bulges are thought to be the result of corrosion of bulk uranium within the conditioned wasteform; the corrosion product has a larger volume than the original uranium metal. The affected packages remain in a passively safe state in storage at Sellafield and RWMD is now working with Sellafield Ltd through the Letter of Compliance assessment process to investigate the significance of these bulges and to determine whether they are a concern for transport and GDF safety cases. This assessment [1] has led to the production of an action plan which will allow RWMD and Sellafield to determine and document whether additional packaging measures will be required to make the MEP packages compatible with transport and disposal safety cases. For example, the question of whether it would be acceptable if one or more bulges were to rupture during transport, potentially releasing radioactive material into the sealed transport container, has been posed. In order to comply with the generic Transport Safety Case [2], any potential release of radioactive material from the transport container would need to be demonstrated to be below the limits specified by the IAEA Transport Regulations [3]. In addition, the transport container may need to be decontaminated once the affected package had been removed in the remote handling facility at a GDF.

The case considered here is a good example of how we are working with the waste producers to ensure that we understand how waste packages are evolving while they are held in interim storage and are taking appropriate action to ensure that they will be disposable when a GDF is ready to receive them. An action plan is now in place to address and document any issues associated with the affected MEP packages.

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lessons learned will be incorporated into the future management of MEP waste packages and the design of future waste packages.

B.2.4 Strategic environmental assessment

B.2.4.1 Methodology for undertaking strategic environmental assessments

Raised issues:

<table>
<thead>
<tr>
<th>ID: 241-01</th>
<th>A quantitative approach to the assessment of effects gives the impression of certainty. Should a more qualitative approach be adopted?</th>
<th>Peer Review Generic Environmental Assessment and Sustainability Report</th>
<th>DSSC peer review 2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>ID: 241-02</td>
<td>The treatment of uncertainty in the generic assessment work could be improved by identifying key areas of uncertainty and developing appropriate ways to deal with them.</td>
<td>Peer Review Generic Environmental Assessment and Sustainability Report</td>
<td>DSSC peer review 2010</td>
</tr>
<tr>
<td>ID: 241-03</td>
<td>How do we clearly capture and present the relative magnitude of effects during different implementation phases?</td>
<td>Peer Review Generic Environmental Assessment and Sustainability Report</td>
<td>DSSC peer review 2010</td>
</tr>
<tr>
<td>ID: 241-04</td>
<td>Qualitative / perceptual issues may be important for the Strategic Environmental Assessment – but how do we capture, assess and present them?</td>
<td>Peer Review Strategic Environmental Assessment Methodology</td>
<td>DSSC peer review 2010</td>
</tr>
<tr>
<td>ID: 241-05</td>
<td>To satisfy the Strategic Environmental Assessment Regulations the assessment work must be shown to have influenced development of the Geological Disposal Implementation Plan.</td>
<td>Peer Review Strategic Environmental Assessment Methodology</td>
<td>DSSC peer review 2010</td>
</tr>
<tr>
<td>ID: 241-06</td>
<td>Detailed approach is needed for each Strategic Environmental Assessment assessment topic, in particular to identify the importance / sensitivity of affected resources and receptors.</td>
<td>Peer Review Generic Strategic Environmental Assessment Scoping report</td>
<td>DSSC peer review 2010</td>
</tr>
<tr>
<td>ID: 241-07</td>
<td>Detailed approach to assessing cumulative effects and interactions is needed in the Strategic Environmental Assessment.</td>
<td>Peer Review Generic Strategic Environmental Assessment Scoping report</td>
<td>DSSC peer review 2010</td>
</tr>
<tr>
<td>ID: 241-08</td>
<td>The possible need for trans-boundary consultation (as per the UK SEA Regulations) should be acknowledged and an appropriate consultation route identified.</td>
<td>Peer Review Generic Strategic Environmental Assessment Scoping report</td>
<td>DSSC peer review 2010</td>
</tr>
<tr>
<td>ID: 241-09</td>
<td>An Environmental Impact Assessment should be undertaken and integrated with the Strategic Environmental Assessment.</td>
<td>Peer Review Strategic Environmental Assessment methodology</td>
<td>Jan 2011</td>
</tr>
<tr>
<td>ID: 241-11</td>
<td>Baseline definition for Strategic Environmental Assessment / EIA will include assumptions about the long term management of HAW in the absence of geological disposal. Need to develop, justify and agree these assumptions.</td>
<td>Peer Review Strategic Environmental Assessment methodology</td>
<td>Jan 2011</td>
</tr>
</tbody>
</table>

**RWMD Response:**

Strategic Environmental Assessment (SEA), which includes Sustainability Assessment and Environmental Impact Assessment, is an integrated process we will use to assist in our strategic decision making, to record and explain those decisions and how they were reached, and to explain how consultation with stakeholders has influenced our Geological Disposal Implementation Plan and Programme [1]. It is also a requirement of UK SEA regulations and we will ensure that we follow the relevant guidance and best practice for large projects as we develop our SEA.

The issues included in this topic can be divided into four groups, which consider:

- the way we consider and present uncertainty (issues ID: 241-01, ID: 241-02);
- the level of detail included in the work we have published to date (issues ID: 241-06, ID: 241-07);
- the scope of the work we have published to date (issues ID: 241-03, ID: 241-04, ID: 241-08, ID: 241-10); and
- the interaction between different SEA documents and between the SEA and other parts of our programme (issues ID: 241-05, ID: 241-09, ID: 241-11).

The development of scope and methods for the SEA and other environmental assessments that will be required to support the development of a geological disposal facility is the subject of a dedicated project within RWMD. At this stage of the Managing Radioactive Waste Safely (MRWS) site selection process when we do not have a site for a geological

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disposal facility, we are at an early stage in the development of the SEA so our approach
and methods are not yet fully developed. We are following an agreed strategy [2], which
recognises that the development of the SEA requires a staged approach, and have recently
published documents that describe our proposed approach to SEA during Stage 4 of the
MRWS site selection process [3], our proposed generic scope of work for SEA [4], and the
results of a generic SEA [5] that we have carried out to illustrate our methodology and
inform decision making. In the absence of site-specific information, we have had to base
our work to date on assumptions which we believe to be appropriate for the current stage
of the programme, and have intentionally limited the level of detail we have included. We
will clearly be able to be more specific and quantitative and include more detail once we
are able to consider a real site. We have ongoing work to further develop and refine the
scope of the SEA. For example, we recently held a workshop to discuss the way we treat
and present uncertainty in our SEA process. Engagement with stakeholders, both internal
and external, and statutory consultees is an important part of our strategy set out in [2].
We will ensure that appropriate account is taken of their observations, comments and
recommendations as our programme moves forward, and work with our colleagues to
ensure that there is appropriate feedback from the SEA to documents such as the
Geological Disposal Implementation Plan and Programme.


B.2.5 Site assessment methodology

B.2.5.1 Use of assessments in the site selection process

Raised issues:

| ID: 251-01 (See also ID: 214-02) | Resolution of gas issues and their incorporation into site selection considerations. Issue refers to the conflict between the requirement to provide a barrier to radionuclide release and the requirement to allow bulk gas to escape to prevent pressure build-up. | Nuclear Waste Advisory Associates' Issues Register Issue - 12 | June 2010 |

**RWMD Response:**

We will need to take all aspects of geological disposal facility (GDF) performance into account when characterising a site for a GDF and developing an optimised GDF design for that site. The inventory of potentially gas generating materials and the way in which the characteristics of the host rock influence both gas generation within a GDF and the migration of gas away from a GDF will all need to be considered (see also topics 1.6.2, 1.6.3, 1.6.4 and 2.1.4). We have recently published our Gas Status Report [1], which sets out our current understanding of gas generation in a GDF and the subsequent migration of gas through the geosphere. We also outline some of the engineering solutions that might be used, and have been proposed by other waste management organisations, to ensure that unacceptable over-pressures cannot develop within a GDF, while at the same time providing the required level of containment for gaseous and dissolved radionuclides.

During Stage 4 of the MRWS site selection process we will undertake initial assessments to guide the selection of areas and sites for more detailed investigations and to give confidence that all sites being considered have the potential to satisfy safety case requirements. We will continue to address gas generation and migration during Stage 5 of the MRWS site selection process where we will be able to characterise the properties of the host rock and develop our GDF design. Our current programme is designed to equip us with the information and tools we will need to make rapid progress in this area once we know the properties of a GDF site. We are confident that we understand what the issues are that we will need to address once we have a site.

B.3 Site characterisation

B.3.1 Data acquisition

B.3.1.1 Surface-based data collection methods

Raised issues:

| ID: 311-01 | Characterising the site adequately: The most recent UK experience of site characterisation was the Sellafield investigations that ended more than 10 years ago... UK experts have been involved in overseas site characterisation programmes but the level of involvement has been limited... an issue is whether there are sufficient numbers of personnel to plan and execute a site characterisation programme... Furthermore, the UK needs sufficient practical resources such as laboratory facilities, suitable drilling rigs and the personnel required to run them. ...The UK has only limited experience in URLs. | Environment Agency Science Programme Contractor Report: Technical issues associated with deep repositories for radioactive waste in different geological environments Issue 7, 5.7.2, p105 | August 2009 |
| ID: 311-02 | Geosphere characterisation - areas have been identified that, CoRWM considers, would benefit from R&D. For example, R&D may be required to define the chemical descriptions and models for the near field, geosphere and biosphere and in the definition of models of site-scale hydrology, hydrogeology and paleohydrogeology. ... It is unclear, to CoRWM, whether R&D needs identified from this project are progressing or are being planned, or whether the skills and resources have been identified to undertake the work. | CoRWM doc 2543 Report on R&D for interim storage and geological disposal... 6.13, 91 | October 2009 |
| ID: 311-03 | Develop UK capability in techniques for the sampling and characterisation of subsurface microbial communities... | CoRWM doc 2543 Report on R&D for interim storage and geological disposal... 6.14, 91 | October 2009 |
| ID: 311-04 | CoRWM considers that through the adopted process information gaps | CoRWM doc 2543 | October |
### Issues Identified that Require R&D

Among these will be the following issues:

- **naturally-occurring fractures**
  - To understand the influence of these features fully it is considered that their genesis should be understood.
  - Research into the relationship between fracture distribution and stress fields would aid in site characterisation.
  - Controls on identification and description of the distribution of permeability in low-permeability rock units.
  - Research will be required in relation to understanding, in a fractured hard rock, the connectivity and transmissivity of the network of fractures. In addition research will be required into any lithological and structural controls on permeability distribution.
  - Research to understand the influence of fracture wall roughness and in situ stress would be useful in the characterisation process.
  - Geophysical techniques - research into the use of these techniques in relation to possible GDF sites could inform geosphere characterisation and assist in GDF layout and the design.

### Research and Development for Interim Storage and Geological Disposal

<table>
<thead>
<tr>
<th>ID: 311-05</th>
<th>There remains a requirement to conduct generic research and build essential capability, for example in techniques for the sampling and characterisation of subsurface microbial communities.</th>
<th>CoRWM doc 2543 Report on R&amp;D for interim storage and geological disposal... A.94, 122</th>
<th>October 2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>ID: 311-07</td>
<td>The establishment of a methodology for the determination of the frequency, spread and distribution of high permeability features.</td>
<td>Nuclear Waste Advisory Associates’ Issues Register</td>
<td>June 2010</td>
</tr>
<tr>
<td>-----------</td>
<td>-------------------------------------------------------------</td>
<td>---------------------------------------------------------------</td>
<td>------------</td>
</tr>
<tr>
<td>ID: 311-09</td>
<td>The question of whether site selection and characterisation processes can actually identify a large enough volume of rock with sufficiently favourable characteristics to contain the expected volume of wastes likely to be generated in a given country.</td>
<td>Helen Wallace (for Greenpeace International) Rock Solid Exec summary</td>
<td>September 2010</td>
</tr>
<tr>
<td>ID: 311-09 (See also ID: 713-03)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ID: 311-10</td>
<td>It is by no means clear that sufficient data can be collected, or sufficiently safe sites exist, to rule out scenarios which involve significant radiological releases.</td>
<td>Helen Wallace (for Greenpeace International) Rock Solid Sec 5.1.1</td>
<td>September 2010</td>
</tr>
<tr>
<td>ID: 311-11</td>
<td>The initial state of the site (e.g., in situ stresses, the fracture network, hydrogeochemical conditions at repository depth).</td>
<td>Helen Wallace (for Greenpeace International) Rock Solid Sec 5.1</td>
<td>September 2010</td>
</tr>
</tbody>
</table>

**RWMD Response:**

We recognise that there is a need for a clear approach to site investigation and this is a significant part of our work programme in the current phase of implementation. We have published a strategy for the geoscientific aspects of site characterisation [1] which presents the strategic approach to the implementation of site investigations at candidate sites during Stages 5 and 6 of the MRWS site selection process [2]. We have also published a Status Report which presents the output from the site characterisation studies undertaken by RWMD between October 2004 and March 2010 [3]. These strategy and status reports include strategic approaches and the conclusions of studies which address a number of these issues.

Existing studies commissioned by RWMD [4], our experience of drilling deep boreholes, and a wider review of radioactive waste site characterisation programmes [5] have been used to evaluate techniques available for deep drilling and its applicability for providing a

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platform for meeting the information requirements of a site characterisation programme in the UK. We have also commissioned in-depth reviews of the in-situ techniques which can be applied within boreholes to characterise the geological, hydrogeological, hydrochemical and geomechanical aspects of the geosphere [as summarised and referenced in [3]]. This summarises the range of testing techniques that can be undertaken in boreholes to support characterisation and the definition of baseline conditions at a site. This also includes techniques for characterising in situ stress, fracture networks, hydrogeochemical conditions and the frequency, spread and distribution of high permeability features drawing on experience from other site characterisation programmes. This report concludes that well established techniques are available to meet all the information requirements and therefore, whilst recognising that some development may be required to address site-specific factors, no significant site characterisation research is required at this generic stage of the programme.

Recognising the importance of robust approaches to the interpretation and modelling of data generated from a programme of surface-based investigations a number of studies reviewing the approaches and techniques that have been adopted on other programmes and in other sectors have been undertaken (for example, see [6]). These documents present the process of translating data into understanding, in order to develop an integrated Site Descriptive Model (SDM) of the geosphere and biosphere.

The SDM will be the primary product generated from a programme of surface-based investigations, with data managed as records and available through a web-server. These assets will be the source of site-specific information used to support the development of an Environmental Safety Case and engineering design, to determine suitability of a site(s) for the construction of a geological disposal facility.

We recognise that there are potential gaps in the skills base within the UK that may need to be filled depending upon the specific sites taken forward into Stage 5 of the MRWS site selection process. We also consider that some of these gaps may be filled by accessing the wider global supply chain and by adopting the most appropriate contracting strategy. This strategy is addressing the skills base concern by using our work programme to identify key areas where resource gaps may be critical (for example, see [6] which considers potential gaps in the skills base for the interpretation and modelling of hydrogeological site data). Work like this will be used to support the maintenance and development of relevant skills for delivery of the site characterisation related aspects of our R&D programme and the involvement of the supply chain in the longer term planning of our site characterisation activities.

In addition to this we have strong links with a number of more mature overseas waste management organisations, and seek to engage with these organisations on a wide range of general and specific topics related to site characterisation. Where appropriate RWMD staff will be seconded into these organisations, and indeed, the Geological Investigations Manager recently spent 6 months with Nagra managing the testing campaign of a deep scientific borehole in Northern Switzerland.

## B.3.1.2 Underground investigation methods

### Raised issues:

| ID: 312-01 | Both underground site characterisation and underground R&D are needed at any prospective GDF site in the UK. | CoRWM doc 2543 Report on R&D for interim storage and geological disposal... 5.45, 87 | October 2009 |
| ID: 312-02 | The most effective way to carry out the necessary underground R&D would be in a URF at any site where it is proposed to construct a GDF. | CoRWM doc 2543 Report on R&D for interim storage and geological disposal... 5.46, 88 | October 2009 |
| ID: 312-03 | R&D to be carried out in a URF before waste emplacement begins must be clearly specified, discussed with a wide range of stakeholders... and agreed with regulators. | CoRWM doc 2543v Report on R&D for interim storage and geological disposal... 5.47, 88 | October 2009 |
| ID: 312-04 | Until a site-specific URF is available in the UK, there will need to be increased participation in generic R&D programmes in underground facilities in other countries. | CoRWM doc 2543 Report on R&D for interim storage and geological disposal... 5.48, 88 | October 2009 |
RWMD Response

The MRWS White Paper identifies Stage 6 of the site selection process by the term “Underground operations” and makes clear that the work to be undertaken during this stage will include long-term underground investigations, as well as construction activities. These “investigations” will include underground R&D and site characterisation activities. The MRWS White Paper [1] states that “the aim of this work will be to confirm a site’s suitability to host a geological disposal facility that complies with safety and environmental regulatory requirements”. We would only propose to proceed to construction if these investigations indicate that the site meets these regulatory requirements. The White Paper makes clear that we, as the NDA’s delivery organisation, will have to submit specific assessments for regulatory review at agreed hold points and that the regulators will only permit construction of a geological disposal facility to proceed if the regulatory requirements are met. It also notes that planning permission will be required covering both underground investigation work and construction of the geological disposal facility.

The White Paper notes that even if a planning application were to be made solely for underground investigations, it would be necessary to demonstrate that the location was likely to be appropriate for facility construction. Following on from this, it noted that the implementing organisation is to explore whether a single planning application covering underground investigations and geological disposal facility construction could be possible. This would be dependent in part upon the sufficiency of information gained from prior surface-based investigations.

We support the flexibility that is implicit in these policy statements and is planning its work to respond to them. In particular we will ensure the requirements for underground investigations at a preferred site will be clearly identified through discussion with regulators, the host community and other interested parties during and following completion of surface-based investigations. Importantly, this will include taking account of the results from using the information obtained from the surface-based investigations in developing the engineering design and evolving the safety case for the disposal facility. It will only be at that stage that the scope of site-specific underground investigations required to develop a robust design and safety case can be specified. We will clearly wish to satisfy ourselves and the regulators that the programme of work planned to be undertaken in Stage 6, if yielding favourable results, would be sufficient to enable regulatory approval of the construction of the disposal facility.

Recognising that the requirements for underground investigations will depend strongly on the results of surface-based investigations conducted previously at the preferred site, a flexible approach is being maintained as to the extent and nature of the requirements. In addition we will use our links and co-operation with a network of underground research facilities located in rock-types of relevance to develop an appropriate level of expertise. Since this issue was raised, we have increased our participation in collaborative projects in overseas URLs and also joined the IAEA’s Underground Research Facility (URF) Network which will give access to additional relevant projects and experiments as they arise. This will provide access to the techniques and results of research relevant to features and processes in underground openings and can inform a judgement on the need to conduct equivalent research under the specific conditions of a preferred site.

We recognise that in the even longer term after the initial construction of the disposal facility, as excavations of new disposal vaults and tunnels progress, the work of confirming the suitability of the newly accessed rock volume will continue. Also, long-term underground research and monitoring are envisaged to be required at suitable locations in the facility to support updates to safety cases in respect of periodic re-permitting of disposal at the facility and to ensure that operations and the eventual backfilling, sealing and closure of the facility are carried out in an optimal manner.

With respect to the specific comment on the design drawings we will ensure that the facilities for underground investigation will be explicitly included in future design drawings.

### B.3.2 Data interpretation

#### B.3.2.1 Data and understanding of geology and hydrogeology for some parts of the UK

**Raised issues:**

| ID: 321-01 | Northern Cumbria, between the National Park and the Solway, is geologically even more complex. The whole northern region under consideration has been the subject of hydrocarbon exploration for 40 years; applying logically the exclusion criteria defined by the BGS means that it should have been screened out. | David Smythe Why a deep nuclear waste repository should not be sited in Cumbria: a geological review. | April 2011 |
| ID: 321-02 | The regional hydrogeological regime in west and north Cumbria is dominated by the presence of the Cumbrian mountains. The extreme relief is about twenty times greater than desirable for categories of waste repository hosted in crystalline rocks. That fact alone is sufficient to characterise the region as hydrogeologically unsuitable, quite apart from the demonstrable complexity of the geology. | David Smythe Why a deep nuclear waste repository should not be sited in Cumbria: a geological review. | April 2011 |
| ID: 321-03 | The well-understood geology and hydrogeology, and hence the inherent safety of any chosen potential site, is categorically against the region’s suitability to host a nuclear waste repository. | David Smythe Why a deep nuclear waste repository should not be sited in Cumbria: a geological review. | April 2011 |
| ID: 321-04 | The predictions of fluid flow to make an acceptable safety case can only be made using models which are simple. If models are built from complex geologies they will inevitably be full of multiple errors, omissions, false or | David Smythe Why a deep nuclear waste repository should not be sited in Cumbria: a | April 2011 |
dubious assumptions, and so on, and therefore unsafe.

RWMD Response:
The issues concerning the unsuitability of West Cumbria have been raised by a small number of independent geoscientists. Discussions with a wider range of geoscientists have indicated that the scientific basis for these issues is not widely considered to be valid based upon the available information at this stage in the MRWS Site Selection Process [1]. Furthermore there is considerable feedback from a wide range of geoscientists that the proposed approach to assessing any sites in West Cumbria or anywhere else in the country, should decisions be made to participate, will ascertain whether a site is suitable once the appropriate information is available. We therefore do not agree with the issues as raised and plan to continue our work programme to ensure that we support the MRWS Site Selection Process [2,3].

A fuller response to these issues has previously been prepared [4] and is available on the bibliography and on the West Cumbria MRWS Partnership web site.


B.4 Designing and constructing a GDF

B.4.1 Design development

B.4.1.1 Waste package design for high level waste and spent fuel

Raised issues:

| ID: 411-01 | High level waste & spent fuel canister design not optimised. | Disposability Assessment Database68 AGR Spent Fuel | October 2010 |
| ID: 411-02 | Need to develop variants of the copper canister and cast iron insert for Irradiated Fuel Containers (IFCs) arising from Dounreay, and add to concept. Copper canisters to be standardised in length, and issues around diameter of copper canister to be resolved. | Disposability Assessment Database64 PFR Irradiated Carbide Fuel (Conceptual) | February 2011 |

RWMD response:

We have work in progress to develop a standard range of canister designs suitable for HLW and spent fuel that is compatible with the disposal concept options under consideration in the UK. This will evaluate the required dimensions of the canister and the insert and take into account not only the dimensions and packaging efficiency of the range of UK HLW and spent fuel wastes but also take into consideration manufacturing and handling aspects. This work will consider both copper and steel as possible canister materials [1]. The aim of this work is to standardise the key dimensions of the canister design and optimise the number of spent fuel elements or HLW containers that can be accommodated by each canister to meet the performance requirements of the canister and the overall system. This work will look at the canister design, the canister materials, and also the manufacturing and handling techniques. This work will also consider the dimensions and materials of any insert needed in the canister to accommodate the range of UK spent fuel types, including experimental fuels such as those at Dounreay. This work is due to be delivered to NDA in 2012 and is part of the ongoing work programme.

B.4.1.2 Waste package design for intermediate level waste

Raised issues:

| ID: 412-01 | Consider implications of French designed C1 and C4 SOGEFIBRE concrete casks for operational intermediate level waste from new build reactors. | Disposability Assessment Database ID22 Generic Design Assessment of EPR | September 2010 |

Develop a position on SOGEFIBRE C1 and C4 concrete casks covering stacking and accident performance and work up into relevant WPS documents.

Disposability Assessment Database ID21 Generic Design Assessment of EPR

**RWMD response:**
These issues are very specific to particular proposals from Site Licence Companies (SLCs) and are an example of the on-going dialogue between ourselves and the SLCs. The SLC’s are responsible for the treatment and conditioning of the UK’s waste legacy. NDA RWMD provides guidance on the required standards and options for the treatment and packaging of such wastes based upon the performance of the disposal system. We work with the site licence companies (SLC’s) to assess the proposed methods and options, including the suggested packages or containers that they wish to use. The formal process used within the NDA is the Letter of Compliance process. In essence the SLC’s can seek to optimise their own processes for the treatment and packaging of such wastes in line with their own strategy for the decommissioning and interim storage of the wastes generated on their respective sites. We then assess the suitability of the resulting packages for compliance with the performance and requirements of the disposal facility. This process is overseen by the UK regulators. The SLC’s have a requirement to optimise their part of the overall system and are looking at different options for such wastes including existing packages of the types mentioned in the issues raised that are currently used in the nuclear industry. On our part we have now included within our packaging guidance documents requirements on robust shielded containers of the types mentioned [1]. The assessment of the suitability of using different containers is part of an ongoing dialogue between the SLC’s and the NDA. This process is overseen by the regulators and is used to gain an understanding of whether any proposed containers are suitable and compatible with the UK’s disposal system.

**B.4.1.3 Disposal system design requirements**

**Raised issues:**

<table>
<thead>
<tr>
<th>ID: 413-01</th>
<th>Specification to include maximum strengths for vault floors as used in this assessment. Development of a hypothetical vault floor design with appropriately derived and justified maximum cement strengths, for the purposes of further waste package impact modelling.</th>
<th>Disposability Assessment Database ID48 Use of Ductile Cast Iron Containers for Disposal of intermediate level waste</th>
<th>May 2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>ID: 413-02</td>
<td>The long-term performance of repository closing and sealing materials and the consequences for safety.</td>
<td>Helen Wallace (for Greenpeace International) Rock Solid Sec 5.1</td>
<td>September 2010</td>
</tr>
</tbody>
</table>

| ID: 413-03 | The spacing of the canisters is one of the parameters with most impact on the size and cost of a repository... If the maximum temperature limit were lowered in order to meet concerns about the effects of temperatures below 100°C on bentonite this could significantly increase costs and make it more difficult to dispose of a given quantity of waste in the available volume of bedrock at a potential repository site. | Helen Wallace (for Greenpeace International) Rock Solid Sec 4.2.1 | September 2010 |
| ID: 413-04 | 'How can bentonite be handled unless humidity is kept very low? How is the final quality assured? How can the copper canister be handled without a risk of dropping? In cases of failure to meet quality levels or accidents, how can emplacement be reversed – especially for the largest spent fuel containers? | Peer Review Geological Design Report - Higher Strength Sec 6.2 | DSSC peer review 2010 |
| ID: 413-05 | In the higher strength rock illustrative design, it is currently assumed that the disposal tunnels will be backfilled once all the deposition holes have been filled with disposal canisters. However has any consideration of borehole caps been undertaken? If backfilling is only after all holes have been filled, how can it be ensured that the bentonite quality in the disposal hole is preserved? | Peer Review Summary of Designs Sec 7.3 | DSSC peer review 2010 |
| ID: 413-06 | "crushed rock (70%)' - Too simplistic. How is quality of hole buffer ensured until backfill is emplaced? | Peer Review Outline Design Report - Higher Strength Sec 11.2 | DSSC peer review 2010 |
| ID: 413-07 | "low permeability' - Are there any special design requirements for repository-generated gas, especially in the EDZ? | Peer Review Geological Design Report - Lower Strength Sec 12.2 | DSSC peer review 2010 |
| ID: 413-08 | Bags of Magnesium Oxide (MgO) are currently proposed to be placed on top of stacks of intermediate level and low level waste to act as a buffer. However there may not be a requirement for MgO. Does it provide any recognised safety | Peer Review Geological Design Report - Evaporite Sec 8.2 | DSSC peer review 2010 |
| ID: 413-09 | benefit with regards to the UK wastes? | Peer Review Outline Design Report - Evaporite Sec 3.8 | DSSC peer review 2010 |
| ID: 413-10 | "voids" - This could potentially be problematic unless the formation is very thick. Why not backfill with crushed salt to reduce the amount of deformation of the host rock? | Peer Review Outline Design Report - Higher Strength Sec 8.2 | DSSC peer review 2010 |
| ID: 413-11 | In the higher strength rock illustrative design, the disposal canister will be placed in a deposition hole 'surrounded by a bentonite buffer' - is this possible for a wet rock? | Peer Review Geological Design Report - Lower Strength Sec 12.1 | DSSC peer review 2010 |
| ID: 413-12 | Whilst it is recognised that the optimal closure strategy and any retrieval options will only be decided later following completion of the MRWS programme and further research, we would like to see some consideration of how the potential options may affect the design of the GDF, how the GDF operates and any consequent implications for safety. | Health and Safety Executive Operational Safety Case - Main Report General Comment | DSSC peer review 2010 |
| ID: 413-13 | It is proposed that excavation dimensions would be determined based on the prevailing geotechnical characteristics of the host rock and would be sufficient to provide adequate long term stability for the duration of the construction, operation and closure phases. However during the closure phase, there may also be constraints set by the need to control groundwater flow which may require extensive lining of tunnels in many locations. | Peer Review Outline Design Report - Higher Strength Sec 9.1 | DSSC peer review 2010 |
| ID: 413-14 | For Nagras concept this has not been decided yet. Bentonite most probably in the shaft sections within the host rock. For the adjacent rocks, seals will be placed at locations and with properties determined from: c) long-term safety considerations and d) environmental considerations (avoidance of | Peer Review Geological Design Report - Lower Strength Page 12 | DSSC peer review 2010 |
| ID: 413-15 | "emplacement circuit" - Note that, for Opalinus clay, assured ventilation in the high level waste/spent fuel tunnels is important to assure mechanical stability. Unless the design is changed to include a liner (recommended), this special ventilation requirement needs to be discussed here | Peer Review Geological Design Report - Lower Strength Sec 5.8 | DSSC peer review 2010 |
| ID: 413-16 | "1:6’ – this is a steep incline for large face area construction, which while possible is likely to impose particular burdens on construction processes which may not be optimal (spoil haul practicalities, ventilation requirements – plant labouring etc). Reference to supporting information informing decision-making should probably be at hand, were this configuration to be progressed. | Peer Review Geological Design Report - Lower Strength Sec 8.1 | DSSC peer review 2010 |
| ID: 413-17 | How can the mound be landscaped (to meet planning requirements etc) if spoil from all further excavation works is then to be added to the mound during the lifetime of the site? If there is a requirement for a visual / shielding screen then this does not increase over time – it is required from the moment surface buildings are constructed and waste is first brought to site. Therefore if the mound has met its functional requirements by this early stage is there not a risk that any further addition of material will be considered to be dumping and potentially prohibited leaving a huge quantity of rock to be disposed of off-site? | Peer Review Geological Design Report - Evaporite Sec 7.2 | DSSC peer review 2010 |
| ID: 413-18 | "decontamination is necessary’ - Is it sensible to include full decontamination facilities here. Maybe easier, in case of contamination, to transfer to the surface in an external container. Indeed, if such containers were considered, potentially they could be used for all transport packages, allowing the contamination checks also to be done at the surface. | Peer Review Geological Design Report - Evaporite Sec 8.2 | DSSC peer review 2010 |
| ID: 413-19 | Could some of the surface facilities related to waste emplacement activities be integrated such as the visitors centre, administration, reception, offices, control room etc? | Peer Review Summary of Designs Sec 7.2 | DSSC peer review 2010 |
| ID: 413-20 | In the event of loss of normal supplies from the DNO, the power supply to the essential equipment would be maintained by means of a back-up power system. In accordance with the design principle this would be achieved by way of a duplicate set of diesel generators, each suitably sized to maintain the essential load, and where required localised battery back-up Uninterruptable Power Supplies (UPS). How long could this diesel backup be maintained for? | Peer Review Geological Design Report - Evaporite Sec 9.2 | DSSC peer review 2010 |
| ID: 413-21 | 'Site drainage proposals are likely to be inadequate as they will cause off-site adverse impacts due to the increase in 'flashiness' of the catchment. Hydrology specialist needs to advise on appropriate solutions, particularly bearing in mind the nuclear nature of the GDF. Will the GDF have a sewage works? Will it be necessary to ensure that sewerage is distinct form water drained from the works where there may be nuclear contamination? | Peer Review Geological Design Report - Lower Strength Sec 9.5 | DSSC peer review 2010 |
| ID: 413-22 | Chapter 9.5.3 identifies the potential requirement for sewage treatment plant – this is not covered in Chapter 7. | Peer Review Geological Design Report - Evaporite Sec 7.1 | DSSC peer review 2010 |
| ID: 413-23 | There is no discussion of the need for potential wetland areas / SUDS ponds etc to provide sustainable drainage solutions (either here or in 9.5.3 or 10). If used these will take space and need careful positioning. | Peer Review Geological Design Report - Evaporite Sec 7.1 | DSSC peer review 2010 |
| ID: 413-24 | "the screening mound' - If needed? Is this justified on the basis of cost – benefit analysis. Would screening by trees not be equally effective? | Peer Review Geological Design Report - Evaporite Sec 9.5 | DSSC peer review 2010 |
| ID: 413-25 | "a bund around the site' - Why is this needed? Is this the most | Peer Review Outline Design | DSSC peer review 2010 |
| ID: 413-26 | environmentally acceptable option? Can screening, if needed, not be done with trees? | Report - Evaporite Sec 9.4 | review 2010 |
| ID: 413-27 | “the floor of the drift would be in-filled with concrete to support a rack-and-pinion rail system…” Observation – the means of tunnel excavation will have a significant bearing on whether the access tunnel can be in filled in the way described, or whether the entire tunnel must be completed prior to invert fit-out. One would imagine that operationally, some means of bypassing stalled trains (breakdowns) will be necessary, if their failure –causes blocked access to the only tunnelled means of escape. This may require double width and very long cavern structures ‘on-line’ with the access the tunnel. | Geological Design Report - Lower Strength Sc 8.1 | DSSC peer review 2010 |
| ID: 413-28 | ‘Scale bar. Even if remote handling is not strictly necessary, if such equipment is being designed for Unshielded intermediate level waste, why not use it also for Shielded intermediate level waste/intermediate level waste | Peer Review Geological Design Report - Evaporite Sec 3.2 | DSSC peer review 2010 |
| ID: 413-29 | “every single waste package” - How will this be done? Bar-code system or equivalent for unambiguous waste package identification? | Peer Review Geological Design Report - Evaporite Sec 9.4 | DSSC peer review 2010 |
| ID: 413-30 | ‘To minimise potential operator doses, it might be worth considering tele-operation of all waste emplacement processes. Human access to the active zone would then only occur for maintenance or in event of perturbations. | Peer Review Geological Design Report - Evaporite Sec 8.3 | DSSC peer review 2010 |
| ID: 413-31 | ‘arrivals’ - Note that this might also be handled by improved operational procedures (as experience is gained), working 2 or even 3 shifts / day, etc. | Peer Review Summary of Designs Sec 8 | DSSC peer review 2010 |
| ID: 413-32 | 'Drift locomotives power by …' | Peer Review | DSSC |
| ID: 413-33 | The transport related facilities are described in significantly more quantified detail than the identified buildings. No indication is given as to the size / capacity / throughput / utilisation / etc of any building. | Peer Review Geological Design Report - Evaporite Sec 8.1 | DSSC peer review 2010 |
| ID: 413-34 | How will the high level waste/spent fuel disposal canisters be transferred to the deposition machine? | Health and Safety Executive Operational Safety Case - Main Report Page 29 | DSSC peer review 2010 |
| ID: 413-35 | The need to rotate cylindrical transport containers to load high level waste/spent fuel waste packages into the vertical deposition holes presents a significant technical challenge and hazard. It should be demonstrated that alternative options have been fully considered. | Health and Safety Executive Operational Safety Case - Main Report Page 56 | DSSC peer review 2010 |
| ID: 413-36 | How will the waters pumped from a GDF during construction and operation be managed? | Peer review Near Field Evolution status report | DSSC peer review 2010 |
| ID: 413-37 | If no water flow, thermal constraints may set separation distances. Note that a more critical parameter is the minimum thickness of the salt (separation between waste and overlying/underlying formations). | Peer Review Outline Design Report - Evaporite Sec 3.5 | DSSC peer review 2010 |
| ID: 413-38 | “3m gap’ - Is this regardless of whether high level waste, spent fuel, Plutonium or Uranium? | Peer Review Outline Design Report - Lower Strength Sec 3.8 | DSSC peer review 2010 |
| | “tunnels would be required’ - What is the pitch of canisters in a tunnel? How was this chosen? | Peer Review Geological Design Report - Evaporite Sec 8.4 | DSSC peer review 2010 |
| ID: 413-39 | Would suggest that any references to 'layouts' are described as 'indicative' or 'illustrative' arrangements. Whilst it is acknowledged that the drawings represent a very early representation of scheme definition, some comments on the contents would include: 1. Many underground changes in direction appear to be 'right angles' notwithstanding presumed very small scale of the drawing and early level of design definition, construction practicalities will dictate profiles most suited to tunnelling constructions. 2. It is not immediately apparent from the drawing whether the entire layout is at the same depth. 3. Bifurcating access ways are bisected by other tunnels in a normal direction - an arrangement which should be avoided. 4. Legend doesn't appear to be numbered on plan? 5. As per commentary on text, arrangement appears very vulnerable to blockage howsoever arising given a single tunnelled route to surface facilities (it is noted that shafts will allow alternative vertical circulation for some goods, construction personnel etc). | Peer Review Geological Design Report - Lower Strength 'Drawings, Underground Layout for Upper Inventory (0041051) | DSSC peer review 2010 |
| ID: 413-40 | "rectangular shape' - Why was this selected? What are the reference geotechnical properties assumed for the mechanical stability analysis? How are heterogeneities in properties handled? There should be a reference to the detailed design analysis. | Peer Review Outline Design Report - Evaporite Sec 9.1 | DSSC peer review 2010 |
| ID: 413-41 | "Underground, it has been assumed' - reviewer considers there likely to be significant 'assumption-change' consequences attached to this position, which are not explored or acknowledged. | Peer Review Summary of Designs Sec 7.2 | DSSC peer review 2010 |
| ID: 413-42 | 'Underground layouts are quite detailed: are these supported by logistical analysis for both construction and operation? | Peer Review Geological Design Report - Higher Strength 'Drawings, Underground | DSSC peer review 2010 |
| ID: 413-43 | 'Underground layouts are quite detailed: are these supported by logistical analysis for both construction and operation? | Peer Review Geological Design Report - Lower Strength 'Drawings, Underground Layout, (0041051 and 0041052) | DSSC peer review 2010 |
| ID: 413-44 | Clearly a concept drawing, but a plan or extract of a plan indicating where this situated in the master plan labyrinth of tunnel routes would aide understanding. | Peer Review Geological Design Report - Lower Strength Drawings, intermediate level waste Vault Transfer and Emplacement Longitudinal Section (0041056) | DSSC peer review 2010 |
| ID: 413-45 | See comments on construction tolerances with regards to the position of rails. No tunnel crown structure indicated in this section? | Peer Review Geological Design Report - Lower Strength Drawings, high level waste/spent fuel +Plutonium Tunnel Reception and Emplacement Longitudinal and Cross Section (0041059) | DSSC peer review 2010 |
| ID: 413-46 | See comments on drawing 0041051 2. As per other review comments in text; the likelihood of finding a stratum of such consistency to allow a 6.5 x 4.5km wide area of intensive, and highly regular/symmetrical tunnel working seems rather low. Would recommend that suitable caveats are attached to any such arrangement which address the likelihood that the layout may be far less neat. | Peer Review Geological Design Report - Lower Strength Drawings, Upper Bounding Volume Underground Layout (0041062) | DSSC peer review 2010 |
| ID: 413-47 | "far end of the vault..." - Vaults are accessible from both sides according to Fig 3.3. Is one of these points sealed before emplacement commences? | Peer Review Geological Design Report - Evaporite Sec 8.3 | DSSC peer review 2010 |
| ID: 413-48 | 'Underground layouts are quite detailed: are these supported by logistical analysis for both construction and operation? | Peer Review Geological Design Report - Evaporite 'Drawings, Underground Layout (0041101 and 0041102) | DSSC peer review 2010 |
| ID: 413-49 | "take place on an as required bases..." - Why is this taken as a starting assumption – would this not be derived from the logistical analysis? | Peer Review Outline Design Report - Evaporite Sec 3.6 | DSSC peer review 2010 |
| ID: 413-50 | 'Need to modify layout in response to observations during construction - this needs to be discussed. Possible need, at an early stage, to construct a tunnel around the entire preliminary disposal zone to confirm locations of layout determining features. | Peer Review Geological Design Report - Higher Strength Sec 4 | DSSC peer review 2010 |
| ID: 413-51 | 'Orientation of the vaults may be governed by in situ stresses. That is, the in situ stresses may lead to a sub-optimal geometric arrangements and hence an increase in the facility’s underground footprint. | Peer Review Geological Design Report - Lower Strength Sec 8.3 | DSSC peer review 2010 |
| ID: 413-52 | "30m apart" - Why? Why less than the separation of the smaller high level waste/spent fuel disposal tunnels? | Peer Review Geological Design Report - Evaporite Sec 8.3 | DSSC peer review 2010 |
| ID: 413-53 | 'The shapes of openings indicate that some kind of geotechnical analysis has been carried out: the rock mechanical database used, assumptions (e.g. orientation to stress field, mechanical support used) and calculation procedure should be explicitly noted in the associated text. | Peer Review Geological Design Report - Evaporite 'Drawings, Excavation Profiles (00411013) | DSSC peer review 2010 |
| ID: 413-54 | Is the influence of depth examined and, if not, how can uncertainties associated with this parameter be evaluated? | Peer Review Outline Design Report - Evaporite Sec 3.4 | DSSC peer review 2010 |
RWMD Response:

Given the range of the types of rock occurring at depth in the UK, we currently consider a range of different potential host geological settings for a future disposal facility in work that we are carrying out ahead of any candidate site being identified through the MRWS site selection process. We have taken the approach of using concepts developed, over many decades in some cases, by other national waste management organisations to illustrate the concepts possible for a UK geological disposal facility [1]. We use this information in conjunction with the knowledge gained from over 30 years R&D from the UK’s own disposal programme. Detailed aspects of design that have been raised as issues will be addressed once potential candidate sites and site-specific concept options have been identified. Some of the host environments currently being considered may not come forward as part of the volunteer site selection process and hence some of the issues regarding specific rock types and rock properties may not be relevant as this process continues. This could also be the case for some of the issues raised regarding the location and topography of any potential site. In particular, issues relating to surface buildings and site infrastructure as well as transport and environmental planning and landscaping. Issues relating to the layout, materials and methods for backfilling, closure and sealing of the facility are also highly site-specific and can only be addressed in relation to the geological conditions. We acknowledge that such issues will be part of an ongoing dialogue with regulators and community stakeholders as geological settings and sites are considered.

B.4.1.4 Construction methodology

Raised issues:

| ID: 414-01 | CoRWM considers that design should commence with an integrated review of disposal concepts, underground engineering constraints and the engineered barrier design. The programme outlined in the June 2008 White Paper currently does not identify a specific period for design development nor is CoRWM aware that NDA has defined a process for design development. | CoRWM Doc. 2550. Geological disposal of higher activity radioactive wastes. July 2009 12.28, p45 | October 2009 |
| (See also ID: 631-03) |

| ID: 414-02 | Useful studies could be undertaken to define the influence that the form of the underground openings and excavation and support methods have on design. - Response of the rock mass to excavation and extent of any disturbance of the rock adjacent to underground openings. | CoRWM doc 2543 Report on R&D for interim storage and geological disposal… A.84, 120 | October 2009 |

- Long-term operation and maintenance of GDF tunnels and shafts. |
| ID: 414-04 | 'Use of road headers for tunnelling: Has consideration been given to the issues associated with respirable silica generated from the tunnelling process from open-face tunnelling construction methods? Likewise to the constraints imposed by occupational exposure limitations of nitrogen monoxide in a confined (tunnel) environment? Whilst it is fully appreciated that the level of design development of these GDF proposals is embryonic, the construction (tunnelling) industry has recently given these issues serious consideration following European legislation affecting previously, less stringent working practices. Forming the immense underground volumes contemplated by this programme will require unprecedented labour hours working in these environments, which must be expected to attract potentially restrictive occupational health requirements. The construction industry requires by, statute, the limitation of risk to workers health from the process of construction at design stage (the CDM regulations). Reviewer would recommend that cognisance of these issues from the outset is acknowledged, and recorded in this suite of documents. |
| ID: 414-05 | 'This is not only stress and not only for the salt. What about the EDZ around the shaft and how that may evolve with time? The shaft EDZ may be critical to assessment of flooding risks. |
|        | "Due to the nature of the lower strength sedimentary host rock, it may be necessary at some point in time to undertake periodic remedial work to re-excave parts of the access tunnels to ensure the uninterrupted movement of waste and personnel throughout the operational period of |
| ID: 414-06 | Numerous references made to ‘buffer store’ – are there separate stores for each use or one store for all uses? What is the required capacity for buffer storage? | Peer Review Geological Design Report - Evaporite Sec 7.1 | DSSC peer review 2010 |
| ID: 414-07 | 5000 tonne capacity – what is the basis for this figure? | Peer Review Geological Design Report - Evaporite Sec 7.2 | DSSC peer review 2010 |
| ID: 414-08 | "about 2,500 to 3,000 tonnes' - How is this derived? | Peer Review Geological Design Report - Evaporite Sec 8.5 | DSSC peer review 2010 |
| ID: 414-09 | ‘This is far too simplistic for fractured basement. Water-carrying features are likely to exist on all physical scales (mm – km) and a process for handling these is needed, particularly at the repository level. This is particularly critical for the chosen high level waste/spent fuel concept which is known to be very difficult under even conditions of high humidity and practically impossible in the presence of liquid water (how can this be prevented in a borehole?). | Peer Review Outline Design Report - Higher Strength Sec 9.7 | DSSC peer review 2010 |
| ID: 414-10 | "pre-treatment to control groundwater' - The (tunnelling) construction industry is well served by case history of difficulty in achieving ‘widespread’ effective groundwater control through planned ground treatment. Whereas methods and techniques and material continuously improve, it is difficult and invariably brings with it uncertainty in the efficacy of outcome. Again a presumption that this would be the best approach prior to further design development could be open to some challenge. | Peer Review Geological Design Report - Lower Strength Sec 8.1 | DSSC peer review 2010 |
| ID: 414-11 | "Groundwater control in the top 10m - dewatered, and grouting from the surface to 130m…' - If this configuration is supported by a construction advisor (familiar with rock excavation on the scale of this access tunnel here), recommendation | Peer Review Geological Design Report - Lower Strength Sec 8.1 | DSSC peer review 2010 |
| ID: 414-12 | "rockbolts and mesh with shotcrete' - How are emplacement boreholes supported or lined for water control? | Peer Review Summary of Designs Sec 7.3 | DSSC peer review 2010 |
| ID: 414-13 | "rockbolts and mesh with shotcrete. Concrete segments not discounted' - For low and intermediate level waste caverns, more substantial liner may be needed for mechanical and water control. | Peer Review Summary of Designs Sec 7.3 | DSSC peer review 2010 |
| ID: 414-14 | Rockbolts and shotcrete.. I would imagine that liners would be needed for all openings that require to be open for long periods of time. | Peer Review Geological Design Report - Lower Strength Sec 11.2 | DSSC peer review 2010 |
| ID: 414-15 | "potential long-term instability…' - Why not line cells to give required stability? Would also be required for other long lived facilities (e.g. workshops). | Peer Review Geological Design Report - Evaporite Sec 8.2 | DSSC peer review 2010 |
| ID: 414-16 | Refer to comments on drawing 0041051 regarding resisting ground and groundwater pressures; in addition on this drawing some tunnels and shafts are lined and others are not - why? No obvious rationale. | Peer Review Geological Design Report - Evaporite Drawings, Excavation Profiles (00411013) | DSSC peer review 2010 |
| ID: 414-17 | "drill and blast methods.' - Surely depends on characteristics of overburden? | Peer Review Outline Design Report - Evaporite Sec 9.1 | DSSC peer review 2010 |
| ID: 414-18 | Explosives: it is assumed that emulsion explosives will be used. They consist of non-explosive chemical components which are mixed in the drill hole where the mixture becomes explosive. Those chemicals can in Sweden be handled as chemicals also underground. The igniters, however, contain explosive substances and need to be handled | Peer Review Geological Design Report - Higher Strength 7.2.5 | DSSC peer review 2010 |
with care. But the content of explosive substances is so small in each that the Swedish mining regulations allow fairly large amounts of igniters at the same place.

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<tr>
<td>ID: 414-20</td>
<td>Compromise may be required between construction requirements and safety requirements.</td>
<td>Nuclear Waste Advisory Associates’ Issues Register Issue - 25</td>
<td>June 2010</td>
</tr>
<tr>
<td>ID: 414-21</td>
<td>The possibility of a collapse due to an open phase requires further investigation.</td>
<td>Nuclear Waste Advisory Associates’ Issues Register Issue - 30</td>
<td>June 2010</td>
</tr>
<tr>
<td>ID: 414-22</td>
<td>There is insufficient data to predict chemical causes of cavern collapse.</td>
<td>Nuclear Waste Advisory Associates’ Issues Register Issue - 51</td>
<td>June 2010</td>
</tr>
</tbody>
</table>
RWMD Response:

Engineering construction methodologies have not yet been documented to illustrate how safety requirements and engineering requirements would be fulfilled. Engineering construction methodologies are determined by rock properties and conditions at the site and can only be set out once a potential site has been identified and site specific information is available. The documentation to date has drawn upon knowledge of underground construction across many industries including tunnelling, mining and excavation of underground areas. This has been done to demonstrate that construction technology is well established appropriate to the range of rock properties being considered but also to show that there is a good understanding of underground engineering constraints and how these could be addressed during design and construction. The starting point for the development of the engineering design and construction methodologies is an understanding of the performance requirements of the overall system. At this stage in the process we are working to establish the engineering requirements to allow us to consider how we might construct such a facility when potential candidate sites are identified at the end of Stage 4 of the MRWS site selection process [1]. During Stage 5 of the MRWS site selection process we will develop engineering designs on the basis of our increasing understanding of potential host rock conditions as this is gained from the relevant site investigations.

Currently we keep under review developments that are being made in this field both in the most advanced national geological disposal programmes that are approaching the construction stage, and in related activities. Once geological conditions at a candidate site have been established with sufficient confidence in Stage 5 of the MRWS site selection process we would develop an engineering design specification that could take account of these issues. This design specification would then be subject to further development in response to iterations with safety assessments and the generation of further geological information.

The impact of the excavation damage zone (EDZ) on gas/water flow is a topic that we need to understand. The significance of any impact will be highly dependent upon the design of the disposal facility and the properties of the surrounding host rock. We track developments in understanding of EDZ properties through international projects. Once information on rock properties and stresses became available from site investigations in Stage 5 of the MRWS site selection process we would model the development of an EDZ and assess its significance for gas and groundwater flow. Models of an EDZ would be tested against observations made when excavations are carried out in Stage 6 of the MRWS site selection process.

Weathering and other processes that can affect the stability of excavations that are left open for long periods are routinely dealt with in the civil engineering and mining engineering of underground facilities and tunnels. We aim to draw on such knowledge in the development of our own plans and designs.

The possibility of a collapse of a vault or roadway roof is clearly something that we need to consider. There is a wealth of knowledge and experience from civil engineering and mining engineering projects that we would expect to apply at the relevant stage of the programme when information became available on a candidate site and the engineering design of a disposal facility suited to the site conditions had been developed.

Development of methodologies to support a future demonstration that safety and engineering requirements have been met is an important part of our programme [2].

B.4.1.5 Emplacement strategy

Raised issues:

<table>
<thead>
<tr>
<th>ID: 415-01</th>
<th>&quot;no waste emplacement strategy…' - Why not? Should this not be considered to even out thermal loading? What about selective placement of high level waste and spent fuel to ensure that the latter is in the best possible environment (as decrease of toxicity with time is less)?</th>
<th>Peer Review Outline Design Report – Evaporite Sec 10.1</th>
<th>DSSC peer review 2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>ID: 415-02</td>
<td>Uranium bearing wastes: Suggestion from post-closure safety assessment that we should consider benefits of location such wastes in separate vaults to organic wastes to reduce the solubility and near-field flux of uranium, etc.</td>
<td>Disposability Assessment Database ID37 Magnox Encapsulation Plant Periodic Review</td>
<td>October 2010</td>
</tr>
<tr>
<td>ID: 415-03</td>
<td>Packages containing AWE hydrodynamic vessels will need to be actively managed within the unshielded intermediate level waste vaults to ensure that individual stacks of packages do not contain more than one AWE hydrodynamic vessel.</td>
<td>Disposability Assessment Database74 AWE Hydrus Hydrodynamic Vessels</td>
<td>Nov 2011</td>
</tr>
<tr>
<td>ID: 415-04</td>
<td>The handling systems at the GDF need to be capable of handling eccentrically loaded waste packages. The extreme example being the AWE Hydrus package.</td>
<td>Disposability Assessment Database76 AWE Hydrus Hydrodynamic Vessels</td>
<td>Nov 2011</td>
</tr>
</tbody>
</table>

RWMD Response:

The approach adopted in scoping work to date has been to keep the operations and scheduling of waste arriving at the facility as simple as possible. The resulting avoidance of an emplacement strategy, which would determine where a package was placed within the facility, has so far proved to be a valid approach. However, as more diverse waste forms and packaging solutions are emerging through the work of the NDA, it is recognised that this approach merits reconsideration and is part of our future work programme. Optimisation is a regulatory requirement applicable to all aspects of the design and operation of the facility. The emplacement strategy is an area where there would be a requirement to demonstrate that the proposed strategy is optimal. It is not considered appropriate to carry out such an optimisation at this stage of the development work

however we are considering issues such as making best use of space, chemical compatibility and heat output of different types of wastes and co-location as part of our ongoing work programme.

B.4.1.6 R&D on repackaging

Raised issues:

| ID: 416-01 | R&D into remedial action on failed or out of specification packages should be addressed as a priority. | CoRWM doc 2543 Report on R&D for interim storage and geological disposal... A:12, 101 | October 2009 |

RWMD Response:
The starting point for a geological disposal facility is that waste will be packaged in accordance with the waste acceptance criteria issued by the facility operator. It will be the responsibility of the waste producer to ensure that the acceptance criteria have been met in line with the necessary approvals for consigning the waste. In order to inform the development of the waste acceptance criteria there is continual dialogue between NDA RWMD and the NDA and site licence companies though the Letter of Compliance (LoC) process [1]. This process is overseen by the regulators. This issue is recognised by NDA and research on reworking and dealing with out of specification packages is being carried out within the NDA Direct Research Portfolio.

B.4.1.7 Transport system

Raised issues:

| ID: 417-01 | Requirement needed to specify needs of transport system (e.g. Establish a dedicated transport entity to manage all interactions with consignors, carriers, consignees and regulators and take measures (e.g. external review) to ensure that it remains state-of-the-art). | Peer Review Disposal System Functional Specification | DSSC peer review 2010 |
| ID: 417-02 | Need to be clear who is the Design Authority for transport system. | Peer Review Disposal System | DSSC peer |

Development of an integrated transport strategy could be specified as a functional goal.

**RWMD Response:**

We have developed a generic transport system design and concepts for both road and rail vehicles [1]. In addition we have developed a range of transport containers, in accordance with the IAEA Transport Regulations [2] that could be used to transport the waste packages to a geological disposal facility. At this stage of development we are concentrating efforts on the requirements of an integrated transport system to ensure that the appropriate system can be specified. This specification will link into the NDA overall transport strategy [3]. Accountability as Design Authority for Transport resides with the RWMD Engineering Director, and responsibility is vested in the Head of Design and design team, to act as Intelligent Client for design services. As Design Authority for the transport system design, RWMD works closely with other areas of the NDA in discharging these duties.

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B.5 Stakeholder engagement

B.5.1 Consultations, stakeholder engagement and communications

B.5.1.1 Documentation and stakeholder engagement material

Raised issues:

| ID: 511-01 | RWMD recognises that it needs to produce a shorter and more accessible document on planning for geological disposal, for use in discussions with potential host communities, other stakeholders and the public. | CoRWM Doc. 2550. Geological disposal of higher activity radioactive wastes. July 2009 12.12. p42 | July 2009 |

RWMD Response:

We believe that we have improved the amount of short and easily accessible documentation that exists on the planning for geological disposal. This includes the publication of the Steps Towards Implementation report [1], a 5 page leaflet summarising the detailed document and an animation about geological disposal. We have also published leaflets on the Disposal System Safety Case (DSSC) [2] and our work on the manpower and skills required to implement a geological disposal facility (GDF) [3]. We will continue to produce leaflets in the future and make these available. Together with planned improvements to our website and the production of other interactive communication material, such as videos, animations and better illustrations, we continue work to improve our overall approach to communicating the work that we do and our plans for future work. Our approach to communicating about our work is outlined in our Public and Stakeholder Engagement and Communications Strategy which sets out the types of documents we produce with different levels of detail and language [4]. We seek feedback from stakeholders on our publications through both formal reviews and informal discussions. This feedback is then fed into the development of future materials.

B.5.1.2 Assurance of contractors’ reports

Raised issues:

| ID: 512-01 | Ownership of documents - The level of ownership and review of Contractors’ documents needs to be made clear. | Peer Review Generic Environmental Assessment and Sustainability Report | DSSC peer review 2010 |

ID: 512-02

Issue about the validity of science taken from contractor reports, which “includes no references to papers in scientific journals”.

Helen Wallace (for Greenpeace International) Rock Solid Sec 1

Sept 2010

RWMD Response:

Operating a policy of openness and transparency results in the publication of a variety of documents, including contractor reports to RWMD. These are reports prepared by contractors as the result of the work we have commissioned, including scientific reviews that draw heavily on the available information from scientific and technical journal publications. These reports are published under the contractors’ covers and although they are reviewed by NDA, the views expressed and conclusions drawn are those of the authors and do not necessarily represent those of NDA. We use such reports to supplement information needs and knowledge gaps in the wider scientific and technical understanding of particular aspects of geological disposal in support of drafting our own reports. We are revising our processes to make sure that the ownership of documents is clearer. Our own reports (RWMD reports) are generally prepared by our staff and fully reflect the NDA’s position. We refer to these collectively as our technical baseline which is described fully in our technical strategy [1]. The technical strategy also describes how we work in partnership with contractors to implement geological disposal and how we ensure quality management of contractors’ reports to NDA through review procedures. Where appropriate, independent peer review is used to provide confidence in the scientific and technical quality of deliverables (both for contractor reports and RWMD reports). We will continue to assure the quality of technical work in our programme and ensure it continues to be given a high priority. We will continue to build on the international scientific evidence base and include references to relevant material in our reports. We will also continue to publish the research we undertake at conferences and peer reviewed journals.

B.6 Disposal system specification and derived inventory

B.6.1 Derived Inventory

B.6.1.1 Derived inventory data gaps, uncertainties, and priorities

Raised issues:

| ID: 611-01 | An analysis of relevant radionuclides and levels of significance should be undertaken for the Reference high level waste/spent fuel Concept. The list of 112 Relevant Radionuclides was developed from a consideration of the safety of disposing of ILW and LLW. There is a need to undertake a similar analysis covering the disposal of HLW, spent fuel and other nuclear wastes. | Disposability Assessment Database ID59 high level waste (Preliminary Assessment) | April 2009 |

| ID: 611-02 | Undertake a toxicity screening assessment for the high level waste/spent fuel disposal concept to identify any chemotoxic species that might be present in significant quantities. | Disposability Assessment Database ID61 high level waste (Preliminary Assessment) | April 2009 |
| ID: 611-03 | CoRWM...requested that the NDA.....produces a ‘Future Scenarios’ document that provides an overview of what wastes might be placed into a GDF over time. *This issue relates to a number of recommendations for future work with respect to the UK Inventory.* | CoRWM Doc. 2550. Geological disposal of higher activity radioactive wastes. July 2009 11.10 p37 | July 2009 |
| ID: 611-04 | Review Plutonium/Uranium Derived Inventory assumptions with respect to \( \text{PuO}_2 \), \( \text{UO}_2 \) and \( \text{U}_3\text{O}_8 \) densities. *A density of 8.3 t m\(^{-3}\) has been assumed for both uranium oxides in the Derived Inventory calculations, but \( \text{UO}_2 \) has a greater density (closer to 11 t m\(^{-3}\)). The assumption is stated clearly in the project report, but there will be an opportunity in the future to use a more appropriate one.* | Peer Review Derived Inventory for Plutonium and Uranium | June 2010 |
| ID: 611-05 | Review approach to rounding when calculating the Derived Inventory to ensure consistent and justified rounding throughout multi-step calculations. | Peer Review Derived Inventory reports | June 2010 |
| ID: 611-06 | Correct displacement volumes of Waste Vitrification Plant canisters. *It is recognised that attempting to define geometries for every single stream would be unduly time-consuming. However, a reasonable approach would be to scale the results to take account of the whole masses of materials, by assuming that the average effective plate thicknesses, sphere radii and ratio plate/sphere determined for the majority are indicative of the whole.* | Peer Review Derived Inventory for high level waste/spent fuel | June 2010 |
| ID: 611-07 | Re-examine method for defining geometries for waste streams. *It is recognised that attempting to define geometries for every single stream would be unduly time- | Peer Review Derived Inventory for intermediate and low-level waste | June 2010 |
| ID: 611-08 | Review method of calculating Plutonium from reprocessing spent fuel.  
An implicit assumption used is that the Pu loading (tPu/tU) in spent PWR fuel is the same as in AGR fuel. In practise the Pu loading depends upon the reactor type and burnup and a more refined treatment is needed in future. | Peer Review Derived Inventory for Plutonium and Uranium | June 2010 |
| ID: 611-09 | Review of the use of Plutonium isotopes in Magnox fuel.  
The report states that spent Magnox fuel is assumed to contain no Pu-238, and that plutonium from defence programmes contains no Pu-238 or Pu-242. This approximation is unnecessary as Magnox fuel inventory data including these isotopes are available. Future Derived Inventories should correct this omission. | Peer Review Derived Inventory reports | June 2010 |
| ID: 611-10 | Review methodology for prioritisation of non-radiological hazards.  
Only materials and radionuclides are listed for the process for data enhancement in the Derived Inventory. RWMD should include non-radiological species in the Derived Inventory. Tables 2.1 and 2.2 of the Summary Report are unclear: the materials scheme is based on 5 levels and the radionuclide scheme is based on 3 levels. | Peer Review Derived Inventory reports | June 2010 |
| ID: 611-11 | Review of methodology regarding the consideration of concentrations of priority elements in Magnox alloy and uranium oxide.  
The report makes no attempt to scale Magnox alloy compositions to Mg mass in Mg(OH)$_2$ or U metal fuel | Peer Review Derived Inventory for intermediate and low-level waste | June 2010 |
| ID: 611-12 | Confirm that complexants such as ethylenediaminetetraacetic acid won't be present in significant quantities. | Peer Review Derived Inventory reports | June 2010 |
| ID: 611-13 | The presence of plasticisers within Polyvinyl chloride has not been considered in the Derived Inventory. | Peer Review Derived Inventory reports | June 2010 |
| ID: 611-14 | Evaluate the methodology for Thorium concentrations in steel (as precursor to U233). | Peer Review Derived Inventory for intermediate and low-level waste | June 2010 |
| ID: 611-15 | Methodology regarding material compositions requires review. Some materials have not been assigned a composition, and it is apparent that these have then not been carried forward to the estimate of total waste material composition. The most obvious example (and the one which allowed us to identify the uncertainty) is thorium; waste stream 5G23 contains more than 10 t thorium metal, yet Table 6.3 of the project report declares only 1.35 t Th in all waste materials. | Peer Review Derived Inventory for intermediate and low-level waste | June 2010 |
| ID: 611-16 | Review approach for accounting for trace quantities of other elements in steels and alloys for Derived Inventory calculations. There has been no attempt to account for trace quantities of other elements in the wastes. This might be an area for further work, with a focus on priority species (including residual fluorides in deconverted depleted uranium (DU) tails), the large-volume materials (i.e. DU), and the plutonium residues currently at Sellafield (they are know to be more heavily contaminated). | Peer Review Derived Inventory for intermediate and low-level waste | June 2010 |
| ID: 611-17 | Review approach for accounting for trace quantities of other elements in wastes for Derived Inventory calculations. | Peer Review Derived Inventory for intermediate and | June 2010 |
| ID: 611-18 | Review approach regarding the use of pre- or post-irradiation masses when calculating the Derived Inventory. | Peer Review Derived Inventory for intermediate and low-level waste | June 2010 |
| ID: 611-19 | Review assumptions regarding the mass of stainless steel associated with AGR fuel. | Peer Review Derived Inventory reports | June 2010 |
| ID: 611-20 | Review conditioning material assumptions for Derived Inventory (including grout, pulverised fuel ash compositions etc). | Peer Review Derived Inventory for Plutonium and Uranium | June 2010 |
| ID: 611-21 | Review the assignment of priorities to waste materials in theDerived Inventory. | Peer Review Derived Inventory reports | June 2010 |
| ID: 611-22 | Review the methodology concerning the use of Decontamination Factors to carry impurities forward into Uranium and Plutonium in Derived Inventory. | Peer Review Derived Inventory for high level waste/spent fuel | June 2010 |
| ID: 611-23 | Revise assignment of 'other ferrous metals' in stream 2F22/C. | Peer Review Derived Inventory reports | June 2010 |
| ID: 611-24 | Revisit methodology for the use of best estimates and/or upper/lower uncertainties for composition calculations in Derived Inventory. | Peer Review Derived Inventory for intermediate and low-level waste | June 2010 |
| ID: 611-25 | Some Derived Inventory calculations have only provided best estimates rather than upper and lower uncertainties. | Peer Review Derived Inventory for Plutonium and Uranium | June 2010 |
| ID: 611-26 | Possible selection of ‘most significant radionuclides incorrect. | Nuclear Waste Advisory Associates’ Issues Register Issue - 4 | June 2010 |
Lack of a clearly defined inventory of radioactive wastes, as a result of uncertainty about the quantities of additional waste that will be produced in new reactors, increasing radioactivity of waste due to the use of higher burn-up fuels, and ambiguous definitions of what is considered as waste.

ID: 611-28

Hele
n Wallace
(for Greenpeace International)
Rock Solid Exec summary
September 2010

List of significant radionuclides and associated guidance quantities need to be updated for intermediate level waste, and generated for high level waste, spent fuel irradiated in thermal reactors, and spent fuel irradiated in fast reactors.

ID: 611-29

February 2011

Make and document a decision about application in high level waste and spent fuel (irradiated in both thermal and fast breeder reactors) assessments of 112 radionuclides that were identified as ‘significant’ for intermediate level waste wastes and concepts.

ID: 611-30

February 2011

RWMD Response:

These issues concern potential discrepancies, uncertainties, and gaps in data for the production of our Derived Inventory. Production of the United Kingdom Radioactive Waste Inventory (UKRWI) has been subject to a process of continuous improvement since its inception in the 1980s. Minor refinements frequently occur as waste is packaged since, at such times, additional waste characterisation takes place. The UKRWI undergoes review and enhancement to develop the Derived Inventory on which our designs and safety assessments are based [1]. The Environment Agency has reviewed the process for generation of the UKRWI and the means by which it is converted to a Derived Inventory [2]. The 2010 peer review of the Derived Inventory has also identified a number of areas underlying the production of the Derived Inventory that could be improved (issues 611-04 to ID: 611-25). Based on our evaluation of these they would not significantly change the Derived Inventory, but would improve the accuracy and/or clarity. Therefore, while we will consider and address comments as necessary on our assumptions and data when updating the Derived Inventory estimates, we believe that the Derived Inventory is fit, and will continue to be fit, for our purposes.

Our long-standing and robust process for identifying significant radionuclides for safety of a geological disposal facility involves assessment on a waste stream by waste stream basis of all radionuclides that might contribute to any radiological impacts resulting from...
transport, operations, and disposals [3]. While the current list of 112 relevant radionuclides was developed on the basis of the geological disposal of (intermediate level waste (ILW) and low level waste (LLW) [4], radionuclides that would be expected to be present in wastes arising from the reprocessing of uranium and uranium oxide fuels irradiated in thermal reactors were included. Based on our experience and our knowledge of radionuclides considered in other programmes overseas, we consider that the list is valid for other categories of higher activity radioactive waste, given that the integrity of packaging to be used for (high level waste) HLW and spent fuel is higher than used for ILW. We recognise that the list must be periodically reviewed and updated. It is planned that the next such review (in 2012) will consider HLW, spent fuel and other radioactive materials and will also be based upon the safety assessments undertaken as part of the generic Disposal System Safety Case (DSSC) [5] (issues 611-01, 611-29, and 611-30).

Regarding the prioritisation of non-radioactive materials data (issue 611-02), the process used to update the Derived Inventory begins with a user requirement survey in which RWMD safety assessors and other RWMD inventory users are asked to rank the importance of materials data. This ensures that any new material issues arising either from the research programme or packaging assessments are captured before a new Derived Inventory is developed (hence addressing issues such as issue 611-02).

The radionuclide content of wastes and spent fuel from “new build” is identifiable from existing information and computer programs and we have demonstrated that we can develop inventory estimates for new build wastes in our disposability assessments [6,7] conducted as our input to the regulatory Generic Design Assessment (GDA) process (issues 611-26, and 611-27). Spent nuclear fuel from new build reactor designs is included in the estimate of the upper inventory [8] and has been taken into account in our work on the design and safety assessment of a geological disposal facility [9].

B.6.1.2 Derived Inventory methodology

Raised issues:


[8] We have developed an Upper Inventory to give an indication of the quantities that might need disposal as described in the summary report. We want to be able to demonstrate that a geological disposal facility can be developed to deal with this inventory safely and securely in addition to being confident that the same will be true for a lesser inventory [1].

[9] Note that any scope of work undertaken within the NDA RWMD programme that is of relevance to new build fuel is generic and is undertaken within the wider envelope of conditions of relevance to the full range of wastes in the upper inventory as described in the generic Disposal System Specification (NDA/RWMD/044, 2010). This therefore excludes work that is specific to proprietary new build fuel designs. The Government has stated as policy that operators of new nuclear power stations will be obliged to meet their full share of waste management costs (White Paper on Nuclear Power, Meeting the Energy Challenge, Department for Business, Enterprise & Regulatory Reform, Section 3.70, 2008).
| ID: 612-01 | Inventory of spontaneously fissioning isotopes will therefore be important... There are uncertainties in the likely inventories of heavy actinides because the physical data for their formation are not well known. | CoRWM doc 2543 Report on R&D for interim storage and geological disposal... A.69, 117 | October 2009 |
| ID: 612-04 | Problems with lack of information concerning the chemical context of radionuclides. | Nuclear Waste Advisory Associates' Issues Register Issue - 3 | June 10 |
| ID: 612-05 | Review approach to variability in the high level waste/spent fuel Derived Inventory. | Peer Review Derived Inventory for high level waste/spent fuel | June 2010 |
| ID: 612-06 | Review methodology regarding the use of H-3 and C-14 data for plutonium contaminated material (PCM) waste in Derived Inventory. Within Section 8.3 and elsewhere, there is reference to an absence of H-3 and C-14 specific activity data for Sellafield PCM streams. Given the nature of the waste and associated activity, Nuclear Technologies would not expect there to be an appreciable quantity of H-3 or C-14 in PCM, and consider that this statement should be removed. It might be useful to consult historical documents relating to data recording plans for PCM, or to use the fission product activities reported in the 2007 Inventory together with a generic fingerprint for Magnox fuel to attempt to confirm that the H-3 and C-14 activities are below data recording thresholds. | Peer Review Derived Inventory for intermediate and low-level waste | June 2010 |
| ID: 612-07 | Capture in the Derived Inventory the arisal of Plutonium in a form other than oxide as a result of known events at Sellafield. *Plutonium/uranium in oxide or metal forms is identified as a priority material because it is fissile. This omission of other forms of Pu/U implies that other forms of Pu/U are not fissile. Hence re-wording of the description of the fissile priority item is needed.* | Peer Review Derived Inventory for intermediate and low-level waste | June 2010 |
| ID: 612-08 | Identify whether there are any major sources of Chlorine in wastes. | Peer Review Derived Inventory for intermediate and low-level waste | June 2010 |
| ID: 612-09 | Clarification of reasons for prioritisation of tritium is required. | Peer Review Derived Inventory for intermediate and low-level waste | June 2010 |
| ID: 612-10 | Clarification of reasons for prioritisation of radon is required. | Peer Review Derived Inventory for intermediate and low-level waste | June 2010 |
| ID: 612-11 | Consideration should be given to presentation of information within the Derived Inventory reports. | Peer Review Derived Inventory for intermediate and low-level waste | June 2010 |
| ID: 612-12 | Revise heat output limit for 500 l drum in Derived Inventory reports. | Peer Review Derived Inventory for intermediate and low-level waste | June 2010 |
| ID: 612-13 | Review of approach regarding the use of corrosion factors is required. | Peer Review Derived Inventory for intermediate and low-level waste | June 2010 |
| ID: 612-14 | Review of methodology with regards to infilling/lidding of Windscale Advanced Gas-cooled Reactor boxes with iron-shot concrete. | Peer Review Derived Inventory for intermediate and low-level waste | June 2010 |
| ID: 612-15 | Review methodology with regards to accounting for Windscale graphite in | Peer Review Derived Inventory for intermediate | June 2010 |
| ID: 612-16 | Confirm Derived Inventory is consistent with regards to disposal route of certain waste streams. | Peer Review Derived Inventory for intermediate and low-level waste | June 2010 |
| ID: 612-17 | Review packaging assumptions for specific waste streams as identified in 2007 Derived Inventory. | Peer Review Derived Inventory for intermediate and low-level waste | June 2010 |
| ID: 612-18 | Review assumption regarding intermediate level waste retrieved from Low Level Waste Repository (LLWR) trenches in Derived Inventory.  
*The assumption that may need more justification is that a packaged volume of 100,000 m$^3$ wastes recovered from early LLWR trenches may be routed to a GDF because of high U and Th concentrations. The value of 100,000 m$^3$ appears to be completely arbitrary at present. It is a very large volume of waste, so more justification and discussion would be useful. We also note that there may be difficulties with packaging these wastes in 4m boxes if they have a high alpha inventory, but the assumption of 4m boxes is probably reasonable at present.* | Peer Review Derived Inventory for intermediate and low-level waste | June 2010 |
| ID: 612-19 | Consideration of data for use in the Derived Inventory from sources suggested by peer reviewers. | Peer Review Derived Inventory for intermediate and low-level waste | June 2010 |
| ID: 612-20 | Clarify the nature of certain resins within the Derived Inventory. | Peer Review Derived Inventory for intermediate and low-level waste | June 2010 |
| ID: 612-21 | Review assumptions regarding conservation of C-14 during vitrification. | Peer Review Derived Inventory for high level waste/spent fuel | June 2010 |
| ID: 612-22 | How will uncertainty in the inventory be dealt with in light of the evolving Scottish Government | Peer Review Disposal System Safety Case | DSSC peer review |
policy?

| ID: 612-23 | In the DSSC documents there is a significant over precision of data that implies a level of accuracy and certainty. | Peer Review Disposal System Technical Specification | DSSC peer review 2010 |
| ID: 612-24 | Develop DIQuest to include dose rate calculations for packages inside the SWTC-150 in the N&Q summary report. | Disposability Assessment Database75 AWE Hydrus Hydrodynamic Vessels | November 2010 |
| ID: 612-25 | Detailed dose rate modelling is required for Irradiated Fuel Containers (IFCs) in copper canisters, to support dose rate calculations in Derived InventoryQuest for these packages. | Disposability Assessment Database65 PFR Irradiated Carbide Fuel (Conceptual) | February 2011 |

**RWMD Response:**

These issues concern our methodology for production of the Derived Inventory used for the geological disposal design and safety assessment programme. Production of the United Kingdom Radioactive Waste Inventory (UKRWI) has been undertaken since the 1980s [1]. Production includes several steps providing a rigorous review of the data with the intent of progressively improving the quality of the reported data. Before use within RWMD safety and environmental assessments, inventory data are further reviewed and enhanced to:

- Challenge apparent inconsistencies;
- Improve quality by filling gaps;
- Calculate effects of radioactive decay and build-up into the future; and
- Introduce packaging assumptions and provide “per package” inventories.

We publish this revised data set as the Derived Inventory [2], and we consider this inventory as fit for purpose. The Environment Agency has reviewed the process for generation of the UKRWI and our methodology by which we develop a Derived Inventory from the UKRWI [3].

Production of the UKRWI has been subject to a process of continuous improvement since its inception. Refinements frequently occur as waste is packaged and additional waste characterisation takes place. This new information is then fed back into the next UKRWI and, subsequently, our Derived Inventory. In this way, data and assumptions are improved and the issues raised on the inventory and the methodology for its production are reviewed and addressed. The 2010 peer review of the Derived Inventory identified a number of issues with the methodology for its production (issues 612-05 to 612-21). Those issues raised in the review that could not be addressed immediately have been considered in planning of future work. Methodologies are also being further developed to improve


feedback from waste producers and the Letter of Compliance disposability assessment process to the UKRWI and the Derived Inventory.

As part of our procedures we take account of the uncertainties in the inventory in our design and assessment work (issues 612-01, 612-02, 612-03, 612-23). We also consider mean and maximum possible contents of individual waste packages when carrying out Letter of Compliance waste disposability assessments [4]. Where uncertainties are identified that are significant to the safety case, we or the waste consignors commission appropriate research (e.g. work on Chlorine-36 [5]).

The higher activity radioactive wastes to be managed in the long-term through geological disposal may not include those that are managed under the Scottish Government’s policy for higher-activity waste. However, in order for the design studies and assessments to accommodate potential waste volume variations, it is currently planned that these wastes remain in the Baseline Inventory for the generic disposal system documents (issue 612-22).

It is important to identify the different chemical species present within wastes and understand the impact these species may have on the transport and environmental safety cases for geological disposal of higher activity radioactive wastes (issue 612-04). Information on the chemical form of wastes is one of the many inputs provided by the waste owners to the UKRWI. As noted above the veracity of this information is checked and improved through a number of review stages prior to the data being used for design and safety assessment purposes. Of key significance is the assessment conducted as part of the Letter of Compliance disposability assessment process [4]. The assessment is generally developed in an iterative fashion with opportunities for RWMD to request additional information and/or research to strengthen the case where this is found to be necessary. We consider that we have an adequate understanding of waste streams that represent potential sources of significant amounts of materials that could cause adverse chemical conditions for radionuclide containment and we use our processes to specifically request information on materials that are known to be problematic in this sense.

As part of work planned to continue to improve the Derived Inventory, we aim to obtain methodology reports from waste producers to explain how UKRWI submissions were generated for key waste streams so that this can be documented in the Derived Inventory. Similarly, DIQuest, the software tool used to provide radioactive decay and dose rate calculation functions for the Derived Inventory, will require updating at times to accommodate new types of waste and transport package configuration. Such updating will be scheduled to accommodate the important changes to packaging and transport arrangements between Derived Inventory updates (issues 612-24 and 612-25).

B.6.2 Disposal system specification

B.6.2.1 Disposal system requirements structure

Raised issues:

<table>
<thead>
<tr>
<th>ID: 621-01</th>
<th>Requirements need to be further developed to be applicable to</th>
<th>Peer Review Disposal System</th>
<th>DSSC peer</th>
</tr>
</thead>
</table>


| ID: 621-02 | Further develop the buffer and backfill requirements. | Peer Review Disposal System Technical Specification | DSSC peer review 2010 |
| ID: 621-03 | Identify areas of the disposal system specification to develop text specific to each concept example. | Peer Review Disposal System Technical Specification | DSSC peer review 2010 |
| ID: 621-06 | RWMD should consider adding paragraph numbers or unique identifiers for each requirement. | Peer Review Disposal System Functional Specification | DSSC peer review 2010 |
| ID: 621-07 | Depth of repository: 200 m is questioned to be too shallow: In Sweden the minimum depth is set to 400 m in order to avoid free oxygen in the ground water. | Geological Disposal: Outline design report - Higher strength rock 16.2, page 67 | DSSC peer review 2010 (DSSC44) |
| ID: 621-08 | Disposal System Specification should specify the functions of the disposal system. | Peer Review Environment Agency review of DSS | DSSC peer review 2010 |
| ID: 621-09 | 'MgO' - Apart from the fact that this is used in Waste Isolation Pilot Plant, I see no clear justification for taking this over to the UK case. If it is important, why not include MgO in the high level waste/spent fuel backfill (which has vastly more | Peer Review Outline Design Report - Evaporite Sec 3.8 | DSSC peer review 2010 |
Peer Review assumes that for high level waste repository the minimum depth is 400m and the maximum depth is 900m. This is based on considerations of erosion and decompaction (for the minimum depth) and stress conditions/engineering measures (for the maximum depth).

**RWMD Response:**

The generic Disposal System Specification (DSS) [1,2] aims to provide a comprehensive account of the laws and regulations, the inventory, and other top-level requirements for a geological disposal facility in the UK. We consider the DSS to be appropriate for the generic phase of the programme. In order to support further development of the DSS leading to the site-specific phase of the programme, we are performing a scoping study in 2012 to consider how the requirements on a geological disposal facility for the different categories of higher activity wastes could be set out in a hierarchy showing the relationships and logic of how the requirements are derived and linked together (as suggested by the DSS peer review, see issues 621-04, 621-05 and 621-06). The hierarchy should also distinguish the anticipated disposal system functions and help identify the requirements that will be interpreted differently for the three generic geological settings (issues 621-03 and 621-08). This study is part of our on-going work programme, as set out in our technical strategy [3].

We are also planning to develop and operate a Requirements Management System (RMS) to support ongoing specification and design development and assist coordination of cross-departmental engagement as part of an iterative process for disposal system development. The RMS will be a management tool that will effectively translate the disposal requirements into a format that can be responded to by the design teams. The RMS, when fully developed, will allow each element of the design to be traced to its driving requirement and provide a traceable demonstration that the design solutions as a whole meet the requirements of the DSS [4].

Ultimately, the DSS will present site-specific requirements for a geological disposal system in a hierarchical structure to the concept level. However, site selection is ongoing, the disposal concepts for the different waste groups have not yet been decided, and concept-level requirements are, therefore, mostly only provided as examples (i.e. planning assumptions). The examples are based largely on our work developing illustrative disposal concepts for generic geological settings. This work drew on experience in the UK and disposal programmes in other countries, effectively providing us with a range of concepts.

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for consideration [5,6]. In this situation, the examples in the DSS (e.g. use of magnesium oxide as backfill) are not specified as required but are part of the illustrative disposal concept we have used at the generic stage. It is currently envisaged that we will next develop the DSS to draw out requirements that are specific to different host-rock environments and are applicable to test a range of concepts for that environment. Requirements in the DSS, including those on issues such as depth, the safety functions of disposal system components, and requirements on the engineered barrier system (including buffer and backfill), will be progressively developed to support our concept selection and design processes (hence addressing issues 621-01, 621-02, 621-07, 621-09 and 621-10).

### B.6.2.2 Disposal system requirements specification

#### Raised issues:

| ID: 622-01 | Further work is needed to clarify how a GDF would be licenced to meet the requirements of Government policy on MRWS and to clarify the effect of the Nuclear Site Licence and associated regulatory requirements on provisions for waste retrievability. The peer review panel considers that future DSSC reports should discuss more fully the influences of host rock type and disposal concept on the ease of waste retrievability. | TerraSalus 2.2 TerraSalus Peer Review Summary report | January 2010 |
| ID: 622-02 | Consider the issues associated with macro-voidage in the unshielded intermediate level waste vaults. In particular, identify a possible upper-limit for voidage in order that the significance of particular packaging proposals can be assessed. For example, this might be an upper limit on voidage per cubic metre of packaged waste. | Disposability Assessment Database ID41 AWE Legacy Hydrodynamic Vessels | February 2010 |
| ID: 622-03 | Provide a quantitative analysis of how much voidage is acceptable within a vault / package for post-closure. | Disposability Assessment Database ID52 Use of Ductile Cast Iron Containers for Disposal of intermediate level | May 2010 |

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<p>| ID: 622-04 | The RWMD Design Principles should be listed in the disposal system specification. | Peer Review Disposal System Technical Specification | DSSC peer review 2010 |
| ID: 622-05 | Transport regulations as applicable to the waste, the construction materials and personnel should be addressed separately. | Peer Review Disposal System Technical Specification | DSSC peer review 2010 |
| ID: 622-06 | Consider the potential implications of parallel GDF construction and operational activities. | Peer Review Disposal System Technical Specification | DSSC peer review 2010 |
| ID: 622-07 | Develop the justification for the communications requirement. | Peer Review Disposal System Technical Specification | DSSC peer review 2010 |
| ID: 622-08 | Develop the text within the Disposal System Technical Specification with respect to the physical supports. | Peer Review Disposal System Technical Specification | DSSC peer review 2010 |
| ID: 622-10 | Consider the throughput requirements. | Peer Review Disposal System Technical Specification | DSSC peer review 2010 |
| ID: 622-11 | Develop a comprehensive list of requirements related to services. | Peer Review Disposal System Technical Specification | DSSC peer review 2010 |
| ID: 622-12 | Consider how we might specify what “preferential flow paths” are.Peer review comments considered the current treatment too simple. Future updates to the DSTS should consider the wider aspects of influence of the repository structures on geosphere physical behaviour, hydrogeological and solute transport. | Peer Review Disposal System Technical Specification | DSSC peer review 2010 |
| ID: 622-13 | Develop our thinking with respect to institutional control and the transfer | Peer Review Disposal System | DSSC peer review 2010 |
| ID: 622-14 | Consider the potential for out of spec components throughout disposal system and how we might seek to manage these. | Peer Review Disposal System Technical Specification | DSSC peer review 2010 |
| ID: 622-16 | How do we ensure containers are intact going into the post closure period? | Peer Review Disposal System Technical Specification | DSSC peer review 2010 |
| ID: 622-17 | Further develop the effluents section of the disposal system specification and consider how we would address effluent management at a GDF. | Peer Review Disposal System Technical Specification | DSSC peer review 2010 |
| ID: 622-18 | Air transport requirements to be considered and the specification in this area should be further developed. | Peer Review Disposal System Technical Specification | DSSC peer review 2010 |
| ID: 622-19 | Consider the requirements for temporary and permanent transport infrastructure. | Peer Review Disposal System Technical Specification | DSSC peer review 2010 |
| ID: 622-20 | Requirement needed to specify needs of transport system (e.g. establish a dedicated transport entity to manage all interactions with consignors, carriers, consignees and regulators and take measures (e.g. external review) to ensure that it remains state-of-the art). | Peer Review Disposal System Functional Specification | DSSC peer review 2010 |
| ID: 622-21 | Some more explicit information should be given to indicate the restrictions a GDF will put on land use etc. Are there any special comments to be made on coastal sites? | Peer Review Disposal System Functional Specification | DSSC peer review 2010 |
| ID: 622-22 | Development of an integrated transport strategy could be specified as a functional goal. |
| ID: 622-23 | The following requirements need to be developed and better defined in going forward Section 2.8 “The disposal system shall be designed with due regard to environmental implications, and to social and economic factors”. Section 5.3 “A geological disposal facility shall be commissioned by means of functional tests on all facilities”. What functional tests? This is supposed to be the functional specification. Section 5.4 “A geological disposal facility shall be operated in a manner that provides protection to workers, members of the public and the environment”. Section 5.4 “Arrangements shall be made for the preservation of details of a geological disposal facility”. It is, for example, inconceivable that a facility would be designed in such a way that does not protect workers. These statements need to help define what function is required. |
| ID: 622-24 | Should there be a design requirement relating to operational considerations (e.g. in the event that an accident or fire closes a drift/access route operations would be halted for a few years)? Should such a possibility be ‘designed out’? |
| ID: 622-25 | One part of the Waste Isolation Pilot Plant monitoring program is for worker protection. Waste Isolation Pilot Plant includes TLD, continuous air monitors and portal monitoring as examples of worker protection monitoring. This may be considered in the GDF program as a different project element. |
| ID: 622-26 | Delete requirements on monitoring – this should come in the DSFS: this report should consider particular aspects of implementation in a salt environment'. |</p>
<table>
<thead>
<tr>
<th>ID: 622-27</th>
<th><strong>Text on monitoring regime</strong> – should be specific to hard rock.</th>
<th>Peer Review Geological Design Report - Higher Strength Sec 13</th>
<th>DSSC peer review 2010</th>
</tr>
</thead>
</table>
| ID: 622-28 | Combined ODR and GDF to discuss monitoring at a general level as a site specific monitoring regime has not yet been agreed.  
Following peer review, the original draft detailed design report (ODR) was combined with the high-level GDF design report to produce the DSSC design report. This issue notes that specific requirements for monitoring arising from the host geological environment require consideration, while recognising that such details are site/geology specific and therefore would be undertaken as site specific designs are developed. | Peer Review Geological Design Report - Lower Strength Sec 13 | DSSC peer review 2010 |
| ID: 622-29 | 'as appropriate' - Maybe needs to be over-designed to ensure that the risk of flooding is negligible.  
- *Should a GDF be developed in an evaporate host rock*, this issue concerns design of hydrostatic lining in surface to underground connections (e.g. shaft). | Peer Review Peer Review Outline Design Report - Evaporite Sec 9.1 | DSSC peer review 2010 |
| ID: 622-30 | The inlet cell of the unshielded intermediate level waste vaults should be capable of receiving packages up to 1,850mm in plan.  
This issue is to ensure that the inlet cell is sufficiently sized to allow for receipt of the larger waste packages, such as the boxes currently used at Sellafield for mixed beta gamma waste, and eliminate the risk of orphan packages. | Disposability Assessment Database73 AWE Hydrus Hydrodynamic Vessels | November 2010 |

**RWMD Response:**

We have developed a Disposal System Specification (DSS) to provide a clear definition of the requirements on the disposal system for higher-activity waste disposal [1,2]. The DSS

forms an important input to the development of engineering designs for a geological disposal facility (GDF) and the assessment of fitness for purpose. The DSS is currently generic, but in the future it will be used to develop a site-specific DSS when one or more sites are identified. Hence, some aspects of the DSS are yet to be developed fully. The issues under this topic concern suggested improvements or further developments of the specification of requirements either in, or potentially to be included in, the DSS. Many of the issues have been raised in the peer review of the development of the generic DSS in 2010 (issues 622-04 to 622-23). Those issues raised in the review that could not be addressed immediately are included in our issues register and have been considered in planning of future work.

We are continually working to further develop the DSS in order to ensure that the requirements and constraints are refined in light of the results from ongoing programmes of work, including design development, assessments and R&D, consideration of security and safeguards issues, cost analyses, and public and stakeholder engagement [3]. Our R&D programme includes studies required to support the filling of knowledge gaps that will also support the further development of requirements in the DSS. This currently includes research on issues such as:

- Monitoring [4,5] (e.g. issues 622-09, 622-25, 622-26, 622-27, 622-28);
- Geological stability [4] (issue 622-15);
- Failure of waste containers [4] (issue 622-16);
- Engineering design development (e.g. issues 622-24, 622-29, 622-30);
- Retrievability [4] (issue 622-01); and
- Voidage (issues 622-02, 622-03).

### B.6.2.3 Management of thermal impacts

**Raised issues:**

| ID: 623-01 | Investigate the temperature dependence of the bentonite buffer in the high level waste/spent fuel disposal system as part of the onward R&D programme for the high level waste/spent fuel disposal system. | Disposability Assessment Database ID55 high level waste (Preliminary Assessment) | April 2009 |
| ID: 623-02 | "as waste temperature is....' - Why are some scoping calculations not carried out? The reference waste | Peer Review Outline Design Report - | DSSC peer review |


Properties are defined and it is not difficult to get thermal properties of engineered barrier materials. Properties should also be defined for the reference geology. This would allow sensitivity of temperature to disposal tunnel spacing — and also waste emplacement pitch — to be determined.

<table>
<thead>
<tr>
<th>ID: 623-03</th>
<th>Establish whether the 100°C temperature limit continues to be appropriate for the disposal system and develop the justification.</th>
<th>Peer Review Disposal System Technical Specification</th>
<th>DSSC peer review 2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>ID: 623-04</td>
<td>The heat from the high-level waste in the repository will heat up the buffer/backfill and the surrounding rock of the different repository tunnels over a period of several decades as they are successively filled with the waste. The different components in a repository all have different expansion coefficients and the way they move and compress may lead to a significant change in the hydraulic properties of the interfaces between them. Heating could also cause significant pore pressure changes, particularly in clay rock, affecting the stress distribution, which could in turn damage the structure of the clay rock so that water flows through it more easily.</td>
<td>Helen Wallace (for Greenpeace International) Rock Solid Sec 4.2.1</td>
<td>September 2010</td>
</tr>
<tr>
<td>ID: 623-05</td>
<td>Altered mineralogy may also impact on other properties of the clay… drop in sealing pressure in heat-damaged clay… might affect this...</td>
<td>Helen Wallace (for Greenpeace International) Rock Solid Sec 4.2.1</td>
<td>September 2010</td>
</tr>
</tbody>
</table>

**RWMD Response:**

We have developed a Disposal System Specification (DSS) to provide a clear definition of the requirements on the disposal system for higher-activity waste disposal [1,2]. The DSS is currently generic, but in the future it will be used to develop a site-specific DSS when one

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or more sites are identified. The issues in this topic concern the setting in the DSS of temperature targets in disposal modules to manage the thermal impacts on engineered barriers or the host rock from waste packages. Currently the requirements in the DSS are supported by a well-developed understanding with respect to heat generation and heat transfer processes for both HLW/spent fuel disposal and ILW/LLW disposal, also drawing on research and modelling performed internationally (section 5.2.3.24 of [2], section 3.6 of [3]). However, we are undertaking further work to develop our capability such that we will be able to consider the thermal evolution of disposal concepts for a wide range of engineered barrier system (EBS) design and material options. This capability will help with concept selection and EBS material choices for specific sites.

For example, we have recently begun a HLW/spent fuel disposal area thermal modelling project. This is part of our research programme [3,4] and will support justification of requirements for EBS designs in future issues of the DSS. It is expected that once concept development progresses, we will be able to use heat transport modelling, taking into consideration the UK waste inventory, various design layouts, different host-rock thermal properties and different EBS materials, to inform our programme and demonstrate that DSS requirements are met.

The effect of elevated temperatures on the properties of clay materials is something we will need to understand should these materials be envisaged as part of the multi-barrier disposal system or be selected as a host rock. We have set a limit on the temperature of the clay to be set in the DSS that is cautiously below that at which any significant detrimental processes may occur [5]. However, this limit is simply a planning assumption for the current stage of our programme, and we will be undertaking work to improve our understanding relating to alteration of clay minerals at temperatures above 100°C [4]. This will include reviewing the studies undertaken for overseas programmes [5,6].


B.6.2.4 Temperature target for intermediate level waste modules

Raised issues:

| ID: 624-01 | 'target of 50°C' - What is the justification of this? NB this could create an unnecessary problem in the case that deeper disposal needs to be considered in an area with a relatively high geothermal gradient. | Peer Review Outline Design Report - Evaporite Sec 10.3 | DSSC peer review 2010 |

RWMD Response:

For the intermediate level waste (ILW) modules, a design objective is to provide an environment during the operational phase in which the temperature of the waste packages is within targets specified in the generic Disposal System Technical Specification (DSTS) [1].

The DSTS identifies (Section 5.4.8 of [1]) that the upper temperature limit for the air within disposal module environment during the operational period is set at 50°C to provide satisfactory conditions for in-disposal module electrical equipment (e.g. emplacement cranes).

Minimising waste package temperatures will also help to ensure that the waste packages enter the post-closure period in the best condition practicable. In particular, maintaining lower temperatures in the waste stacks during the operational period will result in:

- lower rates of metallic corrosion, which would enhance the longevity of the waste container walls, and would also reduce the swelling of metallic wasteforms;
- reduced gas generation (due to reduced metallic corrosion rates), which affects wasteform physical integrity and releases of flammable, radioactive or toxic gases.

The DSTS also states (Section 5.2.3.24 of [1]) that ILW disposal modules shall be designed to comply with a long-term maximum temperature target. The target shall depend on the waste characteristics and the nature of the geological environment. For planning purposes, a guidance value of less than 50°C for all waste packages following closure has been assumed. The target is justified to ensure it does not unnecessarily constrain the design of a geological disposal facility or contents of a waste package [2]. However, the target simply represents a planning assumption for the purposes of the current stage of our programme. Once site information becomes available and concept selection has progressed we will be able to review and update the target with further justification, since more specific requirements and environmental control strategies will be dependent on the nature of the geological environment present at a particular site and the depth of the facility. Reviewing the requirements and justifications we do not believe that the targets, as described in the DSTS, will create an unnecessary problem in the case that deeper disposal needs to be considered in an area with a relatively high geothermal gradient.


## B.6.2.5 Barrier interaction in a co-located GDF

### Raised issues:

<table>
<thead>
<tr>
<th>ID: 625-01</th>
<th>A key technical and scientific question is whether it is possible to find a site that will be suitable for such a facility and to demonstrate that there will be no unacceptable near-field interactions over sufficiently long time periods.</th>
<th>CoRWM Doc. 2550. Geological disposal of higher activity radioactive wastes. July 2009 12.30, p46</th>
<th>July 2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>ID: 625-02</td>
<td>R&amp;D may be required at the concept development stage to understand the impact that co-location will have on GDF design. At the detailed design stage the site specific response of the rock mass to construction activity will need to be understood and the long-term stability of all underground openings will need to be established.</td>
<td>CoRWM doc 2543 Report on R&amp;D for interim storage and geological disposal...</td>
<td>October 2009</td>
</tr>
<tr>
<td>ID: 625-03</td>
<td>Co-location of intermediate level waste, high level waste and Other HAW in One GDF - assumption that the geometry of the facility is such that there will be no significant adverse interactions...An important question for site selection and GDF design is how this can be achieved in various geological environments. A key question is whether it is possible to demonstrate that there will be sufficiently limited interaction between the two near-fields over sufficiently long time periods for a post-closure safety case to be developed.</td>
<td>CoRWM doc 2543 Report on R&amp;D for interim storage and geological disposal... A.77, 118</td>
<td>October 2009</td>
</tr>
<tr>
<td>ID: 625-04</td>
<td>Most investigations of the leaching behaviour of vitrified high level waste have considered natural groundwaters, rather than the highly alkaline groundwaters that could be present in a co-disposal situation. As a result, there are significant uncertainties about the reactivity of borosilicate glasses in these circumstances.</td>
<td>CoRWM doc 2543 Report on R&amp;D for interim storage and geological disposal... A.81, 120</td>
<td>October 2009</td>
</tr>
<tr>
<td>ID: 625-05</td>
<td>R&amp;D may be required to enable the options (including co-location) to be evaluated and compared at the conceptual level.</td>
<td>CoRWM doc 2543 Report on R&amp;D for interim storage and</td>
<td>October 2009</td>
</tr>
</tbody>
</table>

(See also ID: 142-06)

(See also ID: 631-07)
| ID: 625-06 | Figure 3.3, Co-location of intermediate level waste, LLW, high level waste and spent fuel disposal areas:
In Sweden the safety assessments have indicated that the pH of pore water needs to be lower than 11. The earlier suggestion to co-locate long-lived LLW and intermediate level waste with spent fuel therefore has been abandoned and separate locations will be selected. It is strongly recommended that NDA RWMD considers the possibility that future analysis will indicate that a co-location is not compatible with BAT, and take suitable precautions by e.g. supplementing the text in the relevant documents with an alternative solution – plan B – in case the co-location should be abandoned. One of the documents in the suite indicates that this could be the case, but the reviewer’s impression is that the issue is not clearly addressed, where appropriate, in all documents of the suite. | Geological Disposal: Outline design report - Higher strength rock 3.2.4, page 14 | DSSC peer review 2010 |

**RWMD Response:**

The question of co-location (a single disposal facility for different types of higher activity wastes) is raised in several sections in this report. Here, we are concerned with how co-location is treated in our generic Disposal System Technical Specification (DSTS) [1]. The DSTS does not foreclose the options for either co-located or separate disposal facilities. Rather, the DSTS requires that interactions between one disposal module and another should not compromise the performance of the disposal system barriers. This is consistent with Government policy set out in the Managing Radioactive Waste Safely (MRWS) White Paper [2].

> “Research will be required to support the detailed design and safety assessment for the disposal facility for each type of waste, and in relation to any potentially detrimental interactions between the different disposal systems … In principle the UK

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Government sees no case for having separate facilities if one facility can be developed to provide suitable, safe containment for the Baseline Inventory... the final decision would be made in the light of the latest technical and scientific information, international best practice and site specific environmental, safety and security assessments.”

Within the scope of the generic Disposal System Safety Case, the generic designs assume 500m separation between disposal modules in order to meet the generic DSTS requirement [3]. This separation is based on studies we have performed to investigate the potential implications of co-location [4,5]. Our post-closure safety assessment (PCSA) calculations have then assumed such separation ensures no interactions [6].

We are undertaking further work at the generic stage to develop a comprehensive, state-of-the-art description of the issues, research and modelling relevant to the determination of the minimum separation distance between the different modules of a co-located disposal facility. This work will support establishment of a framework or methodology to allow the definition of minimum separation distances in support of design and assessment studies when the need arises to examine individual sites within MRWS Stage 4. We are also undertaking research to further develop our understanding of near-field evolution and potential interactions between disposal areas (see, for example, responses for topics 1.3.1 and 1.4.2). This research includes consideration of re-saturation and long-term buffer/backfill alteration processes for a range of disposal concepts and host rock environments, and modelling the temperature field associated with a co-located disposal facility in a number of different geological settings [7].

Beyond the work considering large-scale separation of disposal modules, there are also opportunities in co-location for optimising performance for individual waste types. For some types of waste, rather than separation, a more integrated approach to disposal could potentially provide both performance benefits and reduced costs and environmental impact. As part of the development of a holistic approach for management of the diverse inventory of higher activity wastes in the UK, effort is focused on developing concept options for the range of UK higher activity wastes and materials and understanding the issues associated with optimised management of combinations of waste types, so that these options can be considered and further developed when potential sites are considered. We are exploring these opportunities through our work on optioneering (as discussed in the responses for topic 6.3.3).

B.6.2.6 Retrievability and the impacts of retrieval

Raised issues:


| ID: 626-01 | Operational risks favour backfilling of vaults as soon as possible. This reduces risk of stacks collapsing in an open vault – which will make recovery very much more difficult. In any case, estimates might be made of the time over which waste packages can be assumed to be intact and hence retrieval easier. | Peer Review Geological Design Report – Evaporite Sec 11.2 | DSSC peer review 2010 |
| ID: 626-02 | This presumably applies to “as produced” packages: how long is such performance assured (NB discussion elsewhere considers leaving tunnels open for extended periods of time). Future design reports need to consider impacts of backfill timing on package performance. | Peer Review Outline Design Report – Evaporite Sec 7.1 | DSSC peer review 2010 |
| ID: 626-03 | "backfill" - As noted previously this needs careful justification as leaving tunnel open increases risk of waste stack collapse following corrosion and potential damaging of isolation properties due to creep. | Peer Review Outline Design Report – Evaporite Sec 10.2 | DSSC peer review 2010 |
| ID: 626-04 | What is the design life of the civil-geotechnical works? How is the design life changed by the need to have retrievability? | Peer Review Geological Design Report - Lower Strength Sec 8 | DSSC peer review 2010 |
| ID: 626-05 | Whilst it is recognised that the optimal closure strategy and any retrieval options will only be decided later following completion of the MRWS programme and further research, we would like to see some consideration of how the potential options may affect the design of the GDF, how the GDF operates and any consequent implications for safety. | Health and Safety Executive Operational Safety Case - Main Report General Comment | DSSC peer review 2010 |

**RWMD Response:**
These issues concern management of the potential for conflicting requirements to keep a geological disposal facility (GDF) open after waste has been emplaced to allow for monitoring and ease of retrieval (retrievability), and to close a facility at the earliest opportunity to provide for greater safety, greater security, and minimise the burdens of cost, effort and worker radiation dose on future generations. In the UK geological disposal
programme, Government policy on retrievability is provided in the Managing Radioactive Waste Safely (MRWS) White Paper [1].

“the decision about whether or not to keep a geological disposal facility (or vaults within it) open once facility waste operations cease can be made at a later date in discussion with the independent regulators and local communities. In the meantime the planning, design and construction can be carried out in such a way that the option of retrievability is not excluded. Any implications for the packaging of wastes will be kept under review.”

Therefore, the generic Disposal System Technical Specification (DSTS) [2] does not provide detailed requirements on retrievability, noting that decisions will be taken at a later date and that, in the meantime, the planning, design and construction of a geological disposal facility shall be carried out in such a way that the option of retrievability is not excluded [2]. We have considered how retrievability could be addressed in our illustrative generic designs [3]. Ease of retrieval was also considered in the reports that describe and evaluate the range of concept options for higher activity wastes [4,5].

As the MRWS site selection process progresses, any decisions with respect to retrievability will be made in discussion with the Government, regulators, and local communities. This decision-making will need to take account of relevant waste-specific and site-specific characteristics affecting ease of retrieval in combination with a range of other factors, such as risks of increased corrosion or stack collapse (e.g. issue 626-01). To conform with regulatory guidance, any provisions for retrievability should not unacceptably affect our environmental safety case [6]. The DSTS and the development of the disposal system design will be reviewed in light of decisions on retrievability and their potential impacts as part of the iterative development of the disposal system specification and design [7].

We have set out our approach to the issue of retrievability in a position statement published in 2010 [8]. This approach includes:

- consideration of the long-term integrity of waste packages in our Disposability Assessments;

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• stakeholder engagement and involvement in international initiatives looking at the drivers behind stakeholder preferences for retrievability and investigating how stakeholder opinions have evolved; and

• participation in international programmes of work on retrievability such that we can develop the disposal system design sensibly to comply with retrievability requirements as they evolve.

Our work to address the technical aspects of retrievability is also described in Section 15.4 of the overview of our research programme [9] (see also topics 1.2.2 and 4.1.3).

B.6.2.7 Safeguards

Raised issues:

| ID: 627-01 | The dilemma presented by the need to simultaneously keep potential nuclear weapons material out of reach, but at the same time accessible in order to monitor it, has not been resolved. | Nuclear Waste Advisory Associates’ Issues Register Issue - 81 | June 2010 |
| ID: 627-02 | Security and safeguards sections are at a high level at this stage in the combined ODR and GDF report. | Peer Review Geological Design Report - Lower Strength Sec 14 | DSSC peer review 2010 |
| (See also ID: 628-01) | \(\Rightarrow\) \textit{‘The lessons learnt from safeguards...’} - Note that these are both crystalline sites. Progress at Gorseleben should be followed if this project is reactivated. \textit{Peer reviewers recommend that future design reports consider lessons learned from Gorseleben.} | Peer Review Geological Design Report - Evaporite Sec 142 | DSSC peer review 2010 |

**RWMD Response:**

The safeguards arrangements for nuclear materials in a geological disposal facility are considerations that we take seriously. Our current generic Disposal System Technical Specification (DSTS) [1] specifies that the disposal system and associated reporting requirements shall comply with the relevant national and international (European Commission and International Atomic Energy Agency) regulations and requirements [2]. These regulations and requirements on safeguards provide for protection of nuclear materials, while facilitating monitoring by the regulatory bodies. Our approach to further defining the necessary arrangements for safeguards will be determined through dialogue with the relevant national and international organisations. We will also draw on experience in the UK on safeguard arrangements at currently operating storage and waste management facilities.

At the generic stage of our programme, it is not possible to specify all of the design or operational detail necessary to address all nuclear safeguards regulations. However, we are undertaking work to support development of nuclear safeguards requirements for the period after closure. We are also developing further some of the current safeguards requirements in our generic DSTS involving understanding any implications of safeguards requirements on the design and operation of a geological disposal facility and how safeguards requirements can be further incorporated as appropriate into the waste package specifications to support the disposability assessment process [2]. This will allow us to identify and manage any conflicts with other requirements, such as those on retrievability, at an early stage.

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### B.6.2.8 Security

#### Raised issues:

<table>
<thead>
<tr>
<th>ID: 628-01</th>
<th>Security and safeguards sections are at a high level at this stage in the generic geological design report.</th>
<th>Peer Review Geological Design Report - Lower Strength Sec 14</th>
<th>DSSC peer review 2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>ID: 628-02</td>
<td>Requirements from this assessment (and some others) for Category I physical protection, compared to limitations of current security plan to lower levels of protection.</td>
<td>Disposability Assessment Database ID78 PFR Irradiated Carbide Fuel (Conceptual)</td>
<td>October-10</td>
</tr>
<tr>
<td>ID: 628-03</td>
<td>RWMD to clarify the Physical Protection requirements for packages containing spent civil nuclear fuel.</td>
<td>Disposability Assessment Database ID71 AGR Spent Fuel</td>
<td>October-10</td>
</tr>
<tr>
<td>ID: 628-04</td>
<td>Seek clarification from Office for Civil Nuclear Security on the need for Category I standards of Physical protection for AWE hydrodynamic vessels. This is based on the description of waste packages as defined in Office for Civil Nuclear Security guidance.</td>
<td>Disposability Assessment Database ID72 AWE Hydrus Hydrodynamic Vessels</td>
<td>Nov-10</td>
</tr>
</tbody>
</table>

#### RWMD Response:

The security requirements in the generic Disposal System Technical Specification (DSTS) [1] are specified at a high level. Work planned to address this topic in the next 2-3 years includes review of the specific regulatory requirements for security from the relevant sections of legislation and the refinement of those high-level security requirements in the DSTS that we can address in the current phase of implementation to set out how security arrangements will be met during construction and operational phases of a geological disposal facility. Once complete, we will seek review of our work by the Office of Nuclear Regulation (OCNS) for compliance with NORMS [2].

In future phases of implementation, when the facility designs are site-specific and concept-specific, we will be able to develop further our security requirements in the design specification and provide more detail on how we meet these requirements in a geological disposal facility Construction Plan.

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## B.6.3 Concept Optioneering

### B.6.3.1 Disposal concept selection process

#### Raised issues:

| ID: 631-01 | CoRWM recommends to Government that it should ensure that the NDA carries out option assessments in which a wide range of geological disposal concepts is considered. | CoRWM Doc. 2550. Geological disposal of higher activity radioactive wastes. July 2009 Rec 4, p10 | July 2009 |
| ID: 631-02 | It is also recognised... that there are several key uncertainties (e.g. GDF design optimisation for geology) and that the magnitudes of these will need to be explored through R&D. | CoRWM Doc. 2550. Geological disposal of higher activity radioactive wastes. July 2009 12.20, p44 | July 2009 |
| ID: 631-03 | CoRWM considers that design should commence with an integrated review of disposal concepts, underground engineering constraints and the engineered barrier design. The programme outlined in the June 2008 White Paper currently does not identify a specific period for design development nor is CoRWM aware that NDA has defined a process for design development. | CoRWM Doc. 2550. Geological disposal of higher activity radioactive wastes. July 2009 12.28, p45 | July 2009 |
| ID: 631-04 | It is important to give the same degree of attention to geological disposal concepts with more than one GDF as to concepts with a single combined GDF. | CoRWM Doc. 2550. Geological disposal of higher activity radioactive wastes. July 2009 12.36, p47 | July 2009 |
| ID: 631-05 | It is important for the NDA to consider concepts with more than one GDF, as well as concepts with a single combined GDF. | CoRWM Doc. 2550. Geological disposal of higher activity radioactive wastes. July 2009 12.39, p48 | July 2009 |
| ID: 631-05 | CoRWM is concerned that the NDA may dismiss deep borehole disposal at too early a stage in concept | CoRWM Doc. 2550. Geological disposal of | July 2009 |
| ID: 631-06 | Development...CoRWM therefore encourages the NDA to both keep up to date with developments in deep borehole disposal and to reassess the viability and potential costs of the option at intervals. | Higher activity radioactive wastes. July 2009 12.42, p48 |
| ID: 631-07 | It is not clear to CoRWM whether NDA has plans for such an integrated process, which should include comparisons of design options for each candidate site. | CoRWM Doc. 2550. Geological disposal of higher activity radioactive wastes. July 2009 12.52, p50 |
| ID: 631-08 | R&D may be required to enable the options (including co-location) to be evaluated and compared at the conceptual level. | CoRWM doc 2543 Report on R&D for interim storage and geological disposal... A.83, 120 |
| ID: 631-09 | Major changes (to the repository design) would have significant impacts on project costs. Examples of proposed changes...include: a) thicker copper canisters b) wider spacing of canisters... c) purer bentonite... d) increased excavation depth... All of the above would increase costs significantly. | Helen Wallace (for Greenpeace International) Rock Solid Sec 5.3 |
| ID: 631-09 | "Alternative packaging assumptions are considered throughout the RWMD work programme so as not to foreclose future options regarding the development of a GDF" – This needs to be made more specific: Where in the work programme and in what way? What are the implications for radionuclide behaviour? | Peer Review Geological Disposal: Radionuclide behaviour status report Page 10 |
| ID: 631-10 | The evidence of building on previous options study decisions isn’t apparent. Planning processes will typically place a burden on project developers to provide evidence that options have been considered, assessed and rejected; upon first reading there seems to be | Peer Review Summary of Designs Contents List | DSSC peer review 2010 |
underlying assumptions, without reference to such work. The options assessment process may have been rigorously followed and documented, but cross reference evidence is not apparent, and the report suite might benefit from its summary inclusion.

RWMD Response:

Optioneering studies (i.e. options evaluation) based on a wide range of options are required to support decision-making on a number of levels. Since CoRWM comments were received in 2009, RWMD has published its Proposed Approach to Optioneering [1]. Ranges of potentially suitable disposal concepts and engineered barrier materials have been identified [2,3,4] that we are using to support our programme in the generic phase. At present our optioneering studies are focussed on three broad themes:

- selection of disposal concepts;
- more detailed considerations relating to components, parameters and issues affecting the geological disposal system and development of the disposal system design; and
- consideration of alternatives to development of a geological disposal facility (GDF), such as deep borehole disposal.

We are developing our concept selection process to explain how we plan to maintain a range of geological disposal concepts and progressively screen these to enable the selection of preferred geological disposal concepts at the end of Stage 5 of the Managing Radioactive Waste Safely (MRWS) site selection process.

Drawing on our optioneering work to date, illustrative disposal concepts have been outlined for a number of generic geological environments [5]. The illustrative concepts are being used to:

- further develop understanding of the functional and technical requirements on the disposal system;
- further develop understanding of the design requirements;
- support the scoping and assessment of the safety, environmental, social and economic impacts of a geological disposal facility;
- support development and prioritisation of the R&D programme;
- underpin analysis of the potential cost of geological disposal; and

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• support assessment of the disposability of waste packages.

RWMD seeks to ensure that option studies and assessments are needs-driven, co-ordinated and coherent [6]. All of the specific areas requiring optioneering that have been identified are planned to be addressed either by the current work programme, if they are generic, or have been recorded for future site-specific consideration.

A broad range of factors will need to be considered in optioneering for a geological disposal facility. Most optioneering decisions cannot be carried out in isolation; design decisions taken are likely to impact many options that are available in other areas. A properly integrated, strategic approach to optioneering needs to be both flexible and broad in scope, and the impact of potential options must be considered across the whole programme.

However, some stages in the planning and delivery of a geological disposal facility may not necessarily result in the identification of a single preferred alternative, but in the progressive short-listing, or narrowing down of options within an increasingly tightly defined disposal system specification. We recognise that optioneering requires more than implementation of a structured process. Optioneering also requires that all projects within RWMD include the consideration of options; some of the tools and approaches that are available for considering options are discussed in our proposed approach to optioneering [1]. This includes:

• Attributes - optioneering for a geological disposal facility requires investigation and consideration of the performance of options against a wide range of attributes or factors. These include a range of safety, environmental, technical, social, economic, ethical and security factors;

• Supporting methods and tools - optioneering for a geological disposal facility requires sufficient information on all of the different factors to be considered. Therefore, we will need to maintain and build upon the assessment and analysis methods and tools that are currently available;

• Recording and communicating decisions - A vital part of any decision-making process is recording and communicating decisions, including the process used, the assumptions made and the basis for the decision;

• Keeping alternative waste management options under review - Although a decision has been made by the UK Government to manage higher activity radioactive waste through geological disposal, there is still a requirement to keep alternative long-term options under review and to take account of any developments that impact the reasons used for selecting geological disposal as the long-term management method; and

• Selecting a geological disposal concept - Selecting the most appropriate method for implementing geological disposal will require us to carry out assessments and make decisions at different levels of detail. At the current stage of the programme our work is focused on analysing and developing potentially suitable geological disposal concepts. At later stages we will develop design solutions to implement the concept or concepts that are then being considered.

B.6.3.2 Disposal options for metallic spent nuclear fuels

Raised issues:

| ID: 632-01 | Consider the implications of an additional 2000 copper disposal packages containing Magnox fuel on GDF operations and lifetime plans. | Disposability Assessment Database ID40 Preconceptual LOC for Magnox bulk fuel | March 2010 |
| ID: 632-02 | Consider the issues associated with metallic fuel disposition in a bentonite system. Consider the need to adopt an alternative disposal concept for metallic fuel, to allow for potentially significant gas generation whilst controlling thermal loading. | Disposability Assessment Database ID39 Preconceptual LOC for Magnox bulk fuel | October 2010 |

RWMD Response:

Currently, the strategy for management of spent fuel from Magnox reactors is shipping to Sellafield for re-processing. A contingency option being researched and developed is that the fuel is dried and put in containers in a passively safe form [1]. These containers could then be suitable for disposal if spent nuclear fuel is declared as waste. However, we recognise that for some disposal concept options, developed for other types of spent fuel, the direct disposal of reactive metal fuels could result in the generation of large quantities of gas during the post-closure period once the disposal container has been breached [2].

We are undertaking work to identify the range of viable disposal concepts for different types of spent fuel, as well as further studies of container materials for spent fuel [3]. Any specific requirements on the disposal system for metallic uranium spent fuel (including Magnox spent fuel) will be identified. The work will also identify the range of viable packaging solutions and disposal concepts that meet these requirements.

B.6.3.3 Disposal concept optioneering

Raised issues:

| ID: 633-01 | Influence of different waste form types on the design of the engineered barrier system: the waste form remains undetermined for a number of key waste streams (such as graphite). | Environment Agency Science Programme Contractor Report: Technical issues associated with deep repositories for radioactive waste | August 2009 |


<table>
<thead>
<tr>
<th>ID: 633-02</th>
<th>Influence of different waste form types on the design of the engineered barrier system: New waste forms... will have implications for engineered barrier system design.</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>ID: 633-03</th>
<th>Influence of different waste form types on the design of the engineered barrier system: potential interactions between these new waste forms.</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>ID: 633-04</th>
<th>Because high burn-up fuel contains increased amounts of long-lived hazardous radionuclides in the spent fuel, such as americium, curium and plutonium, for the same amount of energy produced, and generates significantly more heat, the proposed use of high burn-up fuel in new nuclear reactors could have significant implications for repository safety cases.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Helen Wallace (for Greenpeace International) Rock Solid 3.1</td>
<td>September 2010</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ID: 633-05</th>
<th>it would be sensible to give AGR fuel priority in any NDA/RWMD R&amp;D programme into the geological disposal of spent fuels, including transport to a GDF.</th>
</tr>
</thead>
<tbody>
<tr>
<td>CoRWM doc 2543 Report on R&amp;D for interim storage and geological disposal... A.28, 105</td>
<td>October 2009</td>
</tr>
<tr>
<td>ID: 633-06</td>
<td>There will need to be R&amp;D on conditioning and packaging Sizewell B spent fuel for geological disposal.</td>
</tr>
<tr>
<td>ID: 633-07</td>
<td>Important to explore treatment options that would reduce the volume of graphite for geological disposal.</td>
</tr>
<tr>
<td>ID: 633-08</td>
<td>Consider issues raised by including EPR non-fuel core components with spent fuel or Operational intermediate level waste.</td>
</tr>
<tr>
<td>ID: 633-09</td>
<td>Consider issues raised by including AP1000 non-fuel core components with spent fuel or Operational intermediate level waste.</td>
</tr>
<tr>
<td>ID: 633-10</td>
<td>1. Optimise the design of the AGR fuel disposal package. This package design should seek to package the maximum quantity of AGR fuel within the allowable constraints (for example, heat, dose rate, criticality safety, manufacturability etc.).</td>
</tr>
<tr>
<td>ID: 633-11</td>
<td>1. EA consider optimisation of radiological protection to be central to the GDF project and therefore encourage RWMD to include a specific section in the functional specification about the optimisation of radiological protection, and suggested this is an important theme that should recur throughout.</td>
</tr>
<tr>
<td>ID: 633-12</td>
<td>1. Optimisation - Peer review panel considers that further dialogue may be necessary to clarify what is required within the DSSC to demonstrate optimisation.</td>
</tr>
<tr>
<td>ID: 633-13</td>
<td>1. The development of alternative spent fuel disposal concepts needs</td>
</tr>
</tbody>
</table>
to note the potential for adverse effects on post-closure criticality safety associated with horizontal deposition tunnels. The potential for accumulation of fissile material on extended timescales may be more significant where fissile material from multiple packages could accumulate. This is not believed to be an issue for packages emplaced singly in vertical deposition holes.

<table>
<thead>
<tr>
<th>Database ID79 Preconceptual LOC for PFR Irradiated Carbide Fuel</th>
<th>RWMD Response:</th>
</tr>
</thead>
</table>

As explained in Section 4.5 of our approach to optioneering [1], geological disposal concepts for higher activity wastes and materials have not yet been selected. Concepts for a geological disposal facility need to be developed with due consideration of the geological environment. When potential sites are identified and we know the geological environment we will select and develop appropriate disposal concepts. We are developing a concept selection process to explain how we plan to maintain a range of geological disposal concepts and progressively screen these to enable the selection of a preferred geological disposal concept at the end of Stage 5 of the Managing Radioactive Waste Safely (MRWS) site selection process. There will, therefore, be a range of opportunities for optimising geological disposal concepts for higher activity wastes and materials in the site-specific phase of the geological disposal implementation programme [2].

We are undertaking a range of option studies in the generic phase of our programme to support future decision making. In addition to tailoring our generic designs, these studies will develop the experience needed when we carry out optimisation studies later in our programme. Our optioneering considers the full range of higher activity wastes and materials, including wastes from a New Build programme [3], and issues at three different levels [1]:

- Long-term waste management strategies;
- Geological disposal concept options; and
- Geological disposal facility design solutions, covering specific components, parameters and issues related to implementation of a geological disposal system.

As such, our studies capture the issues raised under this topic. We will continue to seek to ensure that our option studies and assessments are needs-driven, co-ordinated and coherent.


[3] Any scope of work undertaken within the NDA RWMD programme that is of relevance to new build fuel is generic and is undertaken within the wider envelope of conditions of relevance to the full range of wastes in the Upper inventory as described in the generic Disposal System Specification (NDA/RWMD/044, 2010). This therefore excludes work that is specific to proprietary new build fuel designs. The Government has stated as policy that operators of new nuclear power stations will be obliged to meet their full share of waste management costs (White Paper on Nuclear Power, Meeting the Energy Challenge, Department for Business, Enterprise & Regulatory Reform, Section 3.70, 2008.)
RWMD has been preparing for the assessment of possible geological disposal concepts, to support optioneering at the appropriate point in the MRWS process, by undertaking several option studies these include:

- identification of generic concepts for high-level waste (HLW) and spent fuel geological disposal [4] and for intermediate-level waste (ILW) and low-level waste disposal [5];
- consideration of the range of materials that could be used in the engineered barrier system (EBS) of the geological disposal facility [6];
- review of HLW and spent fuel disposal concepts that use iron-based canister materials and their post-closure performance [7];
- review of the performance of selected metals as canister materials for UK HLW and/or spent fuel [8];
- review of the suitability of the reference concept for ILW and some LLW in a range of geological environments [9];
- investigation of engineering designs for disposal facilities in different host environments which have been expressed in generic designs for these environments [10]; and

Further work planned in the generic phase of our programme includes:

- to prepare information on integrated sets of geological disposal options to range of UK higher activity wastes and materials to support site assessment during MRWS Stage 4;
- to explore opportunities for, and identify associated issues with, more optimised combinations of disposal concept options for the range of UK higher activity wastes and materials.

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higher activity wastes and materials to support concept option selection during MRWS Stage 5;

- to investigate the applicability of the range of concepts for disposal of vitrified waste;
- to investigate the applicability of the range of concepts for the direct disposal of different types of spent fuel;
- to investigate option studies on relevant aspects of plutonium and uranium disposal concepts;
- to identify the main advantages and disadvantages of selective emplacement and the suitability of particular concepts for this approach; and
- to understand the flexibility of disposal concepts to a range of non standard package types (e.g. larger packages, robust shielded containers), including:
  - to consider the impact on a GDF of many different package types, e.g. GDF infrastructure (handling and transfer arrangements), number of vaults, types of vaults required, emplacement arrangements, the impact of such parameters on the demonstration of a safety case; and
  - opportunities for selective emplacement of waste.

B.6.3.4 Disposability of depleted, natural and low-enriched uranium wastes.

Raised issues:

| ID: 634-01 | Uranium bearing wastes: the post-closure safety assessment suggests that we should consider the benefits of locating such wastes in separate vaults to organic wastes to reduce the solubility and near-field flux of uranium, etc. | Disposability Assessment Database ID37 Magnox Encapsulation Plant Periodic Review | October 2010 |
| ID: 634-02 | There is potential for optimisation of the disposal of uranium carbide. The baseline assumption is disposal within the HLW and spent fuel concept but UC fuel is not very hot, so, for example the spacing between deposition tunnels could be reduced. Alternatively, UC could be disposed of in a developing concept for bulk HEU; the reactivity of UC would need to be managed. | Disposability Assessment Database ID67 PFR Irradiated Carbide Fuel (Conceptual) | October 2010 |
| ID: 634-03 | Disposal system concepts for uranium need to be developed. | Generic Disposal System Specification | January 2011 |
Various stockpiles of separated uranium are included in the Baseline Inventory [1], but Government has not yet decided whether to declare uranium as waste. There is a good understanding of long-term evolution of a range of uranium solids in the literature (obtained in support of uranium mining and understanding of nuclear fuels e.g. [2] and we are applying this understanding carefully for the UK situation. We are undertaking work to support the development of the optimum disposal system for uranium should it be declared a waste. The work is currently concerned with the identification of a range of suitable disposal concepts for uranium wastes to inform the concept selection process and support future decision making. The work includes considerations such as chemical form for disposal, choice of engineered barriers, and facility layout. We have also considered use of depleted uranium waste to fill void space in disposal concepts for other wastes [3,4].

A range of wasteforms for uranium are feasible and work is being performed under the NDA’s Direct Research Portfolio and by Sellafield Ltd to assess some of these potential wasteforms in more detail. Data for radionuclide release rates from uranium wastes in our current assessments are based on literature information (see Appendix A of the Radionuclide Behaviour Status Report [5]). For the case of depleted uranium, we are currently reviewing the available data to obtain improved parameters for radionuclide release to be used in our post-closure safety assessment calculations. This is described in our R&D programme overview [6].

### B.7 Delivery of our programme

#### B.7.1 Processes to support delivery of our programme

#### B.7.1.1 RWMD process for development of a geological disposal system for UK radioactive wastes

**Raised issues:**

<table>
<thead>
<tr>
<th>ID: 711-01</th>
<th>CoRWM recommends to Government that it should ensure that the NDA has an integrated process in place for geological disposal facility design, site assessments and safety case development.</th>
<th>CoRWM Doc. 2550. Geological disposal of higher activity radioactive wastes. July 2009 Rec 5, p10</th>
<th>July 2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>ID: 711-02</td>
<td>How the integration and linkage is managed... is not apparent from the material examined by CoRWM.</td>
<td>CoRWM Doc. 2550. Geological disposal of higher activity radioactive wastes. July 2009 12.22, p44</td>
<td>July 2009</td>
</tr>
<tr>
<td>ID: 711-03</td>
<td>Unclear how DSSC development is to be integrated with GDF design and site assessments.</td>
<td>CoRWM Doc. 2550. Geological disposal of higher activity radioactive wastes. July 2009 12.23, p45</td>
<td>July 2009</td>
</tr>
<tr>
<td>ID: 711-04</td>
<td>Need to describe the range of ways we can demonstrate that we apply an iterative way of working.</td>
<td>Peer Review Disposal System Technical Specification</td>
<td>DSSC peer review 2010</td>
</tr>
<tr>
<td>ID: 711-05</td>
<td>Need to consider how we recognise and resolve conflicts and how we identify and exploit opportunities for synergy. Including Integrated Waste Strategy and regulatory requirements.</td>
<td>Peer Review Disposal System Technical Specification</td>
<td>DSSC peer review 2010</td>
</tr>
<tr>
<td>ID: 711-07</td>
<td>Disposal System Functional Specification does not provide enough cross referencing to other supporting documents and future iterations need to demonstrate better integration with other docs.</td>
<td>Peer Review Environment Agency review of Disposal System Specification</td>
<td>DSSC peer review 2010</td>
</tr>
</tbody>
</table>
RWMD Response:

Our approach to iterative development of the disposal system is described at a high-level in a range of recently published documents, including Steps towards implementation [1], and our Technical Strategy [2]. In particular the technical strategy sets out the role of the Disposal System Specification [3] and describes how it covers a large number of interacting variables relating to the wastes, packaging, transport and geological disposal. This provides the basis for the design development, safety and environment assessments and R&D that underpins the generic Disposal System Safety Case (DSSC).

Following the review of our organisation during 2011 we consider that we are now in a position to build upon the comments and issues from the CoRWM and the DSSC peer review about the lack of detailed information on the relationship between the different functions in the iterative development of the disposal system process and to review our approach.

We are therefore developing a more detailed description of the iterative development of the disposal system process to demonstrate how the process is integrated between functions (including how optimisation will be managed) and provide the published documentation needed to support on-going dialogue with stakeholders in this area. We aim to clarify our approach and update as necessary the diagrams in our documents to respond to peer review comments in further iterations of the development of this suite of documents.

B.7.1.2 RWMD process for information and knowledge management

Raised issues:

| ID: 712-01 | there are several issues that need to be addressed with some urgency: | CoRWM doc 2543 | October 2009 |

i) preservation of documents that describe past R&D (so that knowledge is not completely lost and work has to be repeated)

ii) declassification of as many existing R&D documents as possible, including documents that are marked “restricted” or “commercial” (so that R&D results are widely available)

iii) capturing the tacit knowledge of senior experts who are approaching retirement

iv) development of a suitable knowledge management system for all radioactive waste management R&D in the UK (so that understanding from past and future R&D can be shared, used and passed on to subsequent generations).

Report on R&D for interim storage and geological disposal...

2.31, 23

RWMD Response:

Continuity of knowledge throughout the life of the project is necessary for consistent and reliable decision making and is part of maintaining the capability and competency of the organisation. Although the issues raised refer specifically to knowledge and records on R&D, the response applies across all the work undertaken by RWMD and encompasses information as well as knowledge management.

To provide a platform upon which we will develop our existing arrangements we have produced a knowledge and information lifecycle and vision that has been incorporated into our internal operating procedures. We also have a dedicated project that covers data, information, and knowledge management. During the recent reorganisation of RWMD, a post was included with specific responsibility for knowledge and information management.

Within the individual functions in RWMD (such as R&D and Design), responsibility for information assets is held by the functional lead. The important information within each function has been identified and processes for its active management are being developed. Where relevant, this information includes documents marked “commercial” or “restricted”. Declassification of these documents is considered on a case by case basis. It is anticipated that, once these arrangements are mature, they will provide an effective information and knowledge management structure.

We have recently published our generic Disposal System Safety Case to set out our technical baseline in relation to the safety case for geological disposal. And, as an example of our developing arrangements a proactive approach to capture the tacit knowledge from senior experts who are approaching retirement has recently been introduced. This includes extended handover periods with clearly-defined milestones and the introduction of briefings on topics of particular significance.

B.7.1.3 Research and development strategy

Raised issues:
| ID: 713-01 | CoRWM believes that fundamental research is important for geological disposal,....over periods of tens of thousands of years or more. Uncertainties over such long times can only be addressed if there is a sound understanding of the processes that underlie potential release and transport of radionuclides. Fundamental research may also reveal unknown issues or phenomena that have not yet been considered but which may be of crucial importance. | CoRWM doc 2543 Report on R&D for interim storage and geological disposal... 2.4, 17 | October 2009 |
| ID: 713-02 | “Needs-driven” is too general a term in the context of management of higher activity wastes. | CoRWM doc 2543 Report on R&D for interim storage and geological disposal... 2.6, 18 | October 2009 |
| ID: 713-03 | It is particularly important to set clear R&D priorities... this is best done in an open and transparent way, involving the people who will do the R&D as well as those who will use the results. | CoRWM doc 2543 Report on R&D for interim storage and geological disposal... 2.36, 24 | October 2009 |
| ID: 713-04 | It is not clear how RWMD R&D on geological disposal will be co-ordinated with the R&D by NDA and its SLCs. | CoRWM doc 2543 Report on R&D for interim storage and geological disposal... 3.142, 59 | October 2009 |
| ID: 713-05 | The UK should make increased efforts not only to participate in but also to influence Framework Programmes on R&D for the management of higher activity wastes. | CoRWM doc 2543 Report on R&D for interim storage and geological disposal... 3.151, 61 | October 2009 |
| ID: 713-06 | More stakeholders should be involved in establishing R&D requirements. | CoRWM doc 2543 Report on R&D for interim storage and geological disposal... | October 2009 |
| ID: 713-07 | Both fundamental and applied research will be needed in order to develop a robust Environmental Safety Case. | CoRWM doc 2543 Report on R&D for interim storage and geological disposal... A.51, 110 | October 2009 |
| ID: 713-08 | Further research may not provide desired outcomes. | NWAA Nuclear Waste Advisory Associates’ Issues Register Issue - 97 | June 2010 |
| ID: 713-09 | The high likelihood of interpretative bias in the safety assessment process because of the lack of validation of models, the role of commercial interests and the pressure to implement existing road maps despite important gaps in knowledge. Lack of (funding for) independent scrutiny of data and assumptions can strongly influence the safety case. i) other problems may remain unidentified due to lack of sufficient independent scrutiny. ii) Reliance on industry-funded research... is likely to introduce interpretative bias in repository safety assessments. iii) over confidence in a particular computer model or the assumptions that underpin it. | Helen Wallace (for Greenpeace International) Rock Solid Exec summary & 5.1.1 | Sept 2010 |
| ID: 713-10 | Ensure there is an appropriate level of international communication regarding the work performed (by RWMD). | Peer review Criticality Status Report | DSSC peer review 2010 |
| ID: 713-11 | › Presentation of a strategy and work programme that was visible and demonstrable. | CoRWM doc 2922 (final) CoRWM Annual Report 2010-11 p33, 4.43 | June 2011 |

**RWMD Response:**

There has been more than 40 years of research into geological disposal and there is a strong scientific basis for the approach now being implemented in the UK and in many countries overseas. Similar to other waste management organisations implementing geological disposal internationally, we have an active R&D programme. We have worked
to strengthen this via both the recent RWMD re-organisation and a major procurement exercise, to ensure we can continue to fulfil the role of an intelligent client, and have ongoing access to the key skills and input of consultants and specialists in field of geological disposal of radioactive waste.

The R&D funded by RWMD is directed towards demonstrating a sufficient understanding of the relevant scientific processes to be able to produce a safety case that will meet regulatory requirements. Our R&D Strategy was published in 2009 [1], following extensive stakeholder consultation. In 2011 we published our R&D programme [2], to give visibility to the programme and to show how the R&D is prioritised. Where appropriate we seek to deliver this R&D through international cooperation. We are members of the recently-formed European Technology Platform in Geological Disposal and this is providing additional opportunities for working together on areas of common interest. Within the UK we are members of the Nuclear Waste Research Forum whose role is to promote a common understanding and collaboration between relevant bodies across the UK about respective research and development needs, risks and opportunities required to enable the delivery of the decommissioning of the UK’s nuclear legacy.

The desired outcome of any research is an improved understanding of a scientific or technical issue. In order to build confidence in our scientific evidence base, we have a continued commitment to openness and transparency, including independent peer review and publication of our work in the open literature and the RWMD bibliography. This ensures scrutiny of our work.

In addition to the ‘needs-driven R&D’, we allocate a small percentage of our funding for ‘fundamental’ or ‘curiosity-driven’ research. The recent research call managed by the EPSRC is an example of this. Other fundamental research relevant to geological disposal is funded fully by the Research Councils as part of their programmes.

We agree that it is important: that stakeholders: have access to and can influence our R&D strategy and programme; that our programme is based on sound science; that our programme is subject to appropriate scrutiny; and that it is co-ordinated with other relevant R&D programmes. All of these issues are covered in our R&D strategy [1].

We are currently planning future updates of our R&D strategy and programme, to show how we will move from a generic R&D programme to a site-specific R&D programme as the MRWS programme progresses. These again will be developed in a consultative manner, and we will seek and welcome stakeholder input.


## B.8 Policy, licensing and regulation

### B.8.1 Policy

#### B.8.1.1 UK Government policy on managing radioactive waste

**Raised issues:**

<table>
<thead>
<tr>
<th>ID: 811-01</th>
<th>Need for Government and NDA to consider and explain more fully how they will ensure that appropriate funding will be available during the various phases of the implementation of geological disposal. It is essential that intergenerational equity is taken into account.</th>
<th>CoRWM Doc. 2550. Geological disposal of higher activity radioactive wastes. July 2009 4.7, p21</th>
<th>July 2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>ID: 811-02</td>
<td>Tension between the economic benefits offered to host communities and long-term repository safety, leading to a danger that concerns about safety and impacts on future generations may be sidelined by the prospect of economic incentives, new infrastructure or jobs. There is additional tension between endorsement of deep disposal as a potentially ‘least bad’ option for existing wastes, and nuclear industry claims that deep repositories provide a safe solution to waste disposal and so help to justify the construction of new reactors.</td>
<td>Helen Wallace (for Greenpeace International) Rock Solid Exec summary &amp; 5.2</td>
<td>Sept 2010</td>
</tr>
<tr>
<td>ID: 811-03</td>
<td>MRWS 146 stated that European union regulations permit agreement between different states to enable disposal of waste in other countries. The NDA reply that they are not considering such options. That is remarkable, because it may be both cheaper and more secure to purchase storage in other countries rather than the geologically complex UK.</td>
<td>Reply to the NDA response to MRWS paper 146 Professor Stuart Haszeldine University of Edinburgh</td>
<td>May 2011</td>
</tr>
</tbody>
</table>
RWMD Response:

Through the Managing Radioactive Waste Safely (MRWS) Site Selection Process [1], as initiated in 2001, the UK has acknowledged its responsibility to deal with its nuclear legacy and now has in place the policy, strategy and implementing organisations that:

- ensures the long term protection of people and the environment;
- does this in an open and transparent way;
- is based on sound science; and
- uses public monies effectively.

In 2006, following extensive engagement with experts, stakeholders and the public, CoRWM made a set of recommendations to Government, the primary one being that, within the context of present knowledge, geological disposal was the best method for the long-term management of legacy higher activity waste.

Government accepted this recommendation as that basis of policy for the long term management of higher activity radioactive waste and in 2008 the MRWS White Paper [1] set out a framework for implementing geological disposal in the UK. Fundamental to this implementation framework are:

- the statutory roles of the independent nuclear regulators to ensure that people and the environment are protected and that any geological disposal facility is safe; and
- a siting process based upon voluntarism and partnership with local communities.

These principles together recognise the importance of working with local communities in the implementation of geological disposal which is now widely recognised internationally while ensuring that effective regulation ensures that a geological disposal facility will only be constructed and operated if the independent regulators are confident that it will be safe.

The UK has been a nuclear nation since the 1950s and has a legacy of higher activity radioactive waste that already exists and needs to be managed safely for the long term. Disposal in repositories outside of the UK is not an option that is currently being considered. While European legislation does allow agreement between different states to enable disposal of waste in other countries to at present, no major nuclear nation is proposing to open their facilities to international wastes. It is therefore important that the UK continues to progress a long term solution to the management of higher activity waste.

In addition to the need to manage the existing legacy of higher activity radioactive waste in the UK in its White Paper on Nuclear Power [2] the UK Government concluded that:

"Having reviewed the arguments and evidence put forward, the Government believes that it is technically possible to dispose of new higher-activity radioactive waste in a geological disposal facility and that this would be a viable solution and the right approach for managing waste from any new nuclear power stations. The Government considers that it would be technically possible and desirable to dispose of both new and legacy waste in the same geological disposal facilities and that this should be explored through the Managing Radioactive Waste Safely programme."


Future use of nuclear power in the UK is one of a number of areas where the potential inventory for disposal in a geological disposal facility is uncertain at this early stage in the MRWS process. Recognising the inventory for geological disposal will change over time, RWMD has developed an ‘Upper Inventory’ [3] to allow the implications of inventory uncertainties (such as changes to handling arrangements on sites, changes to plant operating lifetimes, new nuclear power stations, etc) to be explored in RWMD’s generic design and safety and environmental assessment work to demonstrate that a geological disposal facility can be developed to deal with an upper inventory safely and securely.

Recognising the importance of inventory to community consideration of a decision to participate and the inherent uncertainty regarding the inventory for disposal at this early stage of the MRWS process, the MRWS West Cumbria Partnership has been working with Government to develop and agree generic principles [4] to inform any future inventory change process, in order to support near-term decisions regarding further participation.

There have been a number of recent commitments from Government to the implementation of Geological disposal supported by the establishment of a Ministerial Chaired Geological Disposal Implementation Board (GDIB) and a commitment to report Annually to Parliament and other stakeholders on the MRWS process [5]. However, as with Government funding generally the funds provided to the NDA is allocated as part of periodic spending reviews. Given this and the very long term nature of the MRWS process there is potential for insufficient funding in future years to impact the implementation of geological disposal. This is recognised by NDA as a risk and is managed through development of needs driven work programme and regular liaison with Government.

### B.8.2 Licensing

#### B.8.2.1 International marine pollution control legislation

**Raised issues:**

| ID: 812-01 | …to permit the possibility of marine discharges is now considered unlawful. Sellafield falls into such a category, since Nirex modelling of the flow paths from a leaking repository predicts such a discharge. | David Smythe Why a deep nuclear waste repository should not be sited in Cumbria: a geological review. | April 11 |
| ID: 812-02 | MRWS 146 stated that radioactive waste dissolved in groundwater from the repository will eventually leak into the ocean. This NDA reply agrees with that, but appears to conclude this is not important because that will be potentially thousands of years into the future. The NDA are ignoring the fact. | Reply to the NDA response to MRWS paper 146 Professor Stuart Haszeldine University of Edinburgh | May 2011 |

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that leakage into the ocean is against international law.

RWMD Response:
As described in the MRWS White Paper [1] the robust and independent regulation of geological disposal to ensure that both people and the environment are protected is a key part of the framework for implementing geological disposal in the UK.

The Department of Energy and Climate Change has already responded (see reference [2]) to the west Cumbria MRWS partnership to the effect that while protection of the marine environment is important, the UK’s obligations under the OSPAR Convention on the Protection of the Marine Environment of the North East Atlantic do not preclude the development of a geological disposal facility in coastal areas. This response also made clear that the enduring protection of the marine environment would be one of the issues which would be considered in the environmental permitting of any geological disposal facility in light with the legal requirements in place at the time of any permit application.

RWMD will consider the potential environmental effects of any geological disposal facility including any potential effects on the marine environment in the site specific safety cases which it will develop as part of the implementation of geological disposal. Based upon these safety and environmental assessments RWMD will demonstrate in its environmental permit applications that its proposals to develop and operate a geological disposal facility are consistent with relevant UK and international legal requirements including, where relevant, those associated with the protection of the marine environment.

B.9 Cost

B.9.1.1 GDF cost model

Raised issues:

| ID: 911-01 | Risk of significant escalation in repository costs. Difficult to estimate costs accurately - may mean final costs are much higher. | Helen Wallace (for Greenpeace International) Rock Solid Exec summary | Sept 2010 |

RWMD Response:


Our steps towards implementation report [1] sets out how we evaluate the potential cost of the geological disposal programme in order to plan the financing of our programme and to inform the UK Governments staged decision making process [2]. Specifically it states “cost is affected by many factors, but the most significant are the inventory of waste, the timing of waste arisings, the timing and duration of each phase of implementation, the geology at the site of the geological disposal facility and the design of the geological disposal facility itself”.

At the current stage of planning there are inevitable uncertainties about all of these factors. Therefore we have developed not only a reference case, comprising a reasonable set of assumptions around a reference disposal concept as the planning basis for the implementation programme, as described in reference [1], but also a tool to identify the cost impact of other scenarios. The tool is termed the Parametric Cost Model where the factors identified above are the equivalent of parameters in the cost model.

It is recognised that during the process of site identification, investigation and selection, progressively more information will become available which will be used to provide updated estimates of the cost of implementing the programme. A list of typical assumptions has been generated for each host rock type, to allow concept designs, safety assessments and cost estimates to be prepared. For example; an increase in depth would increase costs of construction and add some cost to operations; likewise a reduction in depth could realise reductions in construction and operational costs; or an increase in inventory would increase the costs of construction during the operational period and the operational costs would increase, conversely a reduction in inventory would reduce the construction and operational costs.

The work to generate cost estimates has been completed to provide good indications of the cost and programme for developing and operating a GDF; the potential for variation in cost is recognised. As detailed information is gained from potential sites, it could be expected that the accuracy would be improved. The cost risks associated with such a significant project particularly at this early stage have been recognised [3].

B.10 Working with waste producers

B.10.1 Generic Waste Packaging Specification

B.10.1.1 Strategy for development of the waste package specifications and waste acceptance criteria

Raised issues:


<table>
<thead>
<tr>
<th>ID: 1011-02</th>
<th>Acceptance Criteria.</th>
<th>Disposability Assessment Database ID54 Use of Ductile Cast Iron Containers for Disposal of intermediate level waste</th>
<th>May 2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>ID: 1011-03</td>
<td>Provide a quantitative analysis of how much water is acceptable for a dried waste within a Ductile Cast Iron container.</td>
<td>Disposability Assessment Database ID31 Disposability of Technological high level waste (Preliminary Assessment)</td>
<td>May 2010</td>
</tr>
<tr>
<td>ID: 1011-04</td>
<td>Develop a better understanding of the issues associated with macro voidage for packages containing high level waste and spent fuel in the developing high level waste/spent fuel disposal concepts and work this up in the relevant Waste Package Specification documents.</td>
<td>Disposability Assessment Database ID51 Use of Ductile Cast Iron Containers for Disposal of intermediate level waste</td>
<td>May 2010</td>
</tr>
<tr>
<td>ID: 1011-05</td>
<td>Develop a position on how much internal package pressurisation is acceptable.</td>
<td>Disposability Assessment Database ID27 Generic Design Assessment of AP1000 Reactor</td>
<td>September 2010</td>
</tr>
<tr>
<td>ID: 1011-06</td>
<td>Develop a position on AP1000 spent fuel and non fuel core components disposability and work up into relevant Waste Packaging Specification documents.</td>
<td>Disposability Assessment Database ID23 Generic Design Assessment of EPR</td>
<td>September 2010</td>
</tr>
<tr>
<td>ID: 1011-07</td>
<td>Define an upper gas pressure limit for spent fuel/high level waste disposal canisters and relate this to the residual water content of AGR fuel.</td>
<td>Disposability Assessment Database ID69 AGR Spent Fuel</td>
<td>October 2010</td>
</tr>
</tbody>
</table>

**RWMD Response:**

We are currently updating our entire suite of packaging specifications, and supporting guidance documentation, to ensure consistency with MRWS and with the 2010 generic Disposal System Specification (DSS) and Disposal System Safety Case (DSSC). The
updating [1] is being carried out in consultation with the regulators and the site license companies (SLCs), and is being overseen by our Nuclear Safety and Environment Committee (NSEC).

We intend to produce a hierarchy of specifications which will define high-level requirements for all waste packages that will be the subject of geological disposal, and to a wider range of waste types than is covered by the existing specifications. This will include a consideration of a wider range of concept options for the disposal of different types of waste included the upper inventory. This includes low heat-generating waste such as intermediate level wastes (ILW) and higher heat-generating wastes such as high level waste (HLW) and spent fuel.

This updating is particularly aimed at providing support to SLCs in the development of alternative approaches to the packaging of waste proposals, for example the use of robust shielded waste containers for the packaging of non-encapsulated ILW.

During 2011/12 we have concentrated on the development of the Level 1 Generic Waste Package Specification and the Level 2 Generic Specification waste packages containing low heat generating waste. The latter, which covers all types of waste package containing ILW, will be used as the basis for the updating and extension of our suite of Level 3 Waste Package Specifications (WPS), which define the requirements for the waste packages that could be manufactured using the standardised waste containers (e.g. 500 litre drum, 3 cubic metre box and drum etc.).

The Level 3 WPS will be supported by a range of guidance including:

- Guidance on the achievement of the Level 3 packaging specifications for:
  - unshielded waste packages
  - shielded waste packages; and
  - robust shielded waste packages

- Guidance on the requirements of wastefoms for:
  - encapsulated wastefoms; and
  - non-encapsulated wastefoms.

This guidance, which will be published during 2012, will address the ILW related issues identified above (1011-02, 1011-03 and 1011-04).

As part of ongoing disposability assessments, notably those being carried out to assess proposals to use ductile cast iron containers (DCIC) for the packaging of ILW, work is underway or planned to investigate such issues as pressurisation and the presence of macro-voidage. These disposability assessments use the existing packaging specifications (i.e. [2]) which are fit-for-purpose at the current stage of assessment. The outcomes of the work will feed into the guidance that will support the Level 3 WPS that will be produced for each of the specific DCIC designs.

During 2012/13 we intend to commence the development of Level 2 Generic Specifications for other wastes (i.e. HLW) and materials that may be declared as waste (e.g. spent fuel, uranium and plutonium). The first of these will cover waste packages containing high heat generating wastes and will include a consideration of issues 1011-05, 1011-06 and 1011-07.


Work to address these issues is planned and will be an input to the development of the Level 2 Generic Specification for high heat generating wastes.

With regard to the issue raised by the peer review of the disposal system specification (issue 1011-01) we are currently engaged in the development of a strategy for the development of waste acceptance criteria (WAC) for a future geological disposal facility (GDF). We anticipate that this will include a definition of how the existing generically based packaging specifications will evolve into WAC as the MRWS process progresses. We also anticipate that, this will be accompanied by a progressive evolution of the disposability assessment process into a GDF acceptance process.

**B.10.2 Upstream Optioneering**

**B.10.2.1 Waste packaging grouting facilities at the GDF**

Raised issues:

<table>
<thead>
<tr>
<th>ID: 1021-01</th>
<th>Consider provision of waste package grouting facilities at the GDF.</th>
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<tbody>
<tr>
<td></td>
<td>Disposability Assessment Database ID42 AWE Hydrus Hydrodynamic Vessels</td>
</tr>
</tbody>
</table>

April 2010
RWMD Response:

This issue relates to the strategic decision about whether a packaging/conditioning plant should be located at the GDF for the management of waste requiring disposal in the GDF. This does not relate to the potential need for a plant to repackage or overpack waste packages that are out of specification on receipt at the GDF.

This is an issue that will be subject to a strategic decision that will be managed by NDA and the site license companies (SLCs), however we will be required in the future to support this with work in our programme if requested to do so by NDA. Work by the SLCs and NDA will be undertaken to consider this issue in the future, once work in our programme progresses and we have more certainty about the facility location and the chosen geological disposal concept. At such time we would, together with NDA, the SLCs, and the local community at a site, consider the provision of a packaging or encapsulation plant at the GDF. This work will be managed as part of our programme of optioneering work as it is an issue that will require a balanced consideration of strategic, environmental, economic, and social factors [1].
