LLW Repository Ltd

Low Level Waste Repository

LLWR Environmental Safety Case

Technical Approach to the 2011 Environmental Safety Case

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EXECUTIVE SUMMARY

Introduction

The Low Level Waste Repository at Drigg (the LLWR) is the UK's principal facility for the disposal of solid low-level radioactive waste. The site is owned by the Nuclear Decommissioning Authority (NDA) and operated on behalf of the NDA by a Site Licence Company (SLC) – LLW Repository Ltd.

We, LLW Repository Ltd., are committed to operating the LLWR as an efficient and environmentally safe facility, providing a continuing safe option for the disposal of low-level radioactive waste in the UK, in accord with the terms of the nuclear Site Licence and our Authorisation from the Environment Agency.

Under the terms of the current Authorisation granted by the Environment Agency (EA), we are required to submit an Environmental Safety Case (ESC) for the site no later than 1st May 2011. This report provides a description of the technical approach that we envisage for the 2011 ESC. It is provided to the EA for information and as a basis for discussion, to ensure that the 2011 ESC will efficiently demonstrate compliance with the EA's regulatory requirements.

The approach set out is our best view at present. We will, however, continue to develop, test and evaluate the approaches set out in the report, and we anticipate that the EA may express views on some issues. Thus, it is likely that some of the approaches may be amended before the 2011 ESC. We will bring forward any key changes or issues for consideration at the regular liaison meetings between the EA and the LLWR, and we will update this document before the 2011 ESC.

Structure of the report

Following an introduction, section 1, the report presents our technical approach to the 2011 ESC in four main sections.

- Section 2 presents our understanding of an environmental safety case as required by the EA, establishes a structure for presentation of the 2011 ESC, and addresses general issues including the range of safety arguments, stakeholder engagement and environmental safety culture and management.
- Section 3 presents our approach to system description and understanding. That is, descriptions and understanding of the disposal system, including the site and its future evolution, the disposal facility as it exists today and will be developed, the waste already disposed and the wastes that could be suitable for disposal at the LLWR in future.
- Section 4 presents our approach to evaluation of options and development of the site management plan. That is, the identification, definition and broad evaluation of options for the future development and management of the LLWR, including options related to past and future waste disposals and overall management of the site.

- Section 5 presents our approach to assessment. That is assessments of the performance and safety of the facility during disposal operations, while under active management following completion of disposals, and after the end of active management of the site.

Finally, section 6, presents comments on the overall strategy to achieve a fit-for-purpose ESC, striking a balance between quantitative modelling and assessment arguments and more qualitative and strategic concerns. The section also confirms that each of the requirements of the new draft regulatory guidance for near-surface disposal facilities will be addressed.

Role of the ESC and general issues

The ESC is designed to satisfy the requirements of the EA as set out in the new draft regulatory guidance. The requirements relate to the protection of members of the public and the environment.

Consistent with the EA's definition of Environmental Safety Case as:

"a set of claims concerning the environmental safety of disposals of solid radioactive waste, substantiated by a structured collection of arguments and evidence",

we propose to present arguments and evidence in a number of areas. This will include arguments and evidence related to

- the NDA's National LLW Strategy,
- waste acceptance at the LLWR,
- identification of the best practical environmental options,
- design and operation to best practice,
- strategy for the lifetime management of the site,
- sufficient programmes of site investigation, measurements, research and assessment.
- results from environmental monitoring programmes,
- understanding of the system performance in terms of safety functions,
- quantitative performance assessments taking account of the relevant uncertainties,
- estimates of dose and risk showing consistency with the criteria specified by the EA;
- assessment of impacts to non-human biota and of the non-radiological hazard posed by the disposed waste,
- demonstration of optimisation through integration of arguments and evidence concerning design, understanding and assessment,
- identification of outstanding uncertainties or open decisions with the power to materially affect any of the above arguments, and
- integration of stakeholder concerns.

We are committed to regular engagement with stakeholders on all LLWR matters. As part of the ESC, we will develop a document that provides an accessible summary of the work that we have done and the results.

We are committed to the protection of the environment and health and safety of both workers and members of the public, now and in the future. The commitment is formalised in our Environment, Health, Safety and Quality (EHS&Q) Policy. This and other policies of the LLWR are delivered through the management system as documented in the LLWR Management System Manual.

Strategy for the 2011 ESC

The development of the ESC is an iterative and ongoing process. Building on an established base, it involves progressive development and focused improvement of data, understanding, design options and assessments.

The modelling and analysis comprising the ESC should be proportionate to the hazard, noting that the LLWR if a facility for the disposal of LLW and not higher activity wastes. We consider that the level of detail in the assessment, and the resources invested in underpinning work, are proportionate to the impacts that might arise from the LLWR.

There needs to be a balance between the different models, arguments and analysis, presented in the ESC. The safety assessment leading to estimates of radiological and non-radiological impact is a key part of the ESC, but it is also important to provide confidence building arguments in support of the quantitative results, and to address the other requirements set out in regulatory guidance. The 2011 ESC will place more emphasis on these other requirements and on confidence building arguments than was the case in the 2002 PCSC. Key arguments relate to:

- the need to demonstrate optimisation, in particular the consideration of alternative design, management and, if required, remediation strategies and the selection of sensible options on the basis of logical argument;
- the demonstration of robustness in terms of showing that the safety case is robust if certain assumptions used as a basis for the safety assessment were to be wrong, as well as in terms of general confidence building arguments;
- adequate characterisation of the site and an appropriate level of understanding of the characteristics of the waste and the performance of the engineered system.

Good links have been developed between the ESC and other key projects, so that the ESC can be used as a tool to help manage the site and reach key decisions about its management and on waste acceptance. The key interfaces include:

- with NDA's work, supported by the LLWR, to develop a national strategy for LLW management and disposal;
- with the LLWR's work to develop and substantiate a repository design;
- with the Consignor Support team within the LLWR in relation to waste acceptance issues.

The benefit in involving stakeholders in the development of our plans is also recognised.

Confirmation that the regulatory requirements will be addressed

A key objective of the 2011 ESC will be to demonstrate compliance with the Requirements in the environment agencies' new draft guidance for near surface disposal facilities. Table E1 lists the Requirements and indicates our approach to each Requirement.

Overall, we consider that the approach outlined will lead to an ESC that is a significant step forward from previous safety case submissions. We stand ready, however, to respond to comments and, if necessary, amend our approach in order to take account of the views of the Environment Agency and other stakeholders.

Table E1 Addressing the Requirements in the Draft Regulatory Guidance

Requirement	Approach	Cross reference
R1 Voluntary Agreement	This requirement is directed at the early stage of repository development, whereas the LLWR has been a facility for the disposal of radioactive waste since 1959. It is therefore not of direct relevance to the LLWR.	-
R2 Step-wise Process	A step-wise approach is indicated, involving voluntary submissions to the Environment Agency, during the early stages of repository development. As the LLWR has a current authorisation, the requirement is not of direct relevance.	-
R3 Dialogue with Potential Host Communities and others	The LLWR is committed to dialogue with stakeholders.	Subsection 2.6
R4 Environmental Safety Case	This document described the proposed technical approach to delivering an ESC.	Section 2
R5 Environmental Safety Culture and Management System	We are committed to the protection of the environment and health and safety of both workers and members of the public, now and in the future. The commitment is formalised in our Environment, Health, Safety and Quality (EHS&Q) Policy	Subsection 2.7

Table E1 (Continued)

Requirement	Approach	Cross reference
R6 Dose Constraints during the period of Authorisation	The site will be monitored during the operational period and, if observations warrant this, actions will be taken to reduce discharges. We will use simple modelling approaches to determine potential releases during the operational period – to complement the information obtained from monitoring and to demonstrate that we are developing a consistent understanding of the performance of the facility.	Subsection 5.2
R7 Risk Guidance Level after the period of authorisation	A range of calculations will be undertaken to estimate the risks arising from a range of scenarios.	Section 5
R8 Human Intrusion after the period of authorisation	The radiation doses arising from human intrusion will be addressed as part of the ESC.	Subsection 5.10
R9 Optimisation	A range of options assessments or evaluations will be undertaken to address the key questions about the design, use and management of the site.	Section 4
R10 Environmental Radioactivity	Radiological impacts to non-human species will be estimated using the ERICA approach. We will also compare levels of radioactivity arising from the facility with naturally occurring levels of radioactivity.	Subsection 5.12
R11 Protection against Non-radiological Hazards	Calculations will be undertaken as part of the ESC, using an approach as closely aligned to the approach for radioactive contaminants as is possible. These will be used to assess the extent to which the facility provides adequate protection against non-radiological hazards.	Subsection 5.11
R12 Site Investigation	The LLWR has carried out an extensive programme of site investigation, and is also undertaking further work. The programme of site characterisation, the resulting conceptual models and data and their use in the safety assessment will be described in the ESC.	See references in main text and subsection 3.3.

Table E1 (Continued)

Requirement	Approach	Cross reference
R13 Use of the Site and Facility Design, Construction, Operation and Closure	In the ESC, the reasons for the choice of design and its suitability will be discussed. This will cover the work undertaken on optimisation and reference will also be made to the various engineering studies undertaken.	Optimisation is discussed in Section 4. Reference will also be required to various design documents.
R14 Waste Acceptance Criteria	Waste acceptance criteria are available and will be updated, following submission of the ESC to be consistent with our latest understanding of the safety issues and any updated Authorisation.	Subsection 5.13 and LLWR (2007b)
R15 Monitoring	The LLWR has an integrated, extensive and ongoing programme of monitoring. This will be presented as part of the ESC.	Hilary (2008)

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1 INTRODUCTION

The Low Level Waste Repository at Drigg (the LLWR) is the UK's principal facility for the disposal of solid low-level radioactive waste. The site is owned by the Nuclear Decommissioning Authority (NDA) and operated on behalf of the NDA by a Site Licence Company (SLC) – LLW Repository Ltd [1].

We are committed to operating the LLWR as an efficient and environmentally safe facility, providing a continuing safe option for the disposal of low-level radioactive waste in the UK. This will be achieved in accord with best technical practice for the near-surface disposal of radioactive waste, in compliance with applicable environmental and health and safety legislation, in accord with regulatory guidance and in compliance with the terms of the authorisations under which we operate

Waste is disposed at the LLWR under the terms of authorisations under RSA93 that are periodically reviewed and renewed by the Environment Agency for England and Wales (the EA). The current authorisation, dated 1st May 2006, is divided into a number of schedules, of which Schedule 9 is a list of improvements and additional information that the operator must supply. Requirement 6 of Schedule 9 demands that the operator shall periodically update the Environmental Safety Case for the site covering the period up to withdrawal of control and thereafter and, in particular, such an update shall be submitted to the Agency five years from the effective date of the current Authorisation, i.e. by 1st May 2011.

We have initiated a programme of work to address the requirements of Schedule 9. A prime goal of the work is the production of an Environmental Safety Case by May 2011 (the 2011 ESC). The 2011 ESC will follow the EA's guidance on requirements for authorisation for near surface disposal facilities (currently in draft) (Environment Agencies, 2008). It will build on the experience of the 2002 OESC and PCSC submissions (BNFL, 2002a, BNFL, 2002b) and the EA's review of those documents (Environment Agency, 2005; Environment Agency, 2006), and also our more recent submissions under Schedule 9 (LLWR, 2008a to 2008e; Eden and Barber, 2007; Barber and Henderson, 2008) and the EA's comments thereon.

General issues around the development of a safety case for the LLWR, according to best international practice and appropriate to the context of the LLWR, were set out in a previous "Safety Case Approach" report (Lean and Fowler, 2007). That report remains a valid overview of the general issues. This report outlines a top-level structure for the 2011 ESC, sets out our technical approach in key areas, and outlines work that we are undertaking to further improve the basis for the 2011 ESC. Hence, it is complementary to the previous report, providing information on ongoing work, technical approaches and calculations that we intend to undertake in the 2011 ESC.

The ESC will draw on a number of important strands of work that are proceeding in parallel with the work to develop the ESC. A key activity is the development by the NDA with LLWR

1 United Kingdom Nuclear Waste Management (UKNWM) Ltd. holds a contract from the NDA for the management and operation of the LLWR and shares in the SLC were transferred to UKNWM Ltd. on 1st April 2008.

support of a national strategy for the management of LLW. This will assess the potential uses of, and waste consignment, to the LLWR in a national context, taking account of a range of alternative strategies. There will be important links between this strategy and the arguments that will be deployed in the ESC (see section 3). Work to provide better integration of the monitoring programme and to ensure that it is oriented towards the needs of end users, such as the ESC Project, is proceeding (Hilary, 2008). In addition, there are important activities that will proceed in relation to the optimisation of the design and operations, to which the ESC team will provide key inputs (see section 3).

This document is provided to the EA for information and as a basis for discussion. This is with a view to ensuring that the 2011 ESC accords with the EA's expectations. The approach set out is our best view at present. However, we continue to test, evaluate and develop the approaches set out in the report, and therefore some changes may occur. We will be updating this safety case approach document in the future, as appropriate, and will continue to bring forward any key changes or issues for consideration at the regular liaison meetings between the EA and the LLWR.

2 THE ENVIRONMENTAL SAFETY CASE

2.1 Regulatory guidance

Requirement R4 of the draft guidance on requirements for authorisation for near surface disposal facilities (NS-GRA) (Environment Agencies, 2008) states:

> *"An application under RSA 93 relating to a proposed disposal of solid radioactive waste should be supported by an environmental safety case."*

Supporting text defines an Environmental Safety Case as:

> *"a set of claims concerning the environmental safety of disposals of solid radioactive waste, substantiated by a structured collection of arguments and evidence"*

and further states that the Environmental Safety Case should be designed to show that the management, radiological and technical requirements set out in the chapter (i.e. Requirements 5 to 15 set down in Chapter 6 of the NS-GRA) are met. Further guidance on the Environmental Safety Case is provided in Chapter 7 of the NS-GRA.

Our approach to addressing the 15 requirements in the NS-GRA is summarised in Table 6.1 and discussed further in section 6. We also set out our current view of the key safety arguments and issues in subsection 2.5.

2.2 Roles and nature of the ESC

As well as being required as a condition for authorisation, see above, we regard our Environmental Safety Case (ESC) as a key management and communication tool:

- to develop the LLWR as an environmentally safe facility and
- to communicate the evidence and arguments concerning environmental safety and its basis.

The ESC presents the knowledge and understanding on which our assessments of environmental safety are based. It also provides the basis for our decision-making concerning the options that are available to further improve the facility. The ESC is a very important tool for deciding on future management and waste acceptance issues.

The development of the ESC is an iterative and ongoing process. Building on an established base, it involves progressive development and focused improvement of data, understanding, design options and assessments. The development must integrate information from a wide range of technical studies, as well as non-technical inputs and decisions.

2.3 Structure for presentation

For the 2011 ESC, we propose to present the ESC as three main elements:

- **System description and understanding** – descriptions and understanding of the disposal system, including the site and its future evolution, the disposal facility as it exists today and will be developed, the waste already disposed and expected future wastes that would be suitable for disposal at the facility. This includes characterisation of the wastes, the site and the engineered barriers, understanding of the site hydrogeology and evolution, and results of monitoring.

- **Options and Site Management Plan** – identification, description and broad evaluation of options for the future development and management of the facility up to closure and beyond, including options related to past and future waste disposals and overall management of the site. The assessment will be used, as it is being developed, as a tool to analyse options. Description of a Site Management Plan including preferred options and timeline for the development and management of the site. Variants may be considered, for example, with respect to future waste arisings, engineering and site management.
- **Assessment** – assessments of the performance and safety of the facility during disposal operations, while under active management following completion of disposals, and after the end of active management of the site. The focus will be on radiological risks and doses to members of the public, but the impacts from chemotoxic substances and radiation doses to non-human species will also be considered. The final assessments will be undertaken on the basis of the Site Management Plan.

The work, including the development of each of the above elements, is being executed within a sound management framework that ensures commitment to safety and quality, and is carried out according to an ordered work plan that provides timely information and results for decision-making and steps of the assessment process.

Figure 2.1, part (a), illustrates the schematic connection of elements leading to the ESC and part (b) indicates in which element the GRA requirements for the ESC will be addressed. The red arrows indicate the predominant logical flow of understanding, options and assessment leading to articulation of the ESC. The orange arrows indicate feedback and iteration needed, for example, results of assessment indicate areas in which further data or understanding are needed and guide choices between options.

Figure 2.2 presents an alternative arrangement of the elements of the figure indicating a general document structure for the ESC.

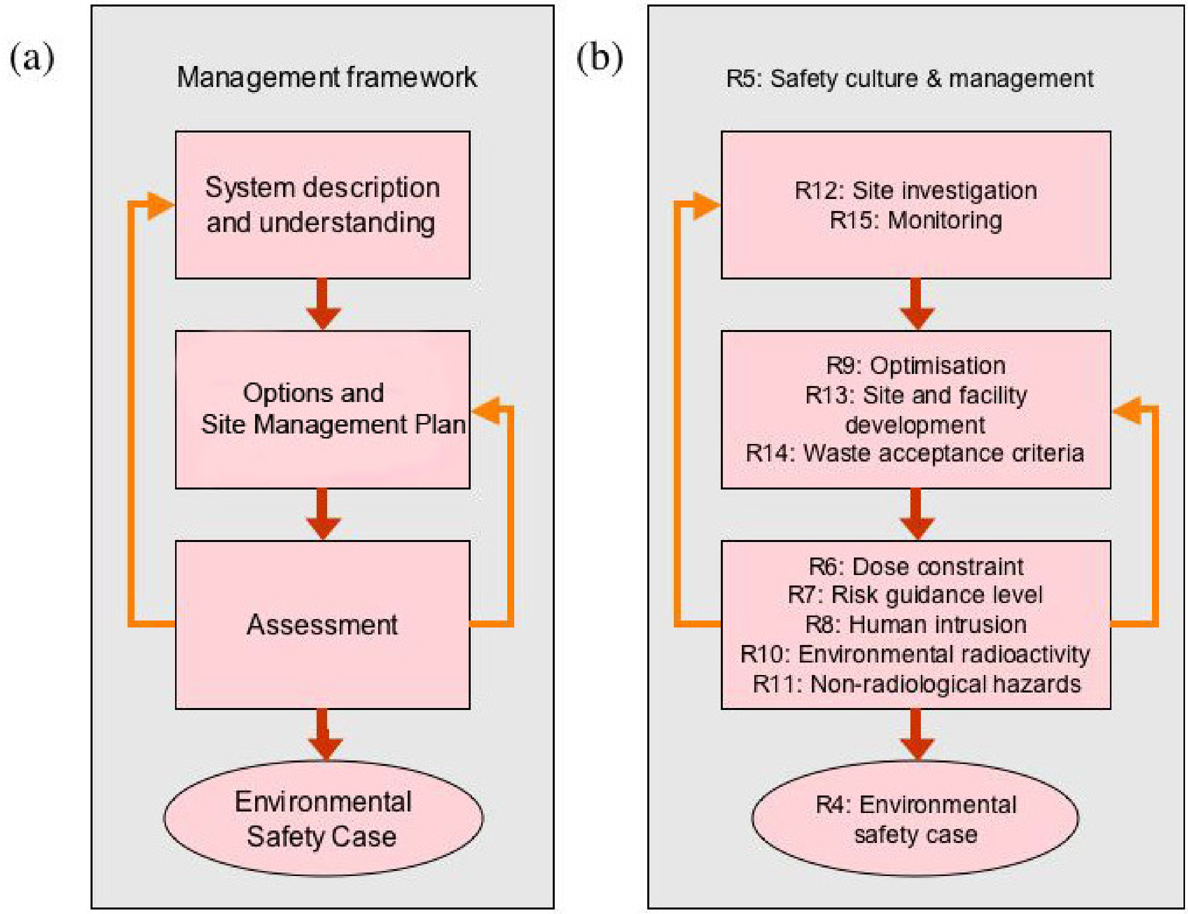

Figure 2.1: Schematic connection of elements leading to the ESC and the elements within which EA's Requirements will be addressed.

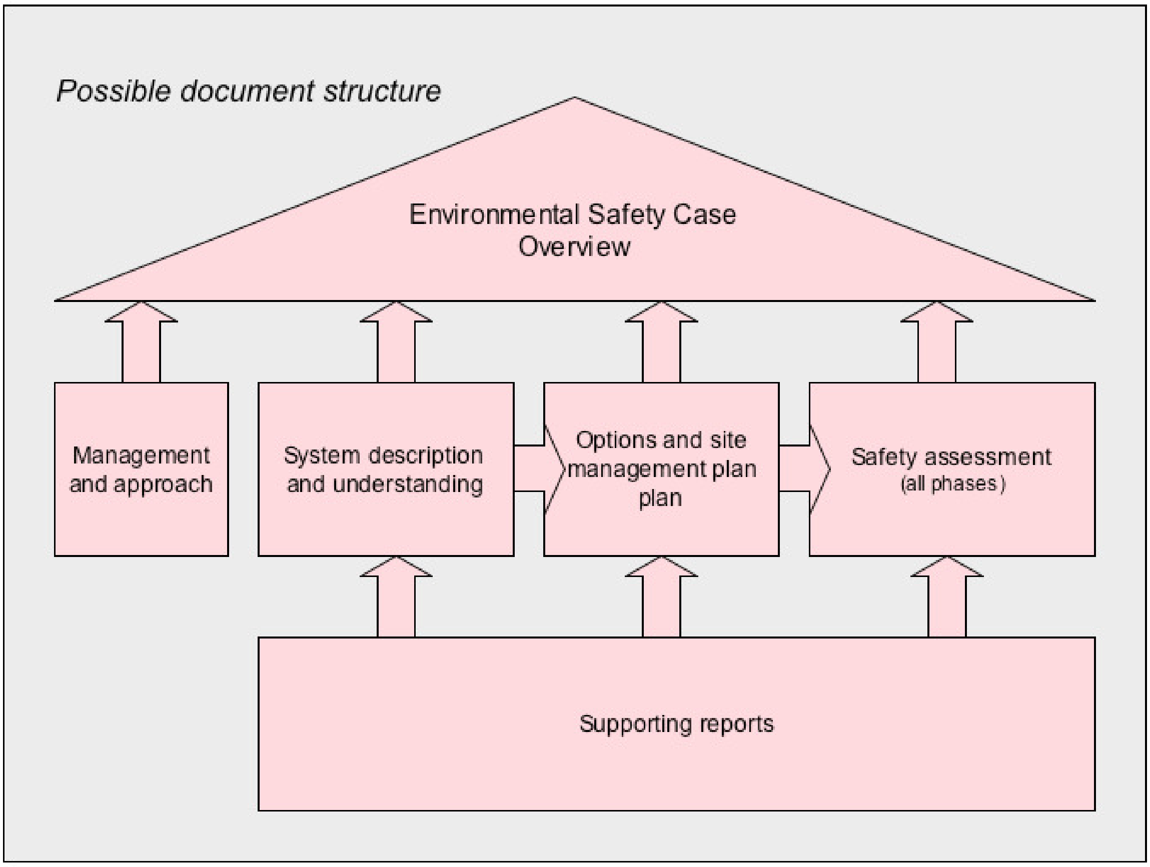

Figure 2.2: Possible document structure – overview, main volumes (some might be subdivided) and supporting reports.

2.4 Scope

The ESC is designed to satisfy the requirements of the Environment Agency as set out in the NS-GRA. The NS-GRA sets a fundamental protection objective:

'to ensure that all disposals of solid radioactive waste to facilities on land are made in a way that safeguards the interests of people and the environment now and in the future, commands public confidence and is cost-effective.'

The Environment Agency guidance and requirements relate to the protection of members of the public and the environment. The focus is on radiological protection of members of the public, but radiological protection of non-human species and protection of members of the public and the environment from non-radiological components of the waste and facility, are also required.

The ESC presents the evidence and arguments that adequate protection is being and will be achieved:

– during waste disposal operations;
– after disposals are complete, while the site remains under management and regulatory supervision;
– after withdrawal of management and regulatory supervision.

In particular, the ESC demonstrates protection consistent with the requirements set out in the NS-GRA.

The ESC is not concerned with protection of workers or conventional safety issues, which are regulated by the HSE. These issues may, however, be an input to choices between waste and site management options.

The ESC is not concerned with conventional environmental impacts, e.g. traffic, noise, visual amenity, which are dealt with in submissions under local planning procedures. Some of these issues may, however, be relevant to choice of site management options e.g. confidence that planning permission can be gained for proposed future site developments and influences on future land uses.

Besides presenting the system description and understanding, options and Site Management Plan and assessments of environmental safety performance, as defined in subsection 2.3, the ESC will also present a high level integration of the arguments and evidence for safety. This will include a qualitative analysis of the safety functions of the facility and the features or controls that satisfy or enhance each function.

2.5 Safety arguments and evidence

The ESC will present the structured arguments and evidence concerning the environmental safety of disposals of solid radioactive waste at the LLWR as required by the NS-GRA (see subsection 2.1).

We propose to present arguments and evidence in the following areas.

1. We will draw on the output of the NDA's National LLW Strategy to set out the role of the LLWR and the wastes that should be disposed.
2. We will show that the conditions placed on the waste that will be accepted at the LLWR are appropriate to ensure environmental safety, in the period of authorisation and afterwards, and that verification procedures ensure that the wastes received meet those conditions.
3. We will examine options for the improvement or remediation of existing facilities at the site and propose options for their future management based, ensuring an appropriate balance between different factors.
4. We will show that proposed new facilities at the site are designed and operated to best practice for low-level radioactive waste radioactive waste disposal with due

attention to the location and nature of the site and the wastes that are to be disposed.

5. We will propose a strategy for the lifetime management of the site, including proposals for site engineering and long-term institutional controls, such that, at an appropriate time, it will be possible to release the site from management control and direct regulatory supervision.

6. We will show that through our programmes of site investigation, measurements, research and assessment that we have developed a sufficiently detailed and reliable description of the local environment and of the disposal system to support our modelling and analysis of the system and, in particular, to support our estimates of performance indicators required by the NS-GRA.

7. We will present results from environmental monitoring programmes that provide direct evidence that releases of radioactivity from the site at present day and in the past are low, and that doses (to the local population and to non-human biota) calculated on the basis of monitoring are very low.

8. We will illustrate a thorough understanding of the performance of the existing and planned disposal facilities in terms of safety functions, e.g. isolation of the waste, containment of radionuclides and attenuation of releases, and the features and processes that promote or potentially reduce those functions.

9. We will assess the performance of the disposal system through quantitative modelling taking account of a full range of relevant uncertainties (see section 5). The assessment will consider the site under present-day conditions and as it may evolve due to environmental changes and human activities.

10. We will integrate our arguments and evidence above concerning design, understanding and assessment, to show that we have done all that we reasonably can in terms of design and site management so that present and future radiological impacts are as low as reasonably achievable.

11. We will present estimates of dose and risk to humans as indicated in the NS-GRA, with the aim of showing that the dose (during the period of authorisation) and the assessed risks and doses (after the period of authorisation) are consistent with the dose constraint, risk guidance level and dose guidance level specified by the EA. We will also assess the impact to non-human biota and the non-radiological hazard posed by the disposed waste. A summary of the approach to showing compliance with the relevant NS-GRA requirements is given in section 6.

12. We will systematically show compliance with each of the Requirements of the NS-GRA. Subsection 6.2 and Table 6.1 indicate how this may be achieved also referring to other sections of this report

13. We will identify any outstanding uncertainties or open decisions with the power to materially affect any of the above arguments, and set out the work needed to resolve the uncertainty or support future decisions.

14. We have explored the key environmental safety issues with a range of stakeholders, have taken account of their views in developing our proposals, and will continue this dialogue to ensure the continuing acceptability of our proposals.

2.6 Stakeholder engagement

In reaching a view about the use, management and operation of the site, consultation with stakeholders is key. Our stakeholders include:

- local residents;
- councils at the parish, district and county level;
- unions and employees;
- regulators such as the EA and the Health and Safety Executive (HSE);
- the Nuclear Legacy Advisory Forum (Nuleaf);
- the West Cumbria Site Stakeholder Group (WCSSG) subcommittee on LLW;
- waste consignors;
- national government;
- politicians;
- the technical community, including our contractors.

We are committed to regular engagement with stakeholders on all LLWR matters, for example the WCSSG LLWR Subcommittee has received presentations on issues specifically relating to repository operations and individual projects, including this Project. Regular interface meetings are held involving Cumbria County Council, the EA, the HSE and the NDA. Quarterly liaison meetings take place between the SLC and Drigg and Carleton Parish Councils, affording the opportunity for any concerns to be raised and addressed. This forum is also used to provide an update on current operations and projects and to discuss future plans for the Repository. Consignors have open access to a LLWR team and meetings are arranged to address specific issues. In addition, a Consignors Forum is arranged on an annual basis. As part of the work reported in Requirement 2, we have held two project-oriented stakeholder workshops to explain our approach and methodology and to seek stakeholder views as an input to the analysis (LLWR, 2008b). We are committed to continuing stakeholder engagement as part of future work.

As part of the ESC, we will develop a document that provides an accessible summary of the work that we have done and the results. This will be as non-technical as possible in orientation and therefore potentially suitable to inform a wide range of stakeholders including local residents and councillors. We are also planning to place additional information relevant to the ESC and the supporting programme of work on the LLWR's website.

2.7 Environmental safety culture and management system

We are committed to the protection of the environment and health and safety of both workers and members of the public, now and in the future. The commitment is formalised in our Environment, Health, Safety and Quality (EHS&Q) Policy (see Box 2.1).

Box 2.1: LLW Repository Ltd. Environment, Health, Safety and Quality Policy

We believe that nothing is more important than the protection of the environment and the health and safety of the workforce, contractors and the public. We are committed to the success of our customers and will achieve this through continuous improvement, operational excellence and delivery of quality products and services.

LLWR commits to:	*We will achieve this by:*
Striving to achieve zero harm to people and minimal impact on the environment through our operations	Carefully identifying and managing any environmental, radiological or conventional hazards associated with our operations in order to minimise actual risks
Maintaining excellent nuclear safety standards at all times	Ensuring proper control, containment and management of our nuclear material
Maintaining our arrangements in compliance with all legal and regulatory requirements, and ISO 14001, 9001 and OHSAS 18001, as a minimum	Operating simple and effective EHS&Q management systems in line with legal and regulatory requirements
Continually improve our environmental performance	Setting and achieving targets to prevent pollution, remove impacts arising from historic activities, reduce waste arisings and disposal and minimise the use of natural resources
Providing clear and uncompromising leadership that constantly and actively promotes strong EHS&Q standards	Communicating our EHS&Q standards and aspirations to all site personnel, and ensuring sufficient SQEP personnel are in place to maintain these standards
Promoting the occupational health and welfare of our staff	Regularly monitoring occupational health and providing information and encouragement to personnel
Learning from our experiences, and the experiences of others, for the benefit of all	Sharing both our best practices and any learning from events with others, and actively utilising the learning from others
Building and retaining the confidence and satisfaction of all of our customers	Continually reviewing and improving the delivery of our high quality, fit for purpose products and services
Encouraging our people to work in partnership, be accountable, questioning and challenging with each other	Maintaining a culture that encourages the free and honest reporting of EHS&Q issues, and listening to, consulting with and responding to our customers, employees, contractors and stakeholders

The LLWR management system is designed to deliver the EHS&Q policy and other policies as documented in the LLWR Management System Manual (LLWR, 2007a).

The management system details the policies, objectives, organisation, processes and procedures for the safe, secure, environmentally responsible and cost-effective clean up of the nuclear legacy and disposal of waste on the Low Level Waste Repository Site. This entails managing the operation of nuclear material storage and disposal and the subsequent decommissioning of redundant nuclear plant compliant with the requirements of:

- the LLW Repository Ltd arrangements;
- authorisations, consents and permits granted by the Environment Agency or Local Authority;
- the Nuclear Decommissioning Authority (NDA) contract;
- British Nuclear Group;
- BS EN ISO 9001: 2000 - Quality Management Systems – Requirements;
- BS EN ISO 14001: 2004 - Environmental Management Systems.

The management system comprises a manual and supporting enablers including LLWR process maps, procedures and working Instructions (operating, maintenance etc.).

The management system applies to all activities carried out by LLWR and compliance with its requirements is mandatory. Access to management system documents is via the LLWR IT infrastructure.

Within the LLWR Management System Manual, the Management Prospectus details the Environment, Health, Safety and Quality management arrangements that LLW Repository Ltd. implements and utilises to manage and operate the LLWR Nuclear Licensed Site,

The prospectus is produced in support of the LLW Repository Ltd. Site Licence in accordance with the guidelines set out in the HSE document 'The Regulation of Nuclear Installations in the UK including notes for licence applicants', and summarises the LLW Repository Ltd. arrangements as licensee for the management of health and safety.

In addition to this, the prospectus details how LLW Repository Ltd. makes arrangements for and complies with its responsibilities and legal duties in terms of environmental protection, including compliance with the authorisations for waste disposal made under the Environmental Protection Act 1990, the Radioactive Substances Act 1993 and the Pollution Prevention and Control Act 1999 (amongst other items of legislation). It should be noted that any general reference in this prospectus to 'Environmental Authorisations' refers to any relevant environmental authorisation, consent, permit or licence issued by the Environment Agency or local government authority in pursuit of environmental protection under the relevant legislation.

The prospectus addresses those aspects of the management systems relevant to the achievement, and where reasonably practicable the enhancement, of the Environmental, Health, Safety and Quality standards that are demanded by the LLW Repository Ltd Environment, Health, Safety and Quality Policy Statement.

The LLW Repository Ltd. Board has adopted the management prospectus and by means of the management arrangements described in this prospectus, LLW Repository Ltd. meets its responsibilities under UK health, safety and environmental legislation, and in particular its responsibilities as a licensee under the Nuclear Installations Act 1965 (as amended) and as a company authorised to store and dispose of waste to the environment under the terms and conditions of Environmental Authorisations.

The management prospectus will be maintained to provide an overall high-level description of the management arrangements for LLW Repository Ltd. and senior management EHS&Q accountabilities.

LLW Repository Ltd. has a suite of environmental, health and safety and quality arrangements, which it is the intention of the LLW Repository Ltd. Board to maintain and develop further to give continual improvement. Changes to the management system are, and will continue to be, subjected to the Nuclear Site Licence Conditions due processes including, where appropriate, arrangements made under Nuclear Site Licence Condition 36 'Control of organisational change' and the RSA 93 LLW Repository Ltd. Authorisation Schedule 1 Condition 6 requirements. Any changes to the arrangements described in this prospectus affecting the requirements of the Nuclear Site Licence or Environmental Authorisations would be subjected to consultation and due process with the HSE Nuclear Installations Inspectorate (NII) and the Environment Agency (EA) where relevant.

3 SYSTEM DESCRIPTION AND UNDERSTANDING

In this section, the approach being used to understand the behaviour of each component of the repository system is described. We describe our approach, the current status and the direction of future work.

3.1 Wastes and inventory

A good understanding of the wastes and inventory is required as a basis for the assessment. To date, considerable effort has been put into the scrutiny of records of the disposals of key radionuclides to the Trenches. As a result of this work, a good understanding has been acquired of the Trench inventory of radionuclides such as ^{238}U, ^{226}Ra and ^{232}Th (Wareing et al., 2008). It has also been possible to form a good appreciation of the distribution of radionuclides within the Trenches (Lennon et al., 2008).

We consider that further improvement of the inventory is required as a basis for the 2011 ESC. Our strategy is to focus on the following areas:

- Reducing the uncertainties in key components of the national LLW inventory and understanding as much as possible about the form of key radionuclides;
- Understanding the waste disposal practices used over time at the LLWR and what implications there might be to the inventory of disposed wastes at the site;
- Considering and evaluating the consequences of different waste treatment and disposal strategies identified as potential components of the NDA's National LLW Strategy.

The work to reduce uncertainties in the future disposal inventory is focused on key radionuclides and key waste streams. This involves review of information in the national inventory, waste stream characterisation documents and consultation with waste consignors. This work is part of and consistent with other plans being taken forward by the NDA to improve the national inventory of LLW. This work will lead to estimates of the range of uncertainty in the disposal inventory of key radionuclides. We will also evaluate the uncertainties associated with the use of fingerprints from recent waste streams to reconstruct the radionuclide inventories of wastes disposed some time ago to the Trenches. This will require comparison of fingerprint-based estimates with real disposal records.

We are undertaking further work to interview a range of both current and retired staff with operational experience of waste disposals at the LLWR and of consigning waste from other sites to the LLWR. This is to determine the practices used, the approach to complying with the appropriate waste acceptance criteria and any information concerning the wastes that were disposed. The work addresses concerns raised by stakeholders about the extent and quality of our knowledge of the disposal inventory during the early development of the LLWR. The output will be used as an input to the work described above on the reduction and characterisation of uncertainties. A key element will be to determine whether any findings or uncertainties have any implications to our view of the performance of the site.

A number of innovative approaches are being considered to waste treatment and management. These are likely to result in changes to the characteristics of the future disposal inventory. The overall future disposal inventory is being developed as an output of work on the NDA's National LLW Strategy. As described in section 3, work will be undertaken by the ESC project team to evaluate the impact of these changes. The inventory used in the 2011 ESC will be based on certain stated assumptions concerning the use of the different available waste treatment and disposal routes.

3.2 Engineered system

The engineered system includes the various engineered barriers (e.g. cap and cut-off walls), the waste itself, surrounding backfill and waste containers. There is need to understand a range of processes that affect the leaching and mobility of contaminants from the waste and the resulting evolution of conditions over time. The range of processes and our current conceptual model are described in LLWR (2008c).

Possible approaches to the treatment of the near field in the 2011 ESC are discussed in more detail in Small et al (2008). As part of that review, the relevant FEPs have been reviewed to determine which require consideration. In particular, the following FEPs or approaches were evaluated in terms of the need to address them in assessment or underpinning models in the 2011 ESC:

- the effects of variation in chemical conditions and the effect on solubility and sorption;
- by-passing of water flow around some wastes;
- consideration of the unsaturated zone;
- waste form release models;
- sorption to a wider range of materials present in the LLWR than grout and soil;
- use of site and experimental leachate data; and
- representation of engineering features.

Assessment modelling is discussed in subsection 5.7.1.

3.2.1 Biogeochemical processes

A number of biogeochemical processes control the environment within the LLWR and influence the release from the wasteform and mobility of radionuclides. Consequently, an understanding of these processes has been a key objective of the LLWR's technical programme. A programme of experimental work and modelling underpinned the conceptual model used in the 2002 PCSC. The biogeochemical program DRINK was used to assess these processes and was used directly as an assessment model (BNFL, 2002c). Its functionality includes groundwater flow, radioactive decay, waste degradation, microbial reactions, sorption, gas generation and geochemical reactions.

Key degradation processes involve the oxidation of organic materials and the corrosion of metals. It is well established that microbial processes mediate and catalyse these slow waste degradation processes, particularly of organic materials. Iron corrosion may be enhanced as a result of microbial processes. Cementitious materials comprising the vault waste form may result in the establishment of alkaline chemical conditions, which may affect the degradation of organic matter and corrosion. Understanding the processes of waste degradation is important to characterising the chemical environment of radionuclides in LLW. Site monitoring studies and waste simulation studies have been undertaken to support the development of this understanding (see BNFL, 2002c).

The DRINK program was used to model the evolution of pH, Eh and other chemical parameters. The principal effects of the disposal of waste and waste form materials in the Trench and Vault environments were to produce reducing conditions by processes of organic waste degradation and corrosion. The model predicted the establishment of chemical conditions in the trenches that were significantly more reduced than in the adjacent geosphere. Site monitoring confirms that reducing conditions are already being established in the trenches, characterised by anaerobic conditions and the production of reduced chemical species such as methane, acetate and sulphide (BNFL, 2002c). The duration of this period of reducing conditions was predicted to last for some thousands of years.

Acidic conditions were predicted to develop in the Trenches as a result of the production of acetate and carbon dioxide resulting from the degradation of cellulose by the microbial processes included in DRINK. After around 2,000 years, when cellulose was predicted to be fully degraded, pH increased above that of the groundwater; this is a result of iron corrosion processes, which yield hydrogen and generate alkalinity.

In the Vaults, alkaline conditions were predicted to develop as a result of the presence of a large proportion of cementitious material releasing alkalis to groundwater. These were expected to persist for some thousands of years. Evidence for the establishment of reducing and alkaline conditions in the vault environment comes from experimental simulant studies (BNFL, 2002c).

This broad conceptual understanding of the system remains valid. However, a further programme of modelling is required prior to the 2011 ESC in order to take account of changes to wastes, waste packaging and design and the results of geochemical modelling and experiment since the 2002 PCSC. In the 2011 ESC, it is not intended to use DRINK as an assessment model (see subsection 5.7), but there is still a need to demonstrate an understanding of the biogeochemical evolution of the system using more realistic models.

It is important to derive an understanding of pH and Eh variations as these conditions can control the chemical behaviour of key radionuclides. For the 2011 ESC, we envisage using coupled models of chemical reaction and transport to examine variations in Eh and pH within components of the facility. These detailed models will underpin the choice of chemical parameters to represent the behaviour of key radionuclides in assessment models.

Estimates of the rates of production of bulk and radioactive labelled gas need to be updated. We envisage using a program such as DRINK that would provide a detailed understanding of the partitioning of carbon species between solid liquid and gas. This will provide an estimate of gas generation appropriate to an updated understanding of the site. The approach would also provide appropriate information to support an assessment of the impact of ^{14}C that is released in groundwater.

We will use appropriate modelling techniques to examine the partitioning of carbon species between gaseous, liquid and solid phases. Of particular importance are reactions with cement phases. It may be necessary to consider reactions at the margins of fractures or other flow pathways. We will also need to assess the impact of proposals to reduce the amount of grout present in the future vaults.

In work to date, a kinetic model for the release of uranium from a Springfields fluoride wasteform has been developed (Small et al., 2008a). Where understanding and data justify this, we will develop further models for the release of activation products from wasteforms. The focus is likely to be on ^{14}C, ^{36}Cl and various metals that are important in the assessment of chemotoxic impacts. In some cases, release of the contaminant may depend on the corrosion rate of the host metal. Supporting chemical modelling may be required.

3.2.2 Flow and transport

A number of FEPs need to be considered, related to groundwater flow and transport through the facility. These include the distribution of flow, which is unlikely to be homogeneous, the presence of a substantial unsaturated zone and the effects and degradation of the engineered barriers on flow.

It is likely that flow through the facility will be focused along particular pathways, for example in the channels between the ISO containers in the Vaults. There are a range of possible effects, which we will investigate using coupled models of transport and chemical reaction. These include potentially limited equilibration between the water and the waste, which would reduce the release of contaminants. Alternatively, such localised flow might mean that the waste could equilibrate with porewater that had not been conditioned to high pH, which might increase the releases of some radionuclides. We will examine alternative scenarios and consider their implications to the safety assessment calculations.

Previous work has shown that it is likely an unsaturated zone will exist within the Trenches and Vaults. We will consider whether this needs explicit representation in any models.

Flows through the engineered system will be controlled by the engineered barriers, which will degrade over time. We envisage eliciting the time dependent flow properties of the barriers, using the same general approach that is described in Paksy (2008). The time-varying flow through the engineered barriers will need to be represented in assessment models. The appropriate approach is still under consideration.

3.3 Geology and hydrogeology

As part of the recent development of the ESC programme, the understanding of the geological and hydrogeological evolution of the site has been reviewed at a number of workshops and is being considered in some specific technical tasks. Key issues that we have identified for further work include:

- examining the links between the geology and the hydrogeology;
- considering alternative hydrogeological conceptual models for the site;
- reviewing the feasibility of constructing heterogeneous porous medium models and their potential utility.

We have taken account of comments raised by the Environment Agency Geosphere Review Group following the 2002 PCSC (Environment Agency, 2005). They identified a number of issues for further consideration:

- consideration of the variability of the geology and associated hydrogeological properties in alternative geological and hydrogeological representations;
- recognition of conceptual or parameter uncertainty;
- structural uncertainty in hydrogeological units;
- demonstration that the possible range of hydrogeological conditions has been adequately considered in the development of upper and lower bounds for the assessment model.

The Peer Review Panel has also questioned the validity of the links between the geology and hydrogeology assumed in the most recent conceptual model of the site (Bennet et al., 2008). Further work to address these concerns has already been commissioned along with a continued programme to update and revise the 2002 understanding of the geology and hydrogeology of the site.

Investigation of the geology and hydrogeology at the LLWR site and surrounding areas has taken place for many decades. Geophysical surveys, trial pits and over a 1000 boreholes within the site boundary have provided a great deal of information on the underlying strata. Beyond the site boundary there are fewer boreholes. It is recognised that between the site and the coast there are few data. To address this area of uncertainty, it is has been proposed that additional boreholes are constructed in the area between the LLWR and the coast, to investigate the geology and to provide long-term hydrogeological monitoring. The aim is to have sufficient data available before 2010 to enable the data to be used as an input to the 2011 ESC.

The geology underlying the LLWR site can be differentiated into solid geology (Sherwood Sandstone) and heterogeneous drift geology (predominantly glacial and interglacial deposits). Both the lithostratigraphic[2] approach (BNFL, 2002d) and the lithofacies[3] approach (Smith et al,

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2 Lithostratigraphic – pertaining to a stratigraphy defined on the basis of rock type.
3 Lithofacies - a lateral, mappable subdivision of a designated stratigraphic unit, distinguished from other adjacent subdivisions on the basis of noteworthy lithological characteristics.

2007) can be used to represent the observed geological conditions. Both approaches have employed a degree of simplification to allow units to be correlated across the site. In the 2002 PCSC, the lithostratigraphic approach subdivided the drift deposits into a succession of stratigraphic units, each of which was described as the accumulated depositional product of a specific glacial event. The 2002 geological interpretation does not delineate in detail the spatial distribution of different sediment types and the corresponding hydraulic properties of those materials. Since 2002, a revised geological interpretation has been put forward with the aim of providing a more suitable basis for subsequent hydrogeological interpretation and modelling. The revised geological interpretation has been used to underpin the engineering design, using a grouped, bulk lithofacies approach, which also takes into consideration the regional geological context of the site and contemporary local analogue exposures. However, although the approach does allow the representation of the drift deposits as a series of lithofacies packages, and the development of a 3-D geological model of the site, each unit is defined on the basis of a broad collection of lithologies. For example, lithofacies package LP2 is described as alternating tills, sands and gravels, so there may be a significant variation in physical properties within the lithofacies package. The validity of this approach is reliant on the assumption that sensible bulk properties can be assigned to each lithofacies package, despite the heterogeneous characteristics of each package.

There is debate about the continuity of units (e.g. individual clay units) over length scales of hundreds of metres. Such correlation is difficult to discern from the examination of borehole logs. However, outcrops appear to suggest continuity over longer length scales. This aspect is being assessed in current work to review alternative conceptual models for the hydrogeology. Work is planned to assess whether the effects of spatial variation in the physical properties of each lithofacies package would have a significant effect on the hydrogeological modelling. The aim is to be able to define an upper and lower length scale for correlations, based on the variations observed in both the borehole logs and the excavation and beach exposures. An additional piece of work has been commissioned to assess whether a stochastic representation of the flow properties may be useful.

The hydrogeological understanding of the site is still broadly consistent with the conceptual model presented in the 2002 PCSC. The conceptual hydrogeological conceptual model is based on the observation that groundwater flow is largely topographically driven. At regional scales, groundwater generally flows from the inland hills that form the Lake District, to the coast. Superimposed upon this regional flow are local flows, influenced by local topography. The hydrogeology of the superficial deposits and sandstone at the LLWR site has been represented in terms of three hydrogeological units or systems:

- Surface and Soil Zone system. This system is located above the water table and acts to divide the rainfall between the surface water system and groundwater systems.
- Upper unconfined groundwater system present above about 6 m AOD. This system may be locally perched. Controls on groundwater are: infiltration, small-scale topography, vertical/horizontal permeability, cuttings and drains.
- Regional groundwater system comprising the deeper superficial deposits and the sandstone, which are in hydraulic connection. Controls on groundwater are: regional

(large-scale) topography, coastline, bulk permeability, and interaction with the Upper groundwater system.

Significant vertical head gradients are observed in the Quaternary deposits above 6 m AOD, in the northwest (i.e. under the disposal area) and central parts of the site. Below this elevation, vertical head gradients are smaller, with no consistent upwards or downwards component, and the horizontal hydraulic gradients are to the southwest. The vertical head differences are likely to result principally from the presence of relatively low permeability clay and silt-dominated materials between the Upper and Regional groundwaters, resulting in vertical flow rates which are lower than local recharge rates.

Tritium measurements in groundwater and surface water in and around the LLWR commenced in 1986 and have provided further evidence of the interaction of the trench leachate and groundwater. The results have shown the development of two distinct tritium plumes in the regional groundwater. One seems to originate from the northwestern part of the trenches and the second seems to originate from the southwestern part of the trenches. Both migrate in a southwesterly direction within the Regional groundwater. Tritium is detected in the Upper groundwater although the absence of values close to the peak leachate tritium activity concentration suggests that there is some dilution and / or that most of the tritium moves vertically downwards rather than laterally. The tritium observations have been used as direct evidence in supporting the conceptual model and in defining contaminant transport pathways. The proposed boreholes between the site and the coast will target both the Upper and Regional groundwater, providing more information on hydraulic gradients, and also adding to the data on the tritium plumes.

The tritium observations indicate that although the majority of groundwater flow through the site will enter the regional groundwater, smaller scale lateral migration also occurs and needs to be considered in any assessment of potential impacts.

A calibrated site-scale model has been developed using FEFLOW and provides a reasonable match to the observed distribution of heads. The model uses the 3-D geological lithofacies model as a framework and extends over an area of 49.4 km^2 with the boundaries of the model largely defined by topographic catchments boundaries and the coast. The model relies on a high degree of anisotropy in the LP2/3 unit to match the development of the hydraulic gradients observed in the Upper groundwater. The lateral conductivities are in the upper part of the range implied by hydraulic testing and there is a question as to whether these conductivities are consistent with estimates of base-flow. A review of the stream hydrograph data is currently being undertaken to re-examine the interaction between the streams and groundwater. Further work will be carried out to review and build confidence in the water balance for the site as well as to provide checks on the validity of the hydrogeological data used in the modelling and assessment.

A FEFLOW, or equivalent 3-D groundwater flow, model will provide the main tool for modelling groundwater flow in the 2011 ESC. The groundwater model has been used to consider the current hydrogeological conditions and represents what are considered to be steady-state conditions. Over the lifetime of the site it is considered that the hydrogeological conditions of the site are likely to change in response to the construction of the final cap, installation of any cut-off walls, changes in rainfall due to climate variations and the effects of coastal erosion. In general, steady-state calculations will be used to represent a limited number of cases and a range of conditions for the site from present day to erosion or inundation of the site. Some transient calculations will also be undertaken (see subsection 5.5).

The development of the site scale model will take into account the findings of the alternative hydrogeological model work and additional work will be commissioned where required to consider alternative conceptual models or parameter uncertainty.

The site scale model will take into account the existing and proposed engineering with the cut-off walls and vertical drain being explicitly represented. Expert elicitation has previously been used to consider the long-term performance of the engineered features and this approach will continue.

The hydrogeological understanding will be used to both identify and parameterise a representation of the groundwater pathways in GoldSim. The groundwater pathways will be represented as specific legs. Where probabilistic calculations are required, a suite of supporting calculations will be commissioned to aid the development of an appropriate response surface.

3.4 Environmental setting

Understanding of the environmental setting for safety assessment includes an understanding of the changes in climate and landform that will affect the site over the period of assessment, and an understanding of local resource use and human habits to inform the stylised representation of the biosphere needed for safety assessment (see subsection 5.6).

3.4.1 Climate and landform

We have undertaken an extensive programme of work in the recent past that addresses climate evolution and the effect of landform changes, largely the impact of rising sea level and coastal erosion on the region around the LLWR.

The choice of appropriate scenarios for climate change has been summarised in Thorne and Kane (2007). This approach is consistent with an approach developed in BIOCLIM (2004). We do not propose any work to significantly update this approach before the 2011 ESC, although we will keep developments under review. In undertaking assessment calculations, we will consider 'what if' questions in relation to assumptions about future climate change and coastal erosion that go beyond the scenarios considered by Thorne and Kane.

Work to date on coastal erosion is summarised in Thorne and Kane (2007) and underlying work is described in Halcrow (2008). A monitoring programme has been carried out, conceptual and simple numerical models have been developed and a view reached of the range of potential future evolutions of the coast. This is the main area for work in the biosphere area prior to the 2011 ESC. Our approach at present is to develop a good programme of monitoring that will be repeated at regular intervals, possibly every ten years. Work is currently due to start to develop a better base line for the long-term programme of monitoring. The key question that we are currently considering is whether there is scope for developing better numerical models of coastal erosion that can be used to improve predictions of the timescales for erosion. The next step is to hold a workshop to address this question.

3.4.2 Local resource use and human habits

Calculation of impacts from the LLWR at the present day can be based on present-day land use and location of human habitations etc. However, since dose calculations are made with cautious assumptions, e.g. considering an individual standing at the site boundary, ingestion of milk from cattle drinking water entirely from the water source with highest level of concentration, or non-human species in the location with highest concentration, detailed characterisation of the local environment, e.g. in terms of what crops are grown where, are not needed.

For times of even a few years into the future, it is considered appropriate to use stylised representations of the biosphere (NEA, 1999) or “reference biospheres” (IAEA, 2003), and this view is endorsed in the recent draft guidance (Environment agencies, 2008). These stylised biosphere descriptions are based on a cautious assumptions for the possible use of local resources by humans, e.g. drinking from a potentially contaminated well (if feasible), eating locally produced terrestrial and marine foodstuffs foods, visiting areas of highest concentration and dwelling locally.

Information on present-day habits in West Cumbria and northwest England has been reviewed by Thorne (2007) based on habit surveys made in relation to current discharges. He has generalised this information to derive habit data for potentially exposed groups (PEGs) using different environments in the vicinity of the LLWR in the future (see subsection 5.6).

Thus, we do not consider that additional site characterisation is needed in order to assess doses to currently exposed groups or doses and risks to PEGs in the future. The exception is that we are seeking information relating to the present day use of wells locally in order to improve the basis for estimating the likelihood of future agricultural or domestic wells.

4 OPTIONS ASSESSMENT AND SITE MANAGEMENT PLAN

This section describes our approach to optimising the management of the site and developing the Site Management Plan. Our intention is to perform a number of studies whose results will provide an important input to decisions concerning site management and hence development of the Site Management Plan. Studies are planned in the following areas:

- Support to the NDA's LLW National Strategy and Plan development;
- Assessment of the effects of innovations in LLW management;
- Trench remediation;
- Operations;
- Pre-closure;
- Closure design;
- Institutional control strategy.

The Site Management Plan will form an important part of the 2011 ESC. The System Description and (final) Assessment will be based on the Site Management Plan.

The studies described in this section largely address performance of the site after closure (even though they concern activities or management of the site up to the end of institutional control). Where operational decisions are addressed, these are directly related to post-closure performance, such as the approach to interim capping or any emplacement strategy. Optimisation studies only indirectly related to post-closure performance will also be undertaken as appropriate. For example, a set of studies will be undertaken to ensure the BPEO and BPM are being used to manage routine and 'one-off' arisings of wastes on the LLWR site, meeting Requirement 1 in Schedule 9 of the current Authorisation. A study will also be undertaken to review the means used to assess activity in disposals, to meet Requirement 3.

4.1 National strategy and disposal inventory – use of the LLWR

The NDA, supported by the LLWR, is currently developing its National Strategy for the management of the nuclear industry's LLW in the UK. The NDA have commissioned a Strategic Environmental Assessment as part of the development of their Strategy. The Strategy will be implemented through a more detailed National Plan. Defra is also developing in parallel a strategy for non-nuclear LLW. These activities follow the publication of a new LLW Policy by the Government in 2007 (Defra, 2007). The NDA National LLW Strategy and Plan is expected to identify the optimal future role of the LLWR, that is, what wastes should be sent to the LLWR and over what period. The Strategy would provide the overall justification for the continued use of the LLWR as a facility for the disposal of radioactive waste, assuming that this is the conclusion of the work.

Clearly, the NDA LLW Strategy cannot provide a full justification for the disposal of wastes at the LLWR; only a full ESC that demonstrates appropriate performance of the facility can do that. The Strategy will need to make assumptions about the acceptability of disposing of wastes at the LLWR, if it is concluded that this is the right approach to managing LLW nationally.

If the NDA LLW National Strategy proposes that the LLWR should continue to be used for the disposal of LLW, this will also identify, at least at a strategic level, the planned future disposal inventory. More detailed analysis of which waste streams should be consigned to the LLWR will be provided by the National Plan and underpinning studies. This analysis will not be solely ‘top down’. The ESC will be used, as plans are being developed, to inform decisions about what wastes might be appropriate for consignment to the LLWR.

A draft NDA LLW Strategy is scheduled to be ready for public consultation by March 2009, with a first Plan ready in February 2009. It is expected that the Strategy will gain ministerial approval by December 2009. The Plan will be further developed and issued again in early 2010. There should, therefore, be a firm basis on which to make assumptions about the future role of the LLWR and the disposal inventory in good time for the final assessments and preparation of the ESC, to be completed by May 2011.

4.2 Evaluation of innovations

The nuclear industry’s approach to LLW management has mostly been to consign waste to the LLWR with little treatment. From the time the LLWR opened in 1959 until vault disposal was introduced in 1988, waste was tumble-tipped into the Trenches. Tumble tipping continued in parallel with the use Vault 8 for a period of years to 1995. Wastes disposed in Vault 8 are mostly placed in ‘ISO’ containers, which are then grouted. Compactable wastes have been compacted in WAMAC at Sellafield since the facility was commissioned in 1994

Government policy is now to increase application of the waste hierarchy and the NDA LLW National Strategy and Plan will set out how this will be achieved at the national level. Options for treating LLW to reduce physical volumes include metal melting, incineration, and compaction. Some waste consignors are already testing different options. These treatments will tend to increase the specific activity of wastes for disposal. They would also allow a greater proportion of the wastes to be fitted into the available physical volume at the LLWR, thus increasing the total amount of activity disposed.

UKNWM has also proposed to the NDA that changes should be implemented to the packaging of wastes at the LLWR. These would also tend to increase the total activity and reduce the amount of grout in future vaults.

The radiological impacts calculated in assessments of the LLWR’s performance depend on the average specific activity of some volume of the Repository, which varies depending on the scenario for radiation exposure. Benefit is currently taken for the grout in the Vaults in assessments because of its effect on near-field chemistry and hence the release of some radionuclides from the Repository. The changes to LLW management outlined above are therefore likely to have some adverse effects on the magnitudes of calculated impacts, even if the differently managed wastes still meet the definition of LLW. There will also be some positive effects as well, for example, activity will not easily be released from the by-products of some metal melting processes.

The extent to which treated and differently packaged wastes can be safely disposed at the LLWR will be assessed, as an input to developing plans at the National and LLWR level.

Disposal inventories, based on different assumptions about waste management, will be developed as a basis for these investigations. It is intended to undertake a simple, high-level study first, to help identify issues, followed by more detailed assessments of potential impacts on repository performance. These assessments will include consideration of potential changes in near-field chemical conditions and evolution.

The final inventory or inventories used as a basis for the 2011 ESC will reflect possible scenarios for future waste management, and will use the best available information at the time of the planned data freeze (currently scheduled for April 2010).

4.3 Trench remediation

Whether or not to retrieve wastes from the Trenches or remediate them in some other way was an outstanding question following the Environment Agency's review of the 2002 PCSC. Optimisation studies have subsequently been undertaken to help develop a fully justified approach to managing the Trenches. The most recent studies are summarised in the LLWR's response to Requirement 2 in Schedule 9 of the site's Authorisation (LLWR, 2008a). It was concluded that retrieval of a large proportion of the Trench wastes is not justified, the detriments being grossly disproportionate compared with the benefits. A small number of techniques, including localised retrieval, in-situ remediation (e.g. in-situ grouting) or the construction of locally enhanced retrieval barriers, were identified that could be applied to the facility in the future were it deemed necessary to intervene to deal with wastes with particularly high localised concentrations of key radionuclides. It was recommended that the question of localised retrieval or intervention should be revisited as part of the 2011 ESC.

A further study will be undertaken to examine whether or not selective remediation of the Trenches is justified. Options for remediation have been identified, screened and some analysis of them undertaken, as reported in LLWR (2008b). Consideration will be given as to which options warrant more detailed analysis before a decision can be made on whether to include selective remediation in the Site Management Plan. These analyses will then be undertaken. They will at least include a more detailed analysis of selective retrieval of wastes. In this study of selective retrieval, one or more sets of waste that would bring significant benefits through their removal will be identified. An operational plan for undertaking the retrieval will be developed and costed. The advantages and disadvantages to the retrievals will be identified and quantified where possible. An options assessment will be undertaken that draws on these data.

4.4 Operations

Where waste packages are emplaced in the Vaults may affect calculated risks and doses. For example, the LLWR's submission against Requirement 2 in our Authorisation identified that placing packages with a relatively high loading of radium lower in waste stacks might reduce calculated doses for some human intrusion cases. The LLWR is committed to examining further the merits of such an emplacement strategy.

An options assessment will be undertaken, in collaboration with the operations team at the LLWR, to examine generally whether an emplacement strategy represents the BPM for managing the wastes.

4.5 Pre-closure

The LLWR's submission against Requirement 2 of our Authorisation concluded that the closure design should include a final cap for the Trenches and Vaults (LLWR, 2008b). The Trenches have already been covered with an interim cap, while the wastes disposed in Vault 8 remain uncovered. The design of the final cap will be addressed as part of the studies discussed in the next subsection. The Site Management Plan also needs to address the timing of construction of the final cap, the approach to interim capping of both the Trenches and the Vaults and the approach to leachate management during operations. Progressive final capping has a number of possible advantages, including the availability of more time to demonstrate the performance of the cap, lower cost (because the costs of extra infrastructure to handle large volumes of capping materials over a short period would be avoided), and reduction of run-off from open vaults. Delay in capping would allow time to test and develop confidence in the capping concept before construction. Alternatives to progressive capping include temporary capping, temporary coverings (tents) and enhancing leachate management systems. Consideration also needs to be given to whether the current interim cap on the trenches continues to represent the BPM of ensuring that radiological impacts from the Trenches are ALARA. An options study will be undertaken to identify the optimal strategy for interim capping, leachate control during operations, and the timing of final capping.

4.6 Closure

The analyses presented in the LLWR's submission against Requirement 2 assumed that engineered features would be constructed by the time of repository closure, including a final cap, vault liners, cut-off walls and vertical drains, consistent with then current LLWR plans. The intention of such features would be to limit infiltration into the repository and to ensure that any contaminated leachate travels downwards, thus reducing the potential for local discharges to the accessible environment. The cap should also prevent or discourage intrusion. The Requirement 2 submission concluded (LLWR, 2008a) that the need for an engineered cap was clear, but that the closure design overall was not demonstrably optimised. Further optimisation studies, making use of the models under development in the ESC Project, will be undertaken to establish an optimal closure design. These studies will be undertaken in collaboration with the engineering team at the LLWR.

4.7 Institutional control strategy

Once a repository is closed it will require some 'institutional control' for a period, to provide time for re-assurance monitoring of performance and to prevent intentional or inadvertent intrusion. Control might be 'active', that is, while the site is regulated and authorised by the Environment Agency. 'Passive' control might follow through measures such as local planning controls and maintenance of records in libraries and archives. Measures might also be taken before the end of active institutional control, such as the placement of markers, to discourage later intrusion.

LLWR's submission against Requirement 2 of our Authorisation concluded that institutional control of the site should continue for as long as reasonably practicable. The NS-GRA notes that '*…it is unlikely that the environment agencies would accept a claim for active institutional control lasting longer than 300 years after waste emplacement'.* The arguments in the ESC will be consistent with this remark.

A strategy for institutional control of the NDA will be developed, which addresses aspects such as:

- re-assurance monitoring;
- site access;
- site markers;
- records retention;
- timescales for active and passive control;
- funding.

4.8 Development of a Site Management Plan

The Site Management Plan is the integrated product of a number of options adopted as the basis of financial and technical planning and safety assessment. It will be developed, based on the outcomes of the studies described above. The Plan may present possible alternatives, some of which may also be assessed.

The Plan will reflect the role for the LLWR identified in the NDA National LLW Strategy and Plan, and the ESC will be based on the disposal inventory implied by this role. The intention is that the ESC will show the performance of the repository taking into account any relevant changes in the management of LLW at the national level.

The Site Management Plan is likely to evolve over time, as the ESC is used as a tool for site management and other chances occur; however, the overall 2011 ESC, including the new Site Management Plan, will form a baseline for assessing the effect of future changes.

4.9 Optimisation and demonstration of optimisation

The NS-GRA sets as a principle, Principle 2, Optimisation: "Both at the time of disposal and in the future, the radiological risks to people and the environment from a disposal of solid radioactive waste shall be as low as reasonably achievable under the circumstances prevailing at the time of disposal, taking into account economic and societal factors and the need to manage any non-radiological hazards." The NS-GRA comments that optimisation should be considered at all stages in the lifecycle of the disposal facility, including use of the site and facility design, construction, operation and eventual closure.

This is confirmed as Requirement R9 (Optimisation): “The choice of waste acceptance criteria, how the selected site is used and the design, construction, operation, closure and post-closure management of the disposal facility should ensure that radiological risks to members of the public and to the environment, both during the period of authorisation and afterwards, are as low as reasonably achievable (ALARA), taking into account economic and societal factors.” As noted in the NS-GRA:

– optimisation is about finding the best way forward where many different considerations need to be balanced;
– the developer/operator should carry out options studies, where there are choices to be made among significantly different alternatives;
– the best way forward is not necessarily the one that offers the lowest radiological risk;
– once a decision has been implemented, it forms part of the framework within which further decisions … must be made.

We consider that optimisation is achieved by implementation of sound, safety-informed choices concerning the facility design, wastes to be disposed and operational management of the facility. The preceding subsections of this section have set out key areas in which choices need to be made and our approach to making and supporting those choices.

The basis for making such choices is the scientific and technical understanding of the disposal system and its performance as informed by iterative safety assessments, as described in section 3. Safety assessments (see section 5), then test the protection offered by the system to confirm consistency with the relevant constraints or guidelines, i.e. constrained optimisation.

For the 2011 ESC, we will make an integrated presentation of the arguments and evidence concerning design, system understanding and assessment, to show that we have done all that we reasonably can in terms of design and site management so that present and future radiological impacts are as low as reasonably achievable. This will include:

– establishing the baseline in terms of the current situation at the LLWR and estimated current and future radiological impacts for the current assumed site development, e.g. as developed in the interim assessment undertaken in support of the Requirement 2 submission (R2 assessment);
– definition of options with regard to the key areas identified in previous sub-sections of this section, to mitigate impact and/or to provide more efficient use of the LLWR within the national waste management strategy;
– qualitative and quantitative assessments, as appropriate, of the relative merits of options in terms of efficient use of the LLWR, environmental safety implications and other concerns of stakeholders;
– development of a Site Management Plan, adopted as the basis of financial and technical planning and safety assessment;

- assessments of the performance of the system against the relevant regulatory criteria set out in the NS-GRA.

5 ASSESSMENT APPROACH

This section describes the approach to addressing NS-GRA Requirements R6, R7, R8, R10 and R11. The section describes the overall approach in each of the technical areas with special attention to areas in which we are planning developments of our approach and additional work for the 2011 ESC.

5.1 Summary of our approach

The 2011 ESC will evaluate the environmental performance and safety of the LLWR against the requirements and criteria set in the NS-GRA (Environment Agencies, 2008). The relevant requirements for environmental safety are:

- Requirement R6: Dose constraints during the period of authorisation;
- Requirement R7: Risk guidance level after the period of authorisation;
- Requirement R8: Human intrusion after the period of authorisation;
- Requirement R10: Environmental radioactivity;
- Requirement R11: Protection against non-radiological hazards.

The aim of the 2011 ESC is to make an integrated and consistent evaluation of the environmental performance over the full lifetime of the LLWR (see section 3).

For the period during which the LLWR remains under operator control and direct regulatory supervision, i.e. during the period of authorisation, the primary requirement is consistency with the dose constraint, Requirement R6. Protection at the present day is primarily assured by ensuring that aqueous and airborne discharges remain within the terms of the Site Authorisation, which is tested through monitoring. Modelling is necessary to estimate the dose impacts from routine discharges and also to assess the importance of accidents or unexpected events with the capacity to lead to the release of radionuclides or contaminants from the site. Modelling is also important to understand the monitoring data and present-day discharges in terms of the sources present on the site and modes of release. This understanding gives the basis for the planning of future disposals, site engineering and site management, and to estimate the discharges during the future operating life and afterwards.

For the period after the withdrawal of operator control and direct regulatory supervision, i.e. after the period of authorisation, the primary requirement is consistency with the risk guidance level, Requirement R7. Estimates of dose and risk into the future, after the withdrawal of operator control, must rely on modelling of the wastes, engineered barriers and site taking account of the possible evolutions and performance of the system, and the uncertainties therein in as far as they are assessable. The biosphere, including aspects of land use and human habits, are represented in a more stylised fashion taking account of current and possible future human activities, but noting that uncertainties related to future human activities and use the site are essentially irreducible. If human actions penetrate into or expose the waste, or significantly damage the barriers that are intended to isolate and contain the waste, this is termed human intrusion, and is assessed against Requirement R8 (see subsection 5.10).

We would address the extent to which the disposal system provides adequate protection against non-radiological hazards, Requirement R11 (see subsection 5.11). We would also aim to show that the radiological effects of a disposal facility on the accessible environment and other species are acceptably low, both during the period of authorisation and afterwards, Requirement R10. This is demonstrated based on assessment of concentrations in environmental media determined by monitoring for the present day and by modelling for times into the future (see subsection 5.12).

Finally, we present our approach to defining the radiological capacity the site (see subsection 5.13). This is based on key scenarios that present limiting impacts in the long-term from the facility, considering both gradual release of radionuclides and also disruption of the facility.

5.2 Integration of the OESC and PCSC

The aim of the 2011 ESC is to make an integrated and consistent evaluation of the environmental performance over the full lifetime of the LLWR. This includes the assessment of:

- present day performance taking account of past disposals and disposal operations according to present practice;
- performance during future disposals taking account of options for disposal practice and site management including the effect of site engineering or other measures that may be enacted as disposals continue;
- performance during a managed phase after completion of disposals, taking account of the progressive enactment of site engineering options, up to the expected release of the site from direct supervision by the operator and regulator;
- performance after the withdrawal of control and direct regulatory supervision, taking account of passive controls which, however, may lapse or be ineffective after some passage of time.

The 2011 ESC will include arguments and evidence for environmental safety over all phases of the facility development. In principle integration is desirable, showing for example that results of present day monitoring and the results of assessment models are consistent. The Operational Environmental Safety Case (OESC) and the PCSC will also be integrated in the sense that inconsistent models will not be used. However, the emphasis in relation to the Safety Case arguments pertaining to the two periods will be different.

During the operational period, a key safety case argument will be that the site is monitored and managed so that releases will be acceptably low. This will include the following considerations and arguments:

- Good practice is used to limit the releases from the facility by limiting the inflows to the repository and collecting, managing and treating the leachate arising.

- A suite of boreholes is regularly monitored for the release of chemotoxic and radioactive contaminants to the environment. Appropriate trigger levels have been defined. If these are exceeded, further investigation or action will be taken to ensure that the site is managed in an appropriate way. The generation of gas is also monitored and arrangements are in place during the operational period to ensure that this gas is vented to atmosphere.
- Cautious models will be developed of the release of contaminants from the facility using the GoldSim software, in the case of the groundwater pathway. These will be used to assess potential impacts.

During the post-closure period, the balance of safety case arguments will change. A key argument will continue to be that good practice has been used in designing and managing the facility in order to optimise performance. Of course, after the end of management control, it would not be appropriate to rely on monitoring and intervention as a basis of the safety case. There will be increased reliance on the use of models and their outputs as a measure of acceptable performance.

For at least one case, a single assessment calculation for the groundwater pathway will be undertaken to represent the evolution of the system from initial disposal through the operational period and into the post-closure period. This will involve some representation within GoldSim of changes to the disposed inventory and the groundwater volume flux through components of the facility over time. This will avoid the presentation of inconsistent results for the operational period. A number of ways of representing the behaviour of the near field are under consideration (see subsection 5.7.1), but it would be desirable to ensure that the calculation is calibrated against currently available monitoring data.

5.3 Pathways, scenarios and FEPs

5.3.1 Pathways

To assess performance during the period of authorisation it is necessary to consider aqueous and gaseous discharges. In the case of aqueous discharges, this includes managed discharges permitted under the authorisation and also impacts from radionuclide or other contaminants that have leaked into local groundwater or the surface environment. In the case of gaseous discharges this includes generalised emissions of radon from the disposed waste.

To assess performance after the period of authorisation it is necessary to consider groundwater-mediated releases and gas-mediated releases, but also the possibilities for disruption of the facility due to natural processes and unplanned human actions. For a near surface disposal facility such as the LLWR, each of these four pathways – groundwater, gas, natural disruption and human intrusion – may be important at different times in the future and may have the capacity to either limit the wastes that can be disposed or determine facility design. Therefore, each pathway must be assessed with equal rigour. This is somewhat different to the safety case for a deep geological repository, in which the groundwater pathway is generally most important and other pathways may be given lesser attention. In addition, a near surface disposal facility and its immediate environment are much more likely be affected by human activities that are uncertain and difficult to predict. These two factors:

- the simultaneous importance of several pathways and
- the impact of irreducible uncertainties related to human activities,

lead towards assessment calculations and a safety case that is characteristically different from that which might be expected for a deep facility. The emphasis is on defining a reasonable and broad set of scenarios and cases, see below, and considering the uncertainties related to each case in a qualitative fashion, rather than attempting to capture the maximum uncertainty within a single quantitative model (see subsection 5.4).

5.3.2 Scenarios

In broad terms, we will assess scenarios that consider the undisturbed performance of the LLWR and also scenarios that consider disruption of the LLWR. The assessment of undisturbed performance will take account of uncertainties related to the degradation of the wastes and engineered barriers and also changes in the local surface environment due to natural processes and human activities not directly compromising the engineered barriers or integrity of the closed repository.

The assessment of the potential for, and impacts of, disruption of the site by natural processes will be based on scientifically-based descriptions of the disrupting processes and their progress. The assessment of the potential for, and impacts of, disruption of the site by unplanned human activities will use information-based descriptions of most likely and reasonable human activities at the site, but ultimately the cases selected for analysis will be necessarily stylised representations that illustrate possible events. As well as assessing the immediate impacts of disruptive events, we assess the longer term effects of natural or human disruption events on the containment performance of the damaged repository.

Further information on the proposed scenarios and cases to be assessed is given in the remainder of this section.

5.3.3 Features, events and processes (FEPs)

An identification of the features, events and processes (FEPs) relevant to the performance of a disposal system, and assurance that the important processes have been appropriately and adequately represented is central to confidence in the completeness of the assessments.

A comprehensive FEP identification and screening exercise was carried out in support of the 2002 PCSC and assessment scenarios were identified by a formal methodology based on analysis of the disposal system as comprising, see (BNFL, 2002e):

- the process system – all those FEPs considered to be important within the system that is represented by an overall assessment model (near field, geosphere and biosphere);
- the system environment – those FEPs external to the process system (EFEPs) that can be thought of as acting on the process system, and may hence generate alternative scenarios.

The identification and screening exercise for the 2002 PCSC was an important step in showing breadth of consideration and consistency with international FEP lists, e.g. those developed by the IAEA ISAM and BIOMASS projects. We consider, however, that the project and our understanding of the LLWR and its environment have moved on. In particular, we consider that we have identified the pathways and scenarios that are likely to be most important and determining in terms of acceptability of past disposals and authorisation of future disposals at the site and the required performance of the site engineering. We also consider that improvements in the understanding and treatment of these scenarios will come not from additional general FEP analysis and audit exercises, but from focused site-specific and facility-specific consideration of the relevant scenarios and FEPs.

Hence, for the 2011 ESC we will:

- carry out a review of the FEP exercises in support of the 2002 PCSC but not repeat the FEP identification, screening and documentation;
- focus our analysis of FEPs on listing and discussing those FEPs that are relevant to the 2011 assessment models, scenarios and cases;
- and, in particular, we will develop a record of which FEPs are included in each model, scenario and case and how each FEP is represented, e.g. as an explicit process in a model, as a boundary condition, by means of parameter range etc.

5.4 Treatment of uncertainty

5.4.1 Sources of uncertainty and the importance of uncertainty

Uncertainty originates from lack of knowledge of parts of the studied system and from the random nature of some phenomena. This lack of knowledge can arise from limited measurements, uncertainty in interpretation of measured data, insufficient understanding of processes, spatial variability and the uncertain occurrence of events. In the context of the LLWR and its assessment, uncertainties arise from:

- uncertainties concerning past and future the waste disposal operations, e.g. the radiological inventory, future engineering and operational choices;
- uncertainties on characteristics of the waste disposal facility and its environment, e.g. due to measurement uncertainty, applicability of literature values rather than measured values, variability of parameters in time and space;
- uncertainties about the long-term evolution of the waste disposal facility and its environment and concerning future events that may have an impact on the waste disposal facility and its environment;
- uncertainties concerning future human behaviour.

It is necessary to recognise the relevant uncertainties and analyse them to the extent that is helpful in guiding the development of the facility and assuring its safety and compliance with regulatory requirements. At a given step, the treatment of uncertainty may be constrained by limited data, the models that are available and uncertainty over the future management of the facility. The treatment of uncertainty within safety assessment aims at:

- identifying priorities for further work to reduce uncertainty where it is important and
- enabling decisions to be taken on the development of the disposal facility that account for the presence of uncertainty.

Some uncertainties will remain unresolved, but this does not prevent an assessment of the safety of the disposal facility taking account of the outstanding uncertainties. As stated in the NS-GRA: "Uncertainties themselves are not obstacles to establishing the environmental safety case, but they do need proper consideration and including in the structure of the environmental safety case as appropriate."

5.4.2 Classification of uncertainty within safety assessments

We note the Agencies' view: 'an important distinction can be made between two types of uncertainties: those that can reliably be quantified and those that cannot.' It is, of course, necessary to identify the relevant uncertainties and analyse them responsibly, and this would include not treating speculative data or assumptions with the same respect or credence as data based on good quality measurements. We consider, however, that there is not a sharp distinction between an uncertainty that can be reliably quantified and one that cannot. Further, in our view, it is not helpful to attempt to align that distinction with a distinction between uncertainties of the natural system and uncertainties related to human behaviour, as indicated in Figure 6.1 in the draft NS-GRA. We agree that it is not helpful to dilute the value of quantitative analysis by folding in uncertainties that are very poorly characterised or that could be better expressed by alternative scenarios or models. Thus, we propose to take note of the Agencies' view and, in our identification and quantification of uncertainties, make clear the basis for our characterisation of the uncertainty and any shortcomings, especially where subjective interpretations or assumptions have been made. We will also not aggregate uncertainties except where they are of compatible nature.

We will adopt a classification of uncertainties that is conventional in radioactive waste disposal assessment, e.g. see (Nagra, 2002), focusing on their mode of treatment in the safety assessment, thus:

- Scenario uncertainty – are the (safety assessment) scenarios considered sufficiently complete in their representation of the possible evolutions of the disposal facility and its environment?
- Model uncertainty – do the models describe the real world features and processes in an adequate way (in safety assessments we aim at not underestimating the impact)?
- Parameter uncertainty – what impact do possible variations of the parameters have on the final results of the safety assessments?

5.4.3 Scenario uncertainty

Scenarios provide a method of reducing the possibly infinite set of future conditions and evolutions to a finite number of representative descriptions of future conditions and evolutions, and thus providing a tractable problem for analysis. The development of an appropriate set of scenarios, although guided by scientific understanding for example in relation to evolution of the natural world, relies heavily on expert judgment; hence it is important to involve a range of experts in the choice and definition of scenarios. Treatment of some uncertainties, for example related to future human behaviour and capabilities, can only ever be schematic and illustrative; in this case, we can offer scenarios and seek to establish consensus with the EA and other stakeholders that these are appropriate and sufficient. Subsections 5.7 to 5.10 of this report indicate our approach to developing scenarios for each of the four major pathways for the 2011 ESC.

5.4.4 Model uncertainty

Model uncertainty can apply to the conceptual model, which describes the phenomena and interactions included within an assessment case, the mathematical model, which is the representation of the conceptual model in terms of parameter values, mathematical equations and boundary conditions, and the computer model, which consists of the code used to solve the mathematical model. Of these, uncertainty in the conceptual model is usually most important. The conceptual model uncertainty may relate to lack of knowledge of the processes but also, often most significantly, to deliberate simplifications in terms spatial resolution and averaging or omission of processes. The aim is to create a model that is cautious in its representation and does not underestimate consequences, e.g. omitting a process that is thought to be beneficial to safety but for which insufficient data is available.

It is generally not possible to assess the uncertainty or bias associated with a deliberately cautious model unless some alternative “more realistic” model or appropriate test data are available. For most models, therefore, we will only seek to present the evidence that the model used is appropriate and cautious, not to assess the model uncertainty or bias. For the key area of performance of the near field, we are currently undertaking work that may lead to the development of alternative models (see subsection 5.7.1). We will also consider the possibilities for alternative model treatments in respect of groundwater release and interception by a well (see subsection 5.7.3).

5.4.5 Parameter uncertainty

The NS-GRA places an emphasis on probabilistic approaches to parameter uncertainty and estimations of risk. We consider that a combination of deterministic and probabilistic calculations, and quantitative and qualitative arguments, are needed to explore and discuss the uncertainties related to long-term performance. This “mixed” approach can be seen in recent performance assessments that are widely regarded as “state-of-the-art” from countries such as Sweden and Switzerland. We value probabilistic calculations as a method of exploring uncertainties within quantitatively defined models, but note that this misses what may be very important uncertainties, due to limitations in the conceptual model (e.g. incomplete understanding or omissions) or limitations in the mathematical or computer model (e.g. inability to handle variations in time).

For the 2011 ESC, we propose to carry out deterministic calculations using reference parameter values and to explore model sensitivity using a combination of deterministic (point value) calculations and also probabilistic calculations over credible parameter ranges where this is appropriate for the most important scenarios. Results of sensitivity analysis will be used to identify key parameters in the most important scenarios. Only then will attention be given as to whether justified probability distributions can be developed for parameters that are most important to performance. We envisage that this will lead to probabilistic simulation of only a few key scenarios in which uncertainty can be represented by parameter distributions. At present, we envisage that the most likely scenario for probabilistic treatment will be assessment of a groundwater abstraction well between the site and the coast, see section 5.7.3. Probabilistic treatment of the ^{14}C and radon gas pathways and coastal erosion may also be possible, but will only be needed if the models include non-linearities. Human intrusion would be a suitable candidate for probabilistic treatment – to estimate mean annual dose or risk – but the NS-GRA guidance related to assessment of human intrusion appears to discourage this.

5.4.6 Register of uncertainties

A sufficient set of calculations will be carried out to provide confidence that the assessment has adequately explored uncertainties related to scenarios, models and parameter values, and to combinations of these uncertainties. In addition, a register of significant uncertainties will be established and maintained, which indicates how significant uncertainties have been addressed and the extent to which further data gathering, calculations or decisions are needed.

5.5 Treatment of time-dependent changes

Conditions will change over time and some of these changes will be relevant to performance. Experience from assessments in which time-dependent modelling has been tested show that a time-dependent representation is most relevant if changes occur during the release or transit of radionuclides or contaminants through the system, e.g. see Sumerling (1992). In the case of the LLWR, the times for transit though the geosphere and also times to reach equilibrium in the biosphere are rather short and therefore time-independent modelling and calculations are sufficient for the most part.

In the 2011 ESC, we will mainly make use of time-independent modelling and steady-state calculations. Such models and calculations are easier to develop and it is easier to justify appropriate parameter ranges, which can take account of uncertainties in both spatial and temporal variability.

Additional calculations will be undertaken as needed to investigate whether time-dependent effects, e.g. the gradual degradation of an engineered barrier, progressive coastal erosion and build-up or decline of activity in biosphere regions, could be important. At present, we consider that the most likely areas in which a time-dependent treatment may be of value is to represent:

- progressive disposal of waste and implementation of engineering measures at the site and consequent hydraulic and chemical changes during the period of authorisation;
- time-dependent degradation or failure of engineered barriers and consequent hydraulic and chemical changes after the period of authorisation.

In the first case, a quasi-time-dependent treatment may be appropriate with changes occurring at specified times in a step-wise fashion. In the second case, uncertainty over timing and degree of changes is important and more flexible or graduated time-dependent modelling may be needed. Possibilities for time-dependent modelling of the near field are currently being investigated in a near-field modelling approach task.

Time-dependent behaviours of the near field source term can be represented within the GoldSim package. We therefore expect to continue to use GoldSim to represent the groundwater-mediated release pathway for the 2011 ESC. The development of Goldsim geosphere network models for different future conditions will be supported by time-independent 3D hydrogeological models (see subsection 3.3). We have assessed the SimER package but do not consider it offers significant advantages for the assessment of the LLWR at present.

5.6 Treatment of the biosphere

In this subsection, our proposed approach to the treatment of the biosphere is set out. To assess annual doses during the period of authorisation, it is appropriate to consider the characteristics of the biosphere and human local resource use and habitation as observed and characterised in the vicinity at the present day. In the longer term, after the period of authorisation, this information is relevant, but a cautiously stylised representation is more appropriate to take account of uncertainties in future natural conditions and human behaviour, as suggested in the NS-GRA.

There are large uncertainties about the evolution of the surface environment (the biosphere), and the habits of humans living in the future. For this reason, the ICRP cautions that estimates of doses and risks should not be regarded as measures of health detriment beyond times of around several hundreds of years (ICRP, 1997), but rather that that estimates of doses and risks should be compared with appropriate criteria in a test to give an indication of whether the repository is acceptable (ICRP, 2000). That is, the calculations are made for the purposes of converting radionuclide releases to the biosphere to a scale relevant to radiological safety, i.e. dose and risk, so that they can be compared with a regulatory or other performance target. They are not to be interpreted as actual doses to humans dwelling in the future.

Another factor is that whereas the properties of the engineered barriers can be optimised by design, and are relatively stable or predictable, the properties of the biosphere in the future are dynamic and outside our control. Thus, whereas assessment of the engineered barriers can be used to guide and design, and to improve potential performance, assessment of the biosphere can only tell us about the putative impacts of radionuclides once in the biosphere. Biosphere assessment is important in that it provides the basis to make the calculations needed to judge whether safety criteria expressed in terms of dose or radiological risk are met, but generally it does not tell us how to design a better repository.

In order to develop models to estimate annual dose to humans, it is most appropriate to focus the development of the biosphere model on the present day exposed groups and the future potentially exposed groups (PEGs). These hypothetical population groups are those that might occupy or draw resources the various tracts of land or water that are liable to become contaminated as a result of radioactive waste disposal at the LLWR.

A description of the identification, selection and characterisation of exposure groups for the operational period and Potentially Exposed Groups (PEGs) for the post-closure period, including potential future climate and landscape conditions, is given in (Thorne, 2007). The method comprises:

- define the context in which the exposure groups or PEGs are present and provide outline descriptions of them;
- identify the pathways of exposure relevant to each exposure group or PEG;
- define the exposure groups or PEGs in terms of present-day population groups;
- select point estimate reference parameter values and uncertainty ranges for adult members of each exposure group or PEG to achieve relative homogeneity of characteristics;
- select point estimate reference parameter values and uncertainty ranges for children and infants associated with each exposure group or PEG;
- audit local resource use and range of uncertainty for each PEG.

Application of this methodology resulted in a set of nine groups relevant to the groundwater, gas and facility degradation pathways from closure through to the end of termination due to the effects of coastal processes. This includes groups using the storm beach and intertidal zone, the facility cap area, water abstracted from a well downstream of the facility, the local streams and of the Site South area, the Ravenglass estuary and bay, and a possible future lagoon, (see subsection 5.7.4).

The groups identified have similarities with the Analogue PEGs adopted in the 2002 PCSC, but also some substantial differences. These differences reflect the shorter assessment timescale and greater emphasis on the potential disruption of the facility by coastal processes. In addition, parameter value ranges are now provided as well as point estimates. Although the principal assessment calculations will be undertaken for adults, reference parameter values and ranges are given for ten-year-old children and one-year-old infants to facilitate comparisons between age groups.

PEGs relevant to assessment of inadvertent human intrusion are also defined. These consider individuals involved directly or indirectly in the activity that gives rise to the intrusion, and those dwelling and/or making agricultural use of land contaminated as a result of intrusions.

5.7 Groundwater-mediated pathways

In this subsection, our overall approach to assessing the groundwater pathway is described, focusing on water abstraction wells, since these give rise to the highest expected radiological impacts. As discussed in the previous subsection, our general approach for modelling the groundwater pathway is to use the GoldSim software (GoldSim Technology Group, 2007). The proposed approach to undertaking probabilistic and transient calculations has been set out above.

5.7.1 Modelling of the near field

Calculations undertaken for an abstraction well between the site and the coast show conditional risks above the risk guidance level (target) (LLWR, 2008e). A key factor leading to these results is that a very simple pessimistic model of near-field release was used. This assumes a well-mixed equilibrium source with a representation of sorption and solubility limitation. The advantage of this model is that it is relatively easy to parameterise and justify. However, it is likely to be very cautious in that it does not represent the rate limited release of contaminants from the wasteform nor the effects of the localisation of groundwater flow within the near field. We envisage that this cautious model will have a role within the safety assessment and the development of safety arguments. However, it is also proposed to develop more realistic versions of this model.

Recently, work has been undertaken to develop a kinetic model for the release of uranium in Springfields wastes from the fluoride wasteform (Small et al., 2008b). There has been success in matching the predictions of this model to observed concentrations of uranium and fluoride in trench leachate. We are currently considering work that might be undertaken to build more confidence in this model.

The radionuclides making the highest contribution to radiological impact for the water abstraction well were ^{238}U, ^{239}Np, ^{14}C and ^{36}Cl (LLWR, 2008e). As a result of work to better understand the inventory in one Springfields waste stream, the expected future disposal inventories of neptunium and ^{238}U have been substantially reduced. In terms of developing a more realistic estimate of the radiological impact for a water abstraction well, the focus is on ^{14}C and ^{36}Cl. We are undertaking work to develop a better appreciation of the forms of these radionuclides in disposed waste. Further, we propose to determine the feasibility of developing models for the rate limited release of these radionuclides from certain wasteforms. For example, the release of the activation product ^{36}Cl from corroding metals could be linked to the corrosion rate. If these models can be supported, we will undertake some calculations for the 2011 ESC using this approach.

Monitoring has provided a good picture of the concentrations of radionuclides in Trench leachate. We will undertake some calculations in which a simple rate constant is chosen to calibrate the model against these observed leachate concentrations. The difficulties of this approach are that it is empirical and not based on process understanding and it is more difficult to pursue for the vaults because currently waste-equilibrated leachate cannot be sampled from the vaults. The advantage of the approach is, however, that the results would be more realistic and match observations. Cautious models may be appropriate for use in assessments, but are not appropriate for interpreting monitoring data. We envisage that such a model could be used as part of the assessment to model the release of contaminants during the operational and post-closure periods, at the same time calibrating the model to current measurements (see subsection 5.2).

As discussed in section 3, we also plan to undertake some calculations to examine the effects of distributed flow within the vaults and trenches. These calculations would take account of certain heterogeneities within the near field. The role of such calculations would be to examine behaviour and build understanding, rather than as a primary model for the estimate of risk. This is because of the difficulty of parameterising such models and the wide range of conceptual alternatives. An important objective would be to demonstrate that well-mixed models are cautious.

Thus we envisage that the safety case for the groundwater pathway may be based on a number of assessment (or more detailed) calculations. We are currently developing and evaluating our approach, but envisage that the models might comprise:

- The well-mixed equilibrium source model used for the Requirement 2 submission, which would reasonably be considered as an upper bound conceptual model;
- A model where the release of certain key radionuclides from the wasteform is represented as a rate-limited process (e.g. based on near-field concentrations), which would provide a more realistic estimate of near-field concentrations;
- A model that is calibrated against observed leachate concentrations, which would be more realistic, but not associated with process understanding;
- More detailed models examining the impact of distributed flow and taking account of the effect of various heterogeneities.

The safety case arguments would probably be developed by reference to all of these models.

As noted above, our approach would generally be to undertake steady-state calculations unless effects were identified that require a transient calculation to be undertaken. However, it is considered that there is a requirement to represent certain time-dependent effects in the near field (see subsection 5.5). During the operational period, these would include the representation of additional source terms as the repository is filled with waste and the construction at different times of various engineered features. In the post-closure period, the relevant effects will be the degradation of those engineered features. A key future activity is to develop an approach to representing the groundwater volume flux through different components of the LLWR as a function of time. Such an approach must be capable of representing uncertainty. The approach is under evaluation; one option is to use a simple network model calibrated against the results from groundwater flow models.

5.7.2 Treatment of the geosphere

We envisage that the treatment of the geosphere will be very similar to that pursued for the R2 assessment, so only a brief summary is provided in this subsection. Our main objectives are to review and build confidence in the conceptual model of the hydrogeology and to acquire further hydrogeological data in the region between the site and the coast (see subsection 3.3). As described in subsection 3.3, we will continue to use a site-scale 3-D groundwater flow model, similar to that used in recent work (Henderson et al., 2008). A range of groundwater flow and contaminant transport calculations will be undertaken with this model. We will make use of groundwater flow models with explicit representation of near-field features. This will enable consideration of design alternatives.

It is considered that the approach to modelling the geosphere in GoldSim will be similar to that pursued in the Requirement 2 submission (Henderson and Paksy, 2008). The geosphere will be represented as a series of one-dimensional legs with the characteristics of those legs determined from the results of the 3-D site-scale groundwater flow model. It is further envisaged that response surfaces will be developed to enable the effects of uncertainty to be addressed through probabilistic calculations. This will require a number of calculations to be undertaken with the groundwater flow model, each with a different choice of parameters.

5.7.3 Treatment of wells

We have recently undertaken a review of the methodology that might be used to assess the impacts of a water abstraction well (Jackson et al., 2008). It is envisaged that the concentrations of radionuclides in abstracted water will be estimated using a suitable GoldSim network model. This model will be developed on the basis of a suite of 3-D calculations of groundwater flow and pathlines and 3-D contaminant transport calculations. Appropriate source-term models would be used, as outlined in subsection 5.7.1.

This calculation will relate to a well supplying an isolated house or ephemeral development, e.g. a camping and caravanning park. Water uses could reasonably be based on those for an isolated house, as ephemeral developments would often have staff or residents present for long periods of the year in semi-permanent accommodation. Larger-scale regional and irrigation wells would be excluded from consideration on the grounds of low likelihood of occurrence, and because the associated radiological impacts would not be greater and might even be rather less than those of a well supplying an isolated house.

The conditional risk arising from a water abstraction well will be presented as an upper bound on the risk. An annual risk will be estimated by multiplying the conditional risk for the water abstraction well by the probability that a well intersects the plume. This will be estimated based on the area frequency data obtained for Nirex 97, which suggested a density of about 1 km^{-2} (Nirex, 1997). This estimate is cautious as an area of land was considered in which settlements are more likely than is the case between the LLWR and the coast. The area of interest may be less than 1 km^2, both because of the modelled extent of the plume and because areas close to the cliff could reasonably be excluded on the basis of arguments relating to water quality and vulnerability to erosion. It seems likely that this approach would decrease assessed risks from those estimated in the analysis undertaken for Requirement 2 (LLWR, 2008e). Supporting analyses in relation to the probability of occurrence are also under consideration and might include a map-based study of the coastal strip to identify the linear density of isolated houses and farms within 300 to 400 m of the cliff line. We will also give consideration to the factors that might mitigate against the development of wells (e.g. the presence of a SSSI between the facility and the coast). However, it is envisaged that quantitative account of such mitigating factors would not be included within the estimate of annual risk.

5.7.4 Modelling of the estuary and lagoon

Climate and landscape change studies (Thorne and Kane, 2008) have identified possible alternative future developments of the Ravenglass Estuary, to the south of the site. The case of the entry of contaminated water or eroded material from the LLWR into an estuary or lagoon environment was not assessed in the R2 assessment (LLWR, 2008e). The case of an enclosed freshwater or brackish lagoon is of particular concern because of the potential for accumulation of radionuclides in lagoon bed sediments and in lagoon food chains.

We have commissioned work to develop suitable models and assess scenarios and cases related to the estuary/lagoon, in order to inform the LLWR as to the need for additional work before 2011. The aim is to provide a scoping assessment that is consistent, in terms of level of detail and caution, with the calculations performed in the R2 Assessment.

Three scenarios are being considered – the present-day estuary, a future open estuary and a future enclosed lagoon. Models for these three scenarios have been defined and can be represented using a compartmental modelling approach. The next steps are to implement the models using the GoldSim software tool, to investigate the dynamics of the estuary and lagoon systems and uncertainties using unit rate of radionuclide inputs, derive dose-per-unit-input factors for a range of radionuclides that are important for operational and post-closure periods, and estimate the dose rates for a representative source terms consistent with those derived in the R2 assessment.

Preliminary work indicates that:

- there is no potential for significant release of solid waste materials to an estuary/lagoon environment, as a result of coastal erosion, river meander or stream down-cutting;
- therefore, the study is focusing on solute releases via groundwater, but a “what if” case will consider the impacts of a nominal release of solid waste to a future estuary/lagoon;
- complex mixing processes occur in the estuary with sediment being created by flocculation processes at the freshwater-saline tidal interface;
- doses related to the estuary and use of adjoining periodically flooded pastures are likely to be lower than those associated with near-surface release to small streams adjacent to the site;
- the viability (formation and persistence) of a lagoon is uncertain and depends on a particular combination of circumstances;
- doses related to a lagoon (if it forms and persists) are likely to be higher than those associated with the estuary.

The significance of the radiological results of the assessment will be judged against and compared with results from other pathways as evaluated in the R2 assessment. This information, together with the understanding gained from modelling of the estuary and lagoon systems, will allow us to make a reasoned decision concerning the treatment of the estuary and lagoon in the 2011 ESC.

5.7.5 Other groundwater-mediated pathways

The well and lagoon are considered to be the most significant groundwater pathways. In addition to these calculations, we will undertake calculations for:

- the discharge of contaminants to the sea or foreshore as in the R2 assessment;
- the local discharge of contaminants to streams in the immediate vicinity of the LLWR with a potential contribution from bathtubbing as in the R2 assessment;

- the possibility of discharges to emergent land if the repository were not to be eroded and sea level were to fall (as a 'what-if' calculation).

A sufficient number of calculations will be undertaken to investigate the effects of changing sea level, changes to infiltration as a result of climate change, coastal erosion and in order to investigate the controlling parameters.

5.8 Gas-mediated pathways

Scientific understanding and experience from monitoring at waste storage and disposal sites, including the LLWR, shows that the radionuclides of concern for gas-mediated pathways are those that can be constituents of bulk gases produced in the repository and those that are themselves gaseous, i.e.:

- tritium (H-3) which can substitute for hydrogen in hydrogen gas (H_2) produced from metallic corrosion or in methane (CH_4) produced from organic degradation;
- carbon-14 (C-14) which can exchange with stable carbon isotopes in methane (CH_4) and in carbon dioxide (CO_2) produced from organic degradation or in methane produced from corrosion of metallic carbides;
- isotopes of the noble gas radon (Rn-222 and Rn-220, the latter known as thoron); these are released as radon atoms, but being insignificant in volumetric terms associate with whatever bulk gases are present.

Of these, tritium is of interest during the operational period, but is unimportant in the post-closure period on account of its relatively short half-life of 12.3 years. Thoron (Rn-220) is generally unimportant on account of its very short half-life of 56 seconds. Thus, C-14 and Rn-222 are identified as the only two radionuclides with the capacity to give rise to significant radiological exposures by gaseous release in the post-closure period.

5.8.1 Assessment of carbon-14

Our approach to the assessment of exposure to C-14 in the 2011 ESC will be based on that demonstrated by McGarry (2003) and reviewed and developed by Ball et al. (2008). This consists of:

- identification of waste streams containing significant quantities of C-14;
- estimation of the inventory of C-14 and its specific associations and form within the relevant wastes;
- estimation of the potential for evolution and release of C-14 labelled gases (CH_4 and CO_2) from the near field environment, taking account of degradation processes and also precipitation of CO_2 as carbonate (or bi-carbonate);
- simple assumptions for migration from the near field to the rooting zone on the cap surface;

- incorporation of C-14 into biomass according to results of the RIMERS models as developed within the NDA RWMD (ex-Nirex) programme;
- consideration of exposures due to intake of C-14 in foodstuffs based on specific activity (Bq C-14 per kg C).

The following developments/improvements will be incorporated into the approach demonstrated by Ball et al. (2008) and summarised in the R2 assessment (LLWR, 2008e):

- a re-evaluation of the inventory C-14 and its specific associations and form within the relevant wastes;
- using this information, scoping of gas evolution using the DRINK or a similar model taking account of uncertainty in the processes leading to gas production and heterogeneity of distribution of C-14 and potentially gas producing wastes;
- examination of potential for retention of C-14 labelled gases by soil biomass and vegetation considering different potential land uses and consequent different plant cover.

Supporting arguments will also be documented to show why this treatment is cautious, e.g. with respect to heterogeneity and uncertainties in gas generation, migration, bio-incorporation and diet. Depending on findings from the above development work, a simple probabilistic model may be defined and parameterised in order to yield a probabilistic calculation of risk via the pathway.

5.8.2 Assessment of radon

Radon occurs naturally and makes the largest contribution to the estimated average dose due to natural sources in the UK (HPA, 2005). This exposure is due to radon daughters attached to dust in indoor air.

The release, migration and exposure processes for radon are quite different from those for other radionuclides and the uncertainties around dose estimates are distinctly different. Thus, although there are some scenarios (related to human intrusion) in which exposure to radon could occur at the same time as exposure to other radionuclides, it is appropriate to keep the assessment of radon separate from the assessment of other radionuclides.

The HPA Consultation Document (HPA, 2008) suggested: “Doses and risks arising from the build up of radon in buildings should be treated separately as there are separate national standards for the total level of radon in dwellings and work places”. The wide variability of natural levels and difficulty of estimation was also cited. We await the new NS-GRA guidance to clarify whether the EA favours this view. Regardless of this, we will undertake assessment calculations in terms of estimated concentration of radon gas in indoor and outdoor air; this quantity can be compared directly with the UK Action Level of 200 Bq m^{-3} for radon in dwellings and also converted to annual dose by the HPA’s standard conversion. This approach avoids detailed consideration of uncertainties related to radon daughter disequilibrium and dosimetry. These uncertainties are common to assessments of radon doses, whether due to natural sources or waste disposal, and should not be taken into account in this context, just as uncertainty in the ICRP dose-per-unit-intake factors is not represented.

We plan to assess the following cases in the 2011 ESC:

- release of radon from the vents within of the temporary cap over the Trenches at present day based on simple calculations and comparison to the results of monitoring;
- release of radon from the whole site (Trenches and Vaults) over the period of authorisation taking account of progressive emplacement of waste and closing and initial covering of the Vaults, involving very simple atmospheric dispersion assumptions;
- release of radon at the surface of the final cap after the period of authorisation (after withdrawal of management control) – the cap can be designed to prevent any radon release but it is not clear whether this is necessary; alternative final cap designs will be considered including a vented design;
- release of radon into dwellings or other buildings constructed on the cap where the construction involves removal or damage to substantial sections of the cap, but not necessarily penetration to the waste;
- release of radon into dwellings or other buildings constructed on top of excavated waste and cap materials as considered in the R2 assessment (LLWR, 2008e).

Results from the first three cases are expected to show low to zero exposures to either members of the public during the period of authorisation or PEG members in the period after authorisation, due to the low releases and atmospheric dispersion in open air conditions. The last two cases offer more significant potential for exposure due to the assumption of release of radon to contained conditions in indoor air, and hence exposure to radon daughters. They are both human intrusion cases since they consider penetration into or exposure of the disposed waste, or significantly damage the barriers that are intended to isolate and contain the waste (see subsection 5.10).

The case of exposure to radon in a building on the cap was not assessed in the R2 assessment, but it was identified as a concern by the Peer Review Panel (Bennett et al., 2008). A simple scoping calculation at the time showed some potential for exposure, but depending very much on assumptions for migration from the waste to the building. Since the R2 assessment, we have undertaken pilot work in which three mechanisms for underground migration of radon have been considered – molecular diffusion, advection with gas produced by degradation processes in the waste, and gas movements driven by barometric pressure cycling. The last process appears to offer most potential for moving radon from its site of production in the waste to a building on the cap, although the effectiveness of the process depends on the heterogeneity of waste and interposed materials. We intend to consider the migration processes further and develop a justified model and input data for radon migration from the waste into an overlying building. The results of the modelling could have implications for cap design.

Exposure to radon in a dwelling constructed on top of excavated waste and cap materials was considered in the R2 assessment and led to the highest estimated annual doses presented – 0.7 and 0.9 mSv for the Trenches and Vaults respectively. Concentrations of radon in homes in the UK vary widely depending on building and floor construction and occupier habits, which are complex to model and even harder to justify data choices for since we are considering future putative buildings of unknown construction and occupancy.

In the R2 assessment, it was argued that the best way to deal with this variability was to adopt a simple empirical model based on average levels of radium in soils and average levels of radon in dwellings. Effectively, this is defining a “reference dwelling” which acts a test receptor for radon releases; this is equivalent to the IAEA/BIOMASS “reference biosphere” approach to develop test receptors for releases of other radionuclides. In preparation for the 2011 ESC, we will carry out work to refine the empirical model based on analysis of extensive data sets held by the HPA and the BGS concerning radon measurements in UK dwellings and associated geological information. This should provide a more confident relation between radium in soils and radon in dwellings based on the UK data, plus information on the effect of other factors such as house construction.

We will also reconsider the human intrusion scenarios to be assessed, as described in subsection 5.10, and ensure that the assessment of human intrusion cases for radon are consistent with those for other radionuclides. Hence, exposures from radon and other radionuclides can be added if the doses would be received by the same PEG.

5.9 Coastal erosion

Based on scientific understanding, and using a combination of quantitative modelling and qualitative evaluation, we are able to provide a well-supported set of climate scenarios and landscape evolution pathways to underpin future post-closure radiological safety assessments for the LLWR, see Thorne and Kane (2007). In particular, we are able to define scenarios for future climate and sea-level rise, and pathways for coastal and landscape evolution, that take account of the relevant uncertainties on global and local scales. Although there are uncertainties concerning the magnitude of sea level rise, coastal morphology and rates of erosion, the work by Thorne and Kane indicates that all the evolution pathways lead to disruption of the LLWR by erosion or inundation on a time scale of many hundred to a few thousand years.

This is a key finding that both focuses attention on the impacts of disruption of the facility by marine erosion at relatively early times and leads to the conclusion that longer-term scenarios for environmental change and human actions, e.g. fall of sea level fall and emergence of a terrestrial biosphere, erosion by generalised denudation and human use of a naturally degraded site, are of less importance.

In preparation for the 2011 ESC, we plan two strands of work to place increased attention on coastal erosion. These are:

- a thorough review of the scope for better modelling of coastal erosion processes over long timescales with a view to refining estimates of the timing of erosion (see subsection 3.4);
- more detailed modelling of the processes of coastal erosion over shorter, directed at understanding the radiological consequences to members of PEGs, taking account of uncertainties in progress and nature of erosion and realistic uses of the cliff, beach and foreshore.

The second study will take cases, as defined by the first study or based on those developed by Thorne and Kane, and develop them in terms of more realistic representation of the nature of the eroding cliffs and distribution of radionuclides as a function of the progress of erosion though the facility. The modelling and calculations will investigate the effects of heterogeneity of the wastes and facility, and alternative assumptions for dispersal of waste, e.g. including the effects of storm events. The question of whether the appearance of the eroding facility, or items within it, may modify human activities or habits in such a way as to increase their exposure will also be considered.

5.10 Human intrusion

We define human intrusion as:

> *"human actions taken after withdrawal of active management control and regulatory supervision that penetrate into or expose the disposed waste, or significantly damage the barriers that are intended to isolate and contain the waste".*

Water abstraction wells are outside the scope of this section and are discussed in subsection 5.7.3. Our proposed approach to assessing human intrusion is as follows.

- Consider, based on current technology and motivations, the potential modes of intrusion that could affect a facility taking account of site characteristics, geology, facility design, post-closure site supervision and record keeping arrangements.
- Judge those modes of intrusion that are most likely and relevant in that they have some capacity for direct excavation of the waste or damage to the engineered and natural barriers relevant to safety.
- Undertake assessments (qualitative and quantitative) of representative human intrusion events or sequences of events as a test of the robustness of the disposal such to such events.
- Consider the likelihood of such events in relative terms to each other, or in absolute terms if possible, to estimate likelihood or relative probability.
- Compare the consequences of human intrusion against a dose criterion (as recommended by the NS-GRA, but allow that the probability or relative probability of occurrence is relevant and include this in the assessment of the acceptability of such consequences.

In the 2002 PCSC (BNFL, 2002b) and the R2 assessment (LLWR, 2008e) intrusion events were assessed involving excavation of different volumes of waste, termed:

- small – representative of the type of disturbance that might be caused by the drilling of boreholes during site investigation;
- medium – representative of the type of disturbance that might be caused by a limited bulk excavation, e.g. associated with the construction of an isolated dwelling;
- large – representative of large-scale excavations associated with major construction projects or archaeological investigations at the site.

These were selected as representative in terms of excavated volume based on a formal expert elicitation study that identified possible developments and events at the site taking account of patterns of land use on the West Cumbrian Coastal Plain (Thorne, 1996). This was followed by a report (Halcrow, 1998) that considered how each of the common site uses would be implemented if the presence of a repository at the LLWR site were to be forgotten, including locations of buildings and wells, as required.

For the 2011 ESC, we propose to re-examine the elicitation and site reports and use this information to determine a set of intrusion events that is representative in terms of both potential impact and relative likelihood. This will include cases that involve damage to the engineered barriers, especially the cap, but do not necessarily lead to significant excavation of waste; such cases are relevant to the release of radon and to the groundwater pathway. Thus, a more balanced discussion and presentation will be developed of the uncertainties around the impacts of possible human actions at the site. Scenarios that consider the excavation and exposure to different quantities of waste, from different sections of the repository, will be assessed, but results can be placed in the context of relative likelihood of the different events.

In common with the previous approach (LLWR, 2008e), consequences will generally be estimated using simple linear models implemented in an appropriate software tool.

5.11 Non-radiological assessment

A key issue is to determine an appropriate approach for the assessment of the impacts of chemotoxic substances. The current draft Environment Agency guidance (Environment agencies, 2008) requires that the non-radioactive impacts must be assessed. The guidance indicates that this need not necessarily be by application of the nationally accepted standards for the disposal of waste that presents non-radiological hazards but not a radiological hazard, but that a level of protection should be applied that is no less stringent than would be provided if the standards were applied. The interpretation of this guidance is currently under discussion with the Environment Agency. As the chosen approach is of great importance, we provide some discussion of the alternatives, focusing on the groundwater pathway as this pathway is of most significance. Releases of gas would also need to be considered, but are not discussed further here.

The LLWR presented an assessment of chemotoxic impacts under Requirement 13 (Barber and Henderson (2008). However, this is regarded as very cautious in a number of respects and the LLWR has therefore commissioned work to take a fresh view of the approach (Kelly and Applegate, 2008).

5.11.1 'Landfill' approach

One approach is to use the standard approach for hydrogeological risk assessment of a landfill (Environment Agency, 2003). A number of more toxic substances are identified as 'List I' and should not be discernible in any discharge to groundwater before any dilution occurs. Further substances are designated as 'List II' and the release of these substances, measured at a compliance point on the site boundary, must be limited according to relevant standards, such as Drinking Water Standards (DWS). Assessment calculations are usually carried out with the program LandSim (see Environment Agency, 2003), although this is not a requirement. LandSim uses as one input the observed concentrations of contaminant in leachate and models the transport of these contaminants in flowing groundwater driven by the head of water within the landfill. Approaches of this sort would be feasible for the Trenches, but not for the Vaults, where currently there is no waste-equilibrated leachate that can be analysed as a basis for the calculations. Some aspects of this approach could be implemented, but a model-based approach is required to estimate concentrations in leachate in the Vaults. It would be normal to apply this methodology for a limited duration, comparable with the period of management control.

5.11.2 'Repository' approach

An alternative approach would be to match the methodology as closely as possible to the methodology used to estimate the impact of radioactive contaminants. This would involve the use of a source-term model to estimate leachate concentrations in near-field porewater, which could be the well-mixed equilibrium source model used in the Requirement 2 submission, a model in which releases are limited by rates of corrosion or wasteform dissolution or a model calibrated against leachate concentrations (see subsection 5.7.1). The impact of contaminants would be assessed by comparing concentrations in environmental media that are accessible to future populations with appropriate standards such as DWS. By analogy with calculations undertaken for radioactive contaminants, calculations would be undertaken up until the expected time of erosion of the facility.

5.11.3 Comparison

It is not clear which approach is more stringent for the period of management control. The landfill approach has more stringent criteria in terms of either the concentrations that might be acceptable or the locations at which the concentrations are measured. The repository approach would often be associated with a much more cautious near-field model. For the post-management period, however, the repository approach is clearly more stringent for the post management period, since landfill assessments would not cover this time period. For the Vaults and to a lesser extent the Trenches, the main challenges to the environment are likely to arise when the engineered barriers have degraded in the post-management period.

A number of intermediate approaches in which aspects of both approaches are combined in an appropriate way, but combining the approaches presents a number of difficulties. The different assessment approaches imply different approaches to design and design optimisation. In addition, there are different approaches to the assumptions and practice in terms of management control and the requirement for a repository to provide acceptable performance in the long term without reliance on management intervention.

5.11.4 Proposed approach

Our proposed approach is:

- To calculate the release of contaminants from the facility using an approach similar to that for radioactive contaminants (noting that source-term developments are being considered as discussed above and in subsection 5.7.1).
- To calculate concentrations relating to the discharge of contaminants to groundwater under the site and at the site boundary as appropriate (as would be required for a conventional landfill assessment) and also the environmental concentrations that would be relevant to the exposure of the PEGs considered for radioactive contaminants.
- To compare these concentrations with appropriate criteria, noting the following:

  - During the operational period, a focus would be on the concentrations of List 1 and List 2 substances at the relevant compliance points, using, as performance measures, the same criteria relevant to a landfill assessment.
  - During the post-closure period, we would focus on the calculation of concentrations in environmental media relevant to the exposure of members of PEGs.
  - If any of the criteria were exceeded, we would consider the acceptability in terms of the practicability of changes to design or inventory and the need to achieve a facility with an appropriate balance between short- and long-term environmental performance. Relevant arguments would be discussed with the Environment Agency and set out in the 2011 ESC.

5.12 Non-human species assessment

Doses to non-human biota that could arise from waste disposal at the LLWR are recognised as especially important because of the location of the site, which is bordered to the south and west by important natural environments encompassed by the Drigg Coast SSSI and SAC. There is also an increased emphasis towards protection of the environment as a principle in the draft NS-GRA relative to previous guidance.

An assessment of radiation doses to non-human biota resulting from releases of radionuclides from the LLWR was carried out to satisfy the EA Schedule 9, Requirement 11 as documented in Eden and Barber (2007). This comprised:

- a desk based appraisal and the screening of pertinent site data against generic criteria, including an assessment of current dose rates to non-human biota using monitoring data input to the ERICA [4] assessment tool;

- an assessment of potential doses to ecological receptors in future based on calculated concentrations in the local environments based on the 2002 PCSC GoldSim model of the LLWR site, as input to the ERICA tool.

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The latter considered the peak radionuclide concentrations in the Drigg stream, stream overbank soils, lower foreshore, local coastal waters and Drigg beach as input to the ERICA tool and also, as a check, into the EA spreadsheet for the assessment of impacts to non-human biota from ionising radiation. Timeframes of up to 4,000 years post-2050 and up to 50,000 years post-2050 were considered.

The study confirmed that the environmental impact from current aerial and liquid discharges from the LLWR is very low, leading to levels below environmental screening levels. The LLWR programme of statutory environmental monitoring, including requirements for ecological receptors, has been reviewed by the EA and the SLC.

Based on the concentrations calculated by the Goldsim model, both the ERICA and EA models indicate negligible risk to selected indicator species in the 4,000-year timeframe. In the 50,000-year timeframe, there is a potential impact on some organisms in the terrestrial and freshwater environments, with peak doses arising from ^{228}Th and ^{239}Pu. This finding, however, is based on some cautious assumptions, including that doses from peak concentrations of each radionuclide are added irrespective of times of occurrence and that the reference organisms occupy media with the highest level of radioactive contamination for 100% of the time.

For the 2011 ESC, we propose:

- to review the Eden and Barber assessment particular with respect to any non-cautious factors concerning the organisms and environments considered and to revise it where necessary;
- to use more recent monitoring data as a basis to re-assess current environmental levels and impact to non-human biota;
- to use results from calculations of radionuclide concentrations in local media as carried out for the 2011 ESC to calculate potential doses to non-human biota species using either the ERICA or EA spreadsheet tool, or by scaling of previous assessment results.

Bearing in mind the expected erosion of the site within a few thousand years, the assessment will focus on a timeframe up to 5,000 years post-closure. Consideration will also be given, however, to potential doses to indicator species during erosion and also as a result of human disruption of the site. The study will also make use of findings from the estuary/lagoon modelling studies to consider doses to non-human biota in these environments.

5.13 Radiological capacity

It is a key objective of the 2011 ESC to estimate a radiological capacity that could be used as a basis for future Authorisation Limits. In achieving this objective, our approach would be to estimate reference capacities that would correspond to meeting the risk guidance level or in the case of human intrusion, the relevant dose criterion. We envisage that were wastes to be disposed leading to higher radiological impacts (i.e. if the reference estimates were to be exceeded), then this would need to be specifically justified in terms of waste stream specific optimisation arguments. As part of the ESC, we will present both information on radiological capacity and our estimate of the impacts for a reference disposal inventory.

It is proposed to base the radiological capacity calculations on reasonable and credible rather than extreme scenarios or calculation cases. We will focus on those scenarios or cases that could result in some challenge to the risk guidance level or dose criterion for human intrusion. Groundwater and gas mediated pathways, human intrusion and coastal erosion scenarios will all be considered as constraints on radiological capacity.

Each case would lead to a constraint on the radionuclide-specific activity concentrations on a particular scale. In some cases, this scale may be relatively small. For example, an individual involved in construction work that resulted in intrusion into the facility might receive a radiation dose related to the average radionuclide concentration at the scale of the foundations of a new building. On the other hand, a member of a household making use of abstracted well water might receive a radiation dose related to the average concentration at the scale of say an individual vault (depending for example on the geometry of the plume of contamination and the distance from the repository). We will analyse each case to determine the scale at which the constraint applies.

It is envisaged that constraints from analysis of the different cases will be used as the basis of proposed Authorisation Limits. Consideration will also need to be given to the approach to managing disposals to ensure that they remain within these limits and also that available disposal capacity is used as efficiently as possible. Some criteria will be required in order to consider the acceptability of wastes on a container-by-container basis. For example, it might be decided to identify ISOs with particularly high concentrations of a specific radionuclide and only to accept them after some specific further review. It might be appropriate to define activity concentration trigger levels to prompt such specific review. In deriving an update of the Conditions for Acceptance (LLWR, 2007b), it will also be necessary to review the ESC to determine whether there are any developments in understanding that might have implications for the Conditions for Acceptance. A particular area for review would be in relation to the chemotoxic component of the disposal inventory. In our submission for the 2011 ESC, we will explain our overall approach to the development of waste acceptance criteria.

We will propose that future authorisation limits should be based on the maximum radionuclide-specific concentrations that are consistent with an acceptable level of performance, where the concentration is determined over the scale appropriate to the pathways through which impacts may occur. We suggest that annual limits should not be used, since they reduce flexibility in the management of the facility and may not necessarily be protective depending on how the wastes of most concern are distributed.

We will consider the additivity of contributions to radiological impact from different radionuclides when the contributions arise at the same time and to the same exposed group. When taking account of such additivity, our objective where possible would be to identify simple limits on the quantities of specific radionuclides, rather than to provide formulae setting out relationships between the maximum allowable concentrations of different radionuclides.

We will address the capacity of those radionuclides that are in the disposal inventory and which could reasonably challenge the relevant dose and risk criteria; thus we will not address radionuclides that in terms of the expected inventory give rise to very low radiological impacts.

We will consider where appropriate the form of the disposed radionuclides. For example, some forms of disposed ^{14}C are likely to give rise to ^{14}C-labelled gases and some are not. Thus, it may be appropriate to set different limits depending on the form in which a radionuclide may be present.

For chemotoxic contaminants, we would follow the approach for radioactive contaminants as far as possible. There may be additional constraints deriving from operational and transport safety for radioactive and chemotoxic materials, but these are not addressed here.

6 DISCUSSION

6.1 Overall strategy

A key objective is to develop a fit-for-purpose Environmental Safety Case for delivery to the Environment Agency before May 2011, as required in the LLWR's current Authorisation. The modelling and analysis comprising the ESC should be proportionate to the hazard, noting that the LLWR is a facility for the disposal of LLW and not higher activity wastes. We consider that the level of detail in the assessment, and the resources invested in underpinning work are proportionate to the impacts that might arise from the LLWR.

There needs to be an appropriate balance between the different models, arguments and analysis, presented in the Safety Case. The safety assessment, leading to estimates of radiological and non-radiological impact, is a key part of the Safety Case. However, it is also important to place emphasis on addressing the other Requirements in the NS-GRA that are not related to radiation dose or annual risk. Similarly, there should be emphasis on confidence building arguments. The 2011 ESC will place far more emphasis on these other requirements and on the confidence building arguments than was the case in the 2002 PCSC. Key arguments relate to:

- The need to demonstrate optimisation, in particular the consideration of alternative design, management and, if required, remediation strategies and the selection of sensible options on the basis of logical argument.
- The demonstration of robustness in terms of either showing that the safety case is robust if certain assumptions used as a basis for the safety assessment were to be wrong, as well as general confidence building arguments.
- Adequate characterisation of the site and an appropriate level of understanding of the characteristics of the waste and the performance of the engineered system.

An initial review of the range of safety case arguments is set out in subsection 2.5.

Good links have been developed between the ESC and other key projects. This is important as the ESC should be used as a tool to help manage the site and reach key decisions about its management and on waste acceptance. The ESC needs to take account of strategies and designs developed in other parts of the programme. The key interfaces include:

- With NDA's work, supported by the LLWR, to develop a National Strategy for LLW management and disposal;
- With the LLWR's work to develop and substantiate a repository design;
- With the Consignor Support team within the LLWR in relation to waste acceptance issues.

The importance of work in these areas is emphasised earlier in the report in the context of optimisation studies (see section 4) and inventory studies (see subsection 3.1)

The benefit in involving stakeholders in the development of our plans is recognised. The LLWR has in place a stakeholder engagement plan covering all aspects of the LLWR's work. We are committed to effective further engagement as the ESC develops. As part of this, we plan that a summary of the ESC will be developed that would be accessible to non-technical stakeholders and that we will develop a specific web page providing information on the ESC.

6.2 Addressing regulatory requirements

A key objective of the 2011 ESC will be to demonstrate compliance with the regulatory requirements in the draft NS-GRA. In Table 6.1, the material in the report is matched to the 15 requirements (R1 to R15) in the draft guidance for near-surface repositories. A broader discussion, setting out the basis on which we will meet the requirements, is provided below.

R1 concerns the creation of a voluntary agreement between the operator and the Environment Agency. This requirement is directed at the early stage of repository development, whereas the LLWR has been a facility for the disposal of radioactive waste since 1959. As the LLWR has a current Authorisation, the Environment Agency has a locus for regulatory action without the requirement of a voluntary agreement, so the requirement is of limited relevance to the LLWR.

R2 requires a step-wise approach involving a number of decision points, for example related to the start of site characterisation and at which the operator would voluntarily submit an ESC to the Environment Agency. As the LLWR is a disposal facility with a current authorisation under the radioactive substances, the requirement is again of limited applicability. Nevertheless, it should be noted that the LLWR is following an analogous stepwise approach, both because it is required to comply with conditions in the LLWR's Authorisation requiring the submission of reports and completion of work and because a detailed process of dialogue is an efficient way forward.

R3 indicates that the developer should take the lead in dialogue with the potential host community, other interested parties and the general public. The LLWR has an active programme of stakeholder engagement that addresses this requirement. A commentary is provided in subsection 2.6.

R4 requires an RSA93 application for the disposal of radioactive waste to be supported by an ESC. As noted in section 2, an environmental safety case is:

> *"a set of claims concerning the environmental safety of disposals of solid radioactive waste, substantiated by a structured collection of arguments and evidence"*

Section 2 sets out our approach to producing an ESC. This document is an account of our technical approach to the production of an ESC and complements an earlier more general approach document (Lean and Fowler, 2007).

R5 requires that we should foster a positive environmental safety culture and possess a management system, organisational structure and resources sufficient to provide the necessary management, safety and quality functions. This is delivered through the LLWR management system (LLWR, 2007a), which includes our Environment, Health, Safety and Quality (EHS&Q) Policy as summarised in subsection 2.7.

R6 sets out the dose constraint, applicable during the period of authorisation, R7 the risk guidance level after the period of authorisation and R8 the criteria appropriate to human intrusion. Our safety assessment methodology is set out in section 5. Setting out our approach in this area is a key objective of this document.

R9 deals with optimisation. As noted in the draft NS-GRA, optimisation is about finding the best way forward where many different considerations need to be balanced. As part of our approach, we are:

- Identifying a range of alternative options in relation to the key design and management decisions;
- Evaluating the options using appropriate assessment approaches, including in the case of radiological impact, the approaches set out in section 5;
- Discussing the options and their evaluation with a range of stakeholders, including the regulators;
- Comparing the options using an appropriate formal methodology.

Our approach to optimisation is set out in Section 4. A key link is with the National Strategy for LLW, being developed by the NDA with LLWR support. This national strategy will address the arguments related to the appropriate future use of the LLWR.

R10 points to the need for an assessment to show that radiological impacts on the accessible environment are acceptably low. To address this requirement, we will undertake an assessment of the radiological impacts on non-human biota, using the ERICA methodology (see subsection 5.12). As one of the supporting safety arguments, we will also consider comparisons between levels of radioactivity arising from the facility and those present naturally.

R11 concerns an assessment of non-radiological hazards. Our proposed approach, which has recently been the subject of dialogue between the LLWR and the Environment Agency, is set out in subsection 5.11.

The question of site investigation is addressed by R12. The requirement covers the need to adequately characterise the site and show that its characteristics are consistent with making a safety case. An extensive programme of site characterisation has been undertaken leading to a good geological and hydrogeological understanding of the site (see BNFL, 2002d; BNFL, 2002f; Henderson, 2008; Smith et al., 2007). This is reflected in recent numerical models (Henderson et al., 2008). At present we are taking forward plans for additional boreholes, as discussed in subsection 3.3. The analysis in subsection 5.7 for the groundwater pathway examines the potential radiological impacts taking account of this hydrogeological understanding.

R13 requires that the site is used and the facility is designed, constructed, operated and capable of closure so as to avoid unacceptable effects on the performance of the disposal system. This requirement covers a number of issues related to appropriate characteristics of the design and the use of appropriate construction techniques and methodologies. These questions are closely linked to the questions of design optimisation discussed in section 4. As part of the ESC, we will present or reference information on the approach to engineering design and how we have addressed each of the specific issues identified under R13.

The LLWR has waste acceptance criteria or conditions for acceptance that govern the receipt of wastes at the site (LLWR, 2007b), consistent with R14. The Conditions for Acceptance are consistent with the annual limits set out in the LLWR's current authorisation and take account of our wider understanding of those factors that may impinge on environmental performance. As an output of the ESC, we shall recommend an updated radiological capacity as the proposed basis of new authorisation limits (see subsection 5.13). An updated understanding of performance will also be used to identify any additional constraints on waste acceptance e.g. in relation to the non-radiological component of the wastes.

R15 sets out the need for a programme of monitoring. The LLWR has recently reviewed and developed its monitoring programme into a single integrated programme (Hilary, 2008). This has taken account of the needs of end users, including the ESC project and the requirements of statutory monitoring. As part of the ESC, we will describe the programme of monitoring, demonstrate that it is appropriate and indicate how it has been used as input to the safety assessment or in building confidence in the approach that we have used.

6.3 Next steps

Many aspects of the approach that we set out in this document are subject to testing and development in future work. It is likely that as a result of this work, there will be further modifications to the approach. These will be documented in a future revision of this document and if appropriate the relevant issues will be brought forward for discussion at regular liaison meetings between the LLWR and the Environment Agency.

A key purpose of this document is to seek external views on our developing approach. We understand that the Environment Agency will review this document and provide feedback. The approach document will also be submitted to the LLWR's peer review panel for review. Feedback from these reviews will be considered in further developing the LLWR's technical programme.

Table 6.1 Addressing the Requirements in the Draft Regulatory Guidance

Requirement	Approach	Cross reference
R1 Voluntary Agreement	This requirement is directed at the early stage of repository development, whereas the LLWR has been a facility for the disposal of radioactive waste since 1959. It is therefore not of direct relevance to the LLWR.	-
R2 Step-wise Process	A step-wise approach is indicated, involving voluntary submissions to the Environment Agency, during the early stages of repository development. As the LLWR has a current authorisation, the requirement is not of direct relevance.	-
R3 Dialogue with Potential Host Communities and others	The LLWR is committed to dialogue with stakeholders.	Subsection 2.6
R4 Environmental Safety Case	This document described the proposed technical approach to delivering an ESC.	Section 2
R5 Environmental Safety Culture and Management System	We are committed to the protection of the environment and health and safety of both workers and members of the public, now and in the future. The commitment is formalised in our Environment, Health, Safety and Quality (EHS&Q) Policy	Subsection 2.7
R6 Dose Constraints during the period of Authorisation	The site will be monitored during the operational period and if observations warrant this, actions will be taken to reduce discharges. We will use simple modelling approaches to determine potential releases during the operational period – to complement the information obtained from monitoring and to demonstrate that we are developing a consistent understanding of the performance of the facility.	Subsection 5.2
R7 Risk Guidance Level after the period of authorisation	A range of calculations will be undertaken to estimate the risks arising from a range of scenarios.	Section 5

Table 6.1 (Continued)

Requirement	Approach	Cross reference
R8 Human Intrusion after the period of authorisation	The radiation doses arising from human intrusion will be addressed as part of the ESC.	Subsection 5.10
R9 Optimisation	A range of options assessments or evaluations will be undertaken to address the key questions about the design, use and management of the site.	Section 4
R10 Environmental Radioactivity	Radiological impacts to non-human species will be estimated using the ERICA approach. We will also compare levels of radioactivity arising from the facility with naturally occurring levels of radioactivity.	Subsection 5.12
R11 Protection against Non-radiological Hazards	Calculations will be undertaken as part of the ESC, using an approach as closely aligned to the approach for radioactive contaminants as is possible. These will be used to assess the extent to which the facility provides adequate protection against non-radiological hazards.	Subsection 5.11
R12 Site Investigation	The LLWR has carried out an extensive programme of site investigation, and is also undertaking further work. The programme of site characterisation, the resulting conceptual models and data and their use in the safety assessment will be described in the ESC.	See references in main text and subsection 3.3.
R13 Use of the Site and Facility Design, Construction, Operation and Closure	In the ESC, the reasons for the choice of design and its suitability will be discussed. This will cover the work undertaken on optimisation and reference will also be made to the various engineering studies undertaken.	Optimisation is discussed in Section 4. Reference will also be required to various design documents.
R14 Waste Acceptance Criteria	Waste acceptance criteria are available and will be updated, following submission of the ESC to be consistent with our latest understanding of the safety issues and any updated Authorisation.	Subsection 5.13 and LLWR (2007)
R15 Monitoring	The LLWR has an integrated, extensive and ongoing programme of monitoring. This will be presented as part of the ESC.	Hilary (2008)

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