LLW Repository Ltd

The 2011 Environmental Safety Case

Addressing the GRA

LLWR/ESC/R(11)10031

May 2011

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Role	Name	Signature	Date
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Preface

The Low Level Waste Repository (LLWR) is the United Kingdom's principal facility for the disposal of solid low-level radioactive waste. The LLWR 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 a safe and efficient facility that provides a continuing option for the disposal of low-level radioactive waste in the UK. This will be achieved consistent with good practice for the near-surface disposal of radioactive waste, in accordance with environmental and health and safety regulation and guidance, and in compliance with the terms of our Nuclear Site Licence and Permit to dispose of radioactive waste.

This report is one of a series of reports that present the evidence underpinning the 2011 Environmental Safety Case for the LLWR – the 2011 ESC. The report has been prepared by the Environmental Safety Case Project and is issued under the authority of the Managing Director of LLW Repository Ltd.

ESC objectives

Under the terms of our Permit granted by the Environment Agency, we are required to submit an Environmental Safety Case (ESC) for the LLWR no later than 1st May 2011 and at intervals thereafter as requested by the Agency. The ESC:

- presents the arguments and evidence concerning the environmental safety of disposals of solid radioactive waste at the LLWR, at present and in the future, consistent with the Agency's Guidance on Requirements for Authorisation;
- provides a basis for the environmentally safe management of the site by the SLC, and regulation of the site by the Agency, including setting of conditions on its future management and acceptance of waste.

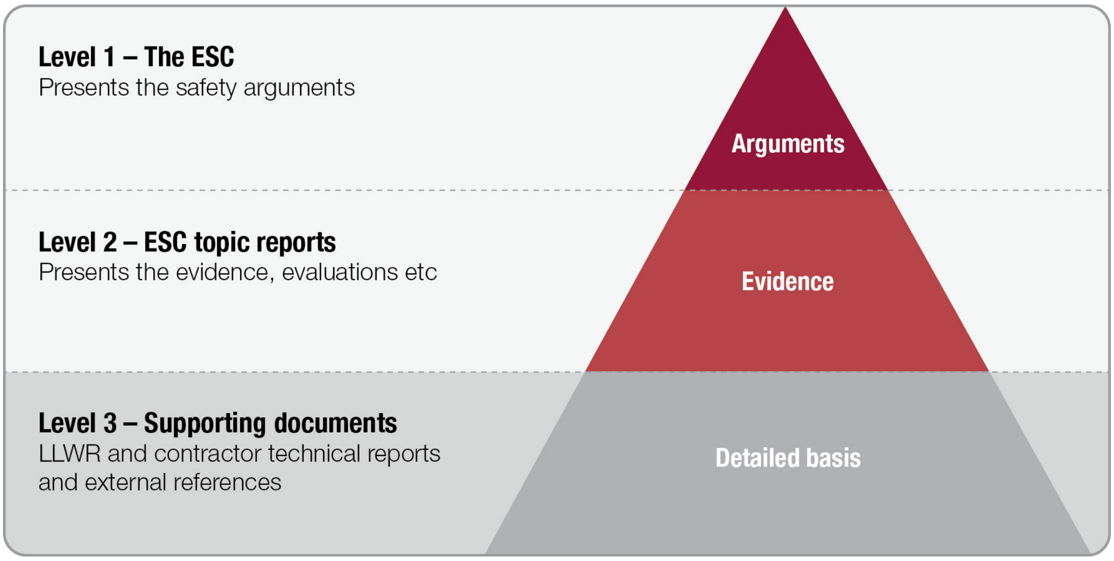
The ESC is addressed primarily to the Agency and is intended to inform and enable their regulation of the LLWR. It also provides a plan for the future management of the LLWR and a baseline against which proposed changes in the plan for the development of the facility can be tested. As such, it will be of interest to our other stakeholders, both local and national.

ESC document plan

The ESC consists of documents at two levels:

- A single 'Level 1' report outlines the plan for the development of the LLWR and the main arguments concerning environmental safety and how this is achieved.
- A series of 'Level 2' reports present the evidence that underpins our safety arguments, including descriptions of our management framework, system understanding, design and management choices, and assessments.

This is a Level 2 report. The ESC Level 1 and 2 reports are listed in the table at the end of this Preface, which also shows for the Level 2 reports the set of arguments for which each report mainly provides evidence. The ESC is supported by a large number of technical and scientific reports and references that we refer to as ‘Level 3’ documents.



The ESC documentation concept

Scope and audiences

The 2011 ESC is based on an optimised ‘Site Development Plan’ developed under our Environmental Safety Strategy. The Plan sets out our proposals and assumptions on operations, remedial activities, vault design, capacity and future waste disposal practice, closure design and management up to the end of management and regulatory control. It provides a basis for our quantitative assessments. The Plan is flexible, however, and will be amended as necessary in the light of UK radioactive waste management needs, operating experience, results of monitoring, future iterations of the ESC, regulatory and planning guidance and decisions, and stakeholder views.

The safety arguments set out in the Level 1 report comprise arguments concerning the development and safety of the Site Development Plan. The Level 1 report focuses on the arguments in principle, referring to the more detailed and quantitative evidence that is presented in the Level 2 reports. The main features and findings of the supporting reports are presented, demonstrating that the Site Development Plan is optimised, and that the assessed safety is consistent with the regulatory guidance over the lifetime of the facility, including after closure. The Level 1 report is intended to be complete enough to inform managers from the Environment Agency, Government ministries and local government representatives and officials on the environmental safety of disposal of radioactive waste at the facility. It is also intended to be an entry point to the safety case for the Agency’s technical staff and assessors.

The Level 2 reports present the evidence that underpins our safety arguments, including descriptions of our management framework, system understanding, optimisation, assessments and proposed conditions for acceptance of waste. The Level 2 reports are primarily addressed to the Agency’s Nuclear Regulator for the site and technical staff, and may be of interest to experts in specific technical fields. To fully satisfy themselves, however, for example, to find supporting information and details of the model formulations and data used, technical specialists and reviewers in specific topic areas may need to refer to Level 3 documents.

We have also produced a Non-technical Summary of the ESC, to help a wider group of stakeholders understand its nature, conclusions and implications.

Level 1	
The 2011 Environmental Safety Case – Main Report [1]	
Level 2	
Management and dialogue	Management and Dialogue [2]
System characterisation and understanding	Site History and Description [3] Inventory [4] Engineering Design [5] Near Field [6] Hydrogeology [7] Site Evolution [8] Monitoring [9]
Optimisation and Site Development Plan	Optimisation and Development Plan [10]
Assessments	Environmental Safety During the Period of Authorisation [11] Assessment of Long-term Radiological Impacts [12] Assessment of Non-radiological Impacts [13] Assessment of Impacts on Non-human Biota [14] Waste Acceptance [15] Assessment of an Extended Disposal Area [16]
Audit	**Addressing the GRA [17]**

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Executive Summary

Disposal of radioactive waste at the Low Level Waste Repository (LLWR) is regulated by the Environment Agency of England and Wales under the Environmental Permitting (England and Wales) Regulations 2010.

Regulatory guidance for disposal of radioactive waste for near-surface facilities is contained in the environment agencies' 2009 '*Near-surface Disposal Facilities on Land for Solid Radioactive Wastes Guidance on the Requirements for Authorisation*' (the GRA). The GRA consists of five Principles, fourteen top-level Requirements, and several hundred more detailed requirements. This report has three specific objectives in support of the 2011 Environmental Safety Case (ESC) for the LLWR:

- To provide a mapping from the requirements set out in the text of the GRA to relevant sections of the ESC.
- To demonstrate that the relevant requirements of the GRA have been or are being met.
- To illustrate the process used to confirm that the ESC and the supporting work programme are sufficiently comprehensive to address all of the relevant requirements of the regulatory guidance.

This report does not address any of the GRA requirements specifically. Rather, it provides a summary of how the requirements in the GRA have been addressed in the ESC, and gives direction to where the relevant material can be found in the Level 1 and other Level 2 ESC reports.

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Contents

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1 Introduction

1.1 Objectives

Disposal of radioactive waste at the Low Level Waste Repository (LLWR) is regulated by the Environment Agency of England and Wales (hereafter the Environment Agency) under the Environmental Permitting (England and Wales) Regulations 2010. Regulatory guidance for disposal of radioactive waste for near-surface facilities is contained in the environment agencies' 2009 '*Near-surface Disposal Facilities on Land for Solid Radioactive Wastes Guidance on the Requirements for Authorisation*' (the GRA) [18]. The GRA consists of five Principles, fourteen top-level Requirements, and several hundred more detailed requirements.

This report has three specific objectives in support of the 2011 Environmental Safety Case (ESC) for the LLWR:

- To provide a mapping from the requirements set out in the text of the GRA to relevant sections of the ESC.
- To demonstrate that the relevant requirements of the GRA have been or are being met.
- To illustrate the process used to confirm that the ESC and the supporting work programme are sufficiently comprehensive to address all of the relevant requirements of the regulatory guidance.

This report does not address any of the GRA Requirements specifically. Rather, it provides a summary of how the requirements in the GRA have been addressed in the ESC, and gives direction to where the relevant material can be found in the Level 1 and other Level 2 ESC reports. One of the most useful functions of the report was its use in the management of the ESC even while it was being developed, rather than its current role in the final product.

1.2 Scope

This report provides a mapping to where material relevant to addressing a GRA requirement can be found in the Level 1 and other Level 2 reports of the 2011 ESC. The Level 1 and Level 2 reports submitted as part of the 2011 ESC are listed in the Preface. This report is concerned only with the regulatory requirements in the GRA [18]. The LLWR is subject to other regulatory requirements, but these are outside the scope of the 2011 ESC and this report.

The GRA [18] is split into two parts, with Part 1 made up of Chapters 4 to 7 being identified as the guidance and Part 2 discussing the national and international context. In the guidance in Part 1, Chapter 4 sets out the Fundamental Protection Objective and the Principles to meet the Objective, Chapter 5 sets out requirements on the process under two top-level Requirements, and Chapter 6 sets out management, radiological and technological requirements ordered under a further twelve top-level Requirements. This arrangement is illustrated in Figure 1.1, taken from the GRA. Chapter 7 then sets out a series of requirements on the ESC itself, many of which build on the principles and requirements in Chapters 4 to 6.

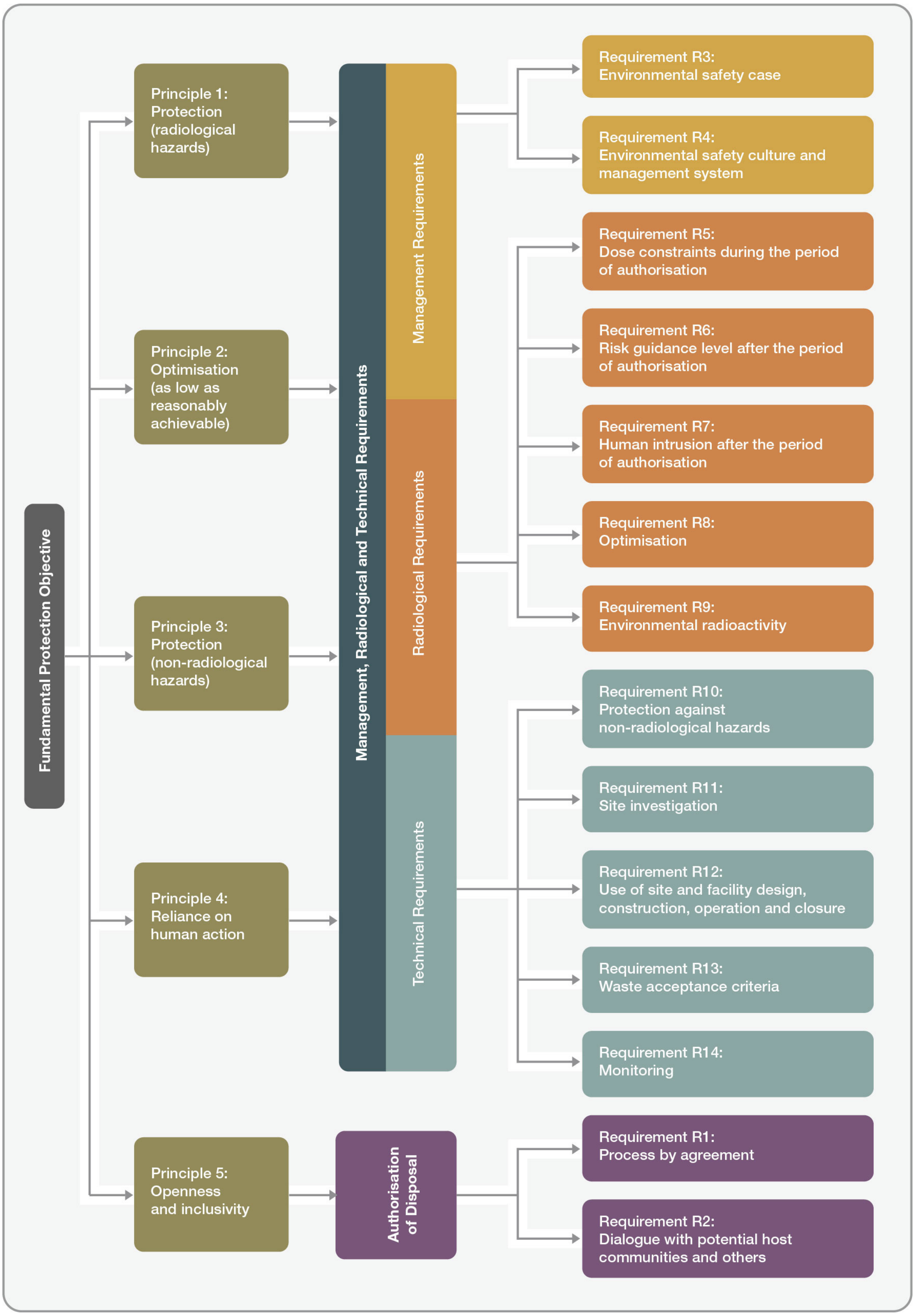

Figure 1.1 Relationship between the Principles and top-level Requirements in Part 1 of the 2009 GRA (Figure 3.1) (note that the chapters referred to in the figure are chapters in the GRA)

The requirements considered in this crosswalk have been extracted from Chapters 5 through 7 of the GRA. It is not considered necessary to produce a mapping from the ESC to Chapter 4 of the GRA which sets out the Fundamental Protection Objective and Principles for radioactive waste management. As the GRA notes (paragraph 3.2.3), if the requirements are fulfilled proportionately to the hazard presented by the waste, then this should ensure that the Principles are properly applied.

A degree of subjectivity has been applied to extract the requirements from the GRA text. The alternative of simply reproducing each paragraph of the GRA as a potential requirement was discussed with the Environment Agency, but it was agreed that each paragraph does not necessarily provide a requirement on us. The set of extracted requirements presented here has been independently reviewed by the ESC Project Team against the text of the GRA as an audit to ensure that the set is comprehensive. As is noted in the introduction to the GRA (paragraph 3.2.4), although the GRA is not mandatory, the term 'requirement' is used in the GRA to emphasise items that are particularly important from the regulatory perspective and where there is a strong expectation that they will be met. Therefore, while we may not meet, or consider appropriate, all requirements in the GRA, a reasoned argument needs to be provided to justify such cases.

The GRA is likely to be updated by the Environment Agency with supplementary guidance about meeting the requirements of the Groundwater Directive (Directive 2006/118/EC) in the near future. In anticipation of this, further requirements extracted from an interim draft of the supplementary guidance have been included in this report [19].

As part of the 2011 ESC, we have undertaken assessments for a repository in the Reference Disposal Area (RDA) (Trenches 1 to 7 and Vaults 8 to 14) and for a repository in an Extended Disposal Area (EDA) (the trenches and vaults in the RDA and Vaults 15 to 20). Our assessment and safety case for the EDA are described in the '*Extended Disposal Area'* report [16], which has not been included in this mapping. Our arguments for a repository in the EDA are essentially the same as for the repository in the RDA, and this Level 2 report focuses on the calculated impacts and differences and similarities with the RDA repository.

1.3 Structure

Section 2 of this report presents the mapping between the ESC and the regulatory requirements in the GRA. The mapping is in the form of a table with the following columns:

- GRA ID. This refers to the paragraph in the GRA from which the requirement text is extracted. Where more than one requirement has been extracted from the same paragraph, a letter suffix (a), (b) etc. is used. Where two paragraphs in the GRA provide essentially the same requirement, a single entry in the table refers to both requirement IDs. Draft requirements from the supplementary guidance about meeting the Groundwater Directive have been given the ID SUP6.1 to 6.7 and SUP7.1 to SUP7.2.

- GRA Requirement. Note that the GRA text has sometimes been edited in order to express paragraphs as a specific requirement or need that is placed on the operator, i.e., LLW Repository Ltd.

- How Addressed. A brief summary of how the requirement has been addressed in the 2011 ESC.

- Mapping to where the requirement is addressed in the ESC. This mapping is to the section level in the Level 1 and Level 2 ESC reports, identified by their reference shown in the Preface table. Where possible, mapping is to the section level, denoted by §. However, general requirements, for example, monitoring, are mapped to whole reports.

A list of acronyms used in the report is given in Appendix 1. A general glossary for the ESC is appended to the '*Main Report*' [1].

2 Mapping Table

Table 2.1 provides a mapping to where the GRA requirements are addressed as necessary in the 2011 ESC. Reference is generally made to the section of a Level 2 ESC report where the evidence can be found for the statement of how the requirement has been addressed in the 2011 ESC. For a few requirements, where a high-level argument is more appropriate, reference is to the '*Main Report*'. Mapping references are ordered in terms of importance, i.e. the key reference is listed first. Draft requirements from the supplementary guidance about meeting the Groundwater Directive are included at the end of the relevant Requirement section using the ID SUP.

Table 2.1: Summary of how the requirements of the GRA are addressed as necessary in the 2011 ESC and supporting work programme.

GRA ID	GRA requirement	How addressed	In ESC
5.2.3	**Requirement R1: Process by agreement.** The developer should follow a process by agreement for developing a disposal facility for solid radioactive waste.	This Requirement is focused mainly on the period before an authorisation exists. As such, it does not apply to the LLWR, where an environmental Permit (which replaces the RSA 93 Authorisation) exists. However, we have used features of the process described in the GRA as a guide to the Environment Agency's expectations during the development of the ESC, and these are extracted below.	Preface [2] §2
5.5.4	Agree the timing and scope of authorisation reviews with the regulator. To support an authorisation review, submit an updated environmental safety case.	The timing and scope of the 2011 ESC have been set by the Environment Agency, as described in the preface to the ESC 2011 reports. The timing of future iterations of the ESC will be agreed with the Environment Agency.	Preface [2] §2.3
5.5.6	When waste emplacement ends, submit a post-operational environmental safety case to show that the facility can be closed in a way that allows the principles and requirements of the guidance to be met.	A post-operational ESC is not yet required, as waste emplacement is ongoing. However, an outline of the closure design and its development is discussed in the 2011 ESC. Development of the RDA would allow the site to continue to operate as the primary destination for disposal of LLW in the UK until about 2080. Development of the EDA would provide capacity for continued operation up to about 2130.	[1] §3.4 [10] §5.2, §7.3, §7.4 [5] §8

GRA ID	GRA requirement	How addressed	In ESC
5.5.7	To support a request for revocation of the authorisation, submit a final environmental safety case to demonstrate that the facility meets the principles and requirements of the guidance. This might be submitted some time after closure of the facility if there is a period of active institutional control.	A final ESC is not yet required, as revocation of the authorisation is not yet being sought. The current plans are for the site to remain under management control, and it is assumed regulatory control, for a period of at least 100 years after final disposals and possibly up to 300 years.	[1] §3.4
5.7.1	**Requirement R2: Dialogue with local communities and others.** The developer should engage in dialogue with the planning authority, local community, other interested parties and the general public on its developing environmental safety case.	We engage with the range of stakeholders listed in the GRA requirement on a regular, planned basis. The process is set out in the LLWR Regulator and Stakeholder Engagement Schedule. The ESC Project also has a dedicated stakeholder engagement plan.	[2] §3
5.7.2	The developer is expected to engage widely in discussion of its ESC. Flexible approaches for engaging in discussions are required that adapt to meet a community's needs and expectations.	We engage with stakeholders through presentations and discussions at meetings, site and community open days, articles on our website, a quarterly site newsletter, and presentations at international workshops. The flexibility of our engagement process is illustrated by the examples of dialogue specific to the ESC given in the '*Management and Dialogue*' report [2] and the modification of the ESC in response to the dialogue.	[2] §3.2

GRA ID	GRA requirement	How addressed	In ESC
5.7.3	Consider, in discussion with the relevant local authorities, how to define 'local community' for any specific proposal, taking into account the nature, size and location of the proposed facility.	There is a LLWR sub-committee within the West Cumbria Sites Stakeholder Group (WCSSG) - an independent body that provides opportunities for members of the public and interested parties to comment on and influence future strategies and plans. Members of the committee include representatives from our management team, the Nuclear Decommissioning Agency (NDA), the Office for Nuclear Regulation (ONR), the Environment Agency, Cumbria County Council, Copeland Borough Council and Drigg and Carleton Parish Council. Quarterly liaison meetings also take place between us and Drigg and Carleton Parish Councils.	[2] §3.1.4
5.7.5	Work with the regulator to make sure that discussions with the planning authority and local community are open, inclusive and constructive. Technical, social or economic issues that might affect development of a disposal facility should be discussed openly with explanations of what the operator or regulator is doing to deal with these issues. Local communities and others should also be able to challenge the views of the developer and/or regulator on technical and other issues.	Examples of dialogue specific to the ESC are given in the '*Management and Dialogue*' report [2]. These include dialogue on technical issues, such as cap design, inventory, waste acceptance criteria, and dialogue on social and economic issues, such as the site-end state. The dialogue has fed into the development of the 2011 ESC.	[2] §3.2
6.2.1	**Requirement R3: Environmental safety case.** An application under RSA 93 relating to a proposed disposal of solid radioactive waste should be supported by an environmental safety case.	As discussed in the preface, the Level 1 and Level 2 ESC reports listed in Preface make up the 2011 ESC.	Preface [1] to [16]

GRA ID	GRA requirement	How addressed	In ESC
6.2.2 7.1.1 7.2.1(c)	The ESC should demonstrate that the health of members of the public and the integrity of the environment are adequately protected. It will be provided by the developer/operator of the disposal facility and should be designed to demonstrate consistency with the principles set out in Chapter 4 of this guidance and that the management, radiological and technical requirements set out in Chapter 6 are met.	The 2011 ESC provides the arguments and the supporting evidence that the public and the environment are adequately protected now and in the future. We have presented the ESC according to our strategy for achieving our proposal for safe, optimised development of the LLWR. We have shown that the arguments and evidence we have advanced in the ESC satisfy the requirements of the GRA.	[1]
6.2.3 6.1.3	Meet each management, radiological and technological requirement in the guidance in a manner proportionate to the level of hazard the eventual inventory of waste in the facility will present.	We have adopted a proportionate approach throughout our ESC work programme. The level of detail in the ESC, and the resources invested in the underpinning work are proportionate to the impacts that might arise from the LLWR, noting that the LLWR is a facility for the disposal of LLW and not higher activity wastes. Proportionality has been taken into account in our optimisation studies and decision-making.	[2] §4.2.3 [10]
6.2.5	**Requirement R4: Environmental safety culture and management system.** The developer/operator of a disposal facility for solid radioactive waste should foster and nurture a positive environmental safety culture at all times, and should have a management system, organisational structure and resources sufficient to provide the following functions: (a) planning and control of work; (b) the application of sound science and good engineering practice; (c) provision of information; (d) documentation and record-keeping; (e) quality management.	We have a positive environmental safety culture, which is supported by our management system. Our organisational structure and leadership enable us to develop and maintain resources and competencies, succession planning and knowledge management. We take safety into account in policy and decision-making and assure continuous improvement by implementing review and learning processes.	[2] §4 [1] §4.2

GRA ID	GRA requirement	How addressed	In ESC
6.2.6	Foster and nurture a positive environmental safety culture, i.e. appropriate individual and collective attitudes and behaviours, and require suppliers to do the same. This culture needs to be reflected in and reinforced by the adopted management system.	We encourage a positive environmental safety culture throughout our organisation and across our suppliers and customers by the adoption of company values that are embedded within the management arrangements.	[2] §4.1
6.2.8(a)	Implement a management system that includes effective leadership, proper arrangements for policy and decision making, a suitable range of competencies, provision of sufficient resources, a commitment to continuous learning and proper arrangements for succession planning and knowledge management.	We are committed to the protection of the environment and the health and safety of both workers and members of the public, now and in the future. This commitment is formalised in our Environment, Health, Safety and Quality (EHS&Q) Policy. This and other policies are delivered through our integrated management system as documented in our Management System Manual.	[2] §4.2 [1] §4.2
6.2.8(b)	The management system should be progressively adapted to provide suitable corporate governance of the organisation over the whole lifecycle of the project, i.e. from the early stages of site investigation onwards until the eventual closure of the disposal facility and any subsequent period of active institutional control.	Our management system is maintained through an annual review covering a range of topics. The review report includes detailed recommendations and a forward action plan for the forthcoming year. The action plan is a key input into our Improvement Plan. The review report is sent to the regulators and forms the basis for their annual review of our performance. This process enables the progressive adaptation of the management arrangements to provide suitable corporate governance of the organisation.	[2] §4.2

GRA ID	GRA requirement	How addressed	In ESC
6.2.9	The written management arrangements supporting the management system should show how, with an appropriate environmental safety culture, environmental safety is directed and controlled. They should also show how the management system is maintained in a living state through regular review, progressive updating and implementation of the management arrangements.	Our policies are documented in our Management System Manual (which also includes our Safety Management Prospectus), which summarises and provides references to the more detailed procedures and guidance, lists of role and post holders, and our top-level process model. The Management System is maintained through annual review. The maintenance, version control and issue of the system are managed through a document control information technology system. Each management system document has a document owner who has the responsibility for the review and amendment of the document through the lifetime of the business.	[2] §4.2, §9
6.2.10	The structure of the developer/operator organisation should be appropriate for its needs including, in particular, its responsibilities for environmental safety. The structure should reflect current and foreseeable operations and should show how key responsibilities are allocated. A new organisation should plan for and establish a structure based on a set of organisational structure principles that are linked to the activities it intends to perform. For an established organisation the structure should remain a 'live' issue, so that it continues to match the business needs and maintains clarity about responsibilities.	Our organisational structure is a live document that is aligned to the current operational baseline and is reviewed monthly to ensure that it reflects our current and foreseeable operations, including the management, operation and restoration of the LLWR site. The organisational charts are annotated to identify which posts, and post holders, hold EHS&Q roles. The Management System Manual details the accountabilities of senior management and shows how key responsibilities are allocated.	[2] §4.2, §4.3

GRA ID	GRA requirement	How addressed	In ESC
6.2.11	The board, directors and managers of the developer/operator organisation should provide strong leadership to achieve and sustain high standards of environmental safety. In particular, environmental safety messages must be seen to come from the top of the organisation and be embedded throughout its management levels.	We have an organisational structure that ensures a continuous unbroken chain of accountability for EHS&Q matters from the LLWR Ltd. Board and the Managing Director to senior management. Environmental safety messages come from the top of the organisation and are embedded throughout our organisation using a combination of communication mechanisms.	[2] §4.2
6.2.12	The organisation should be capable and forward-looking so as to secure and maintain the environmental safety of the disposal system for the whole of the lifecycle of the disposal facility. Roles, responsibilities, accountabilities and performance standards for environmental safety at all levels should be clear and not conflict with other business roles, responsibilities, accountabilities and objectives.	Our organisational structure is hierarchical, with teams that address each of our key business functions. The structure was implemented in 2008 following a due diligence review and reflects our changing role as an organisation that manages both waste treatment and disposal contracts. The structure of the company therefore meets our current needs and allows us to be forward-looking. The Management System Manual details the accountabilities of senior management and shows how key responsibilities are allocated. We control, assess and monitor any changes to key roles using a Management of Change process. In this process significant changes are assessed by the LLWR Safety Committees prior to implementation to ensure that all aspects have been adequately considered, environmental impacts are acceptable, and regulatory requirements are met.	[2] §4.2

GRA ID	GRA requirement	How addressed	In ESC
6.2.13	The management system should enable the organisation to develop and maintain the resources and competencies needed to ensure environmental safety. The written management arrangements should show how the organisation achieves and maintains a trained, qualified and experienced workforce that matches the need.	The Human Resources and Training (HRT) Manager defines site training needs, acts as the intelligent customer for human resources and training services, and leads the activities to plan the workforce, develop the organisation and manage performance. This includes maintenance of our organisational baseline, which is updated on a monthly basis. The organisational baseline defines all associated Duly Authorised Persons (DAP) and Suitably Qualified and Experienced Persons (SQEP), and our plan for keeping all such appointments, and any required training, current and valid.	[2] §4.3
6.2.14	The organisation may need to use contract resource to compliment its in-house capability but the implications of this should be recognised for its ability to remain in control in the short term and longer term. The organisation needs to be a capable operator in its own right and able to oversee and manage the work where it uses contractors. Achieving a suitable balance between employee and contractor numbers should take these aspects into account through a resource plan. The organisation will also need a sufficient capability to ensure that goods and services from its suppliers are of a fit and proper standard to meet the requirements of the relevant RSA 93 authorisation and the environmental safety case.	The personnel that discharge responsibilities with regard to the Site Licence and environmental Permit are part of the organisation and under direct line management control. However, in some areas and specialist disciplines, or to meet fluctuating resource requirements, we employ SQEP subcontractors, following the standards and arrangements defined in our procedures. As a minimum requirement, we ensure that we maintain sufficient expertise in all relevant technical disciplines to enable us to act as an informed and intelligent customer for technical services bought in from outside. For preparation of the ESC, as much of the contracted-out work as possible was procured through competitive framework contracts with specialist providers. ESC Technical Specialists were recruited to the ESC Project Team.	[2] §4.3

GRA ID	GRA requirement	How addressed	In ESC
6.2.15	Maintain relevant competencies over the lifetime of the facility, including any period of authorisation after closure.	Management of Change procedures maintain relevant competencies. Our Managing Director ensures that a deputy is identified for all key EHS&Q posts and roles, and that longer term succession plans for roles are maintained. The ESC Technical Specialists are part of the succession plan for the ESC, and will ensure the smooth succession of ESC management to an on-going team of our staff, who will continue to develop and apply the ESC as a site management tool beyond 2011.	[2] §4.3
6.2.16(a)	Policies and decisions at all levels that affect environmental safety should be rational, objective, transparent and prudent. All relevant considerations need to be taken into account whenever a policy is established or decision is made. New policies and decisions need to relate properly to, and build on, policies already established and decisions already made. Rigorous questioning of all factual material presented and assumptions made should be part of policy and decision making.	Our Environmental, Health and Safety (EH&S) Committee provides a forum for ensuring that policies and decisions that affect environmental safety are rational, objective, transparent and prudent. The EH&S Committee advises our Managing Director on any decisions relating to changes to site operations that could affect either the disposal of waste or discharges to the environment, or that have the potential to affect EH&S performance. The EH&S Committee includes members who are independent of LLWR Ltd., the Parent Body Organisation (PBO) and any related companies.	[2] §4.2.2
6.2.16(b)	Whenever a policy is established or a decision is taken, the reasons for the choice made need to be recorded. The reasons recorded should include the other choices considered and reasons why they were rejected.	Decisions taken during development of the LLWR that affect environmental safety are recorded in the '*Engineering Design'* [5] and '*Optimisation and Development Plan'* [10] *reports*. These reports give the reasons for the choices made, and include the other choices considered and reasons why they were rejected.	[2] §4.2 [5] [10]

GRA ID	GRA requirement	How addressed	In ESC
6.2.17	Lessons should be learned from internal and external sources to assure continuous improvement in all aspects that affect environmental safety. A learning organisation should challenge accepted established understanding and practice by reflecting on experience to identify and understand the reasons for differences between actual and intended outcomes. The organisation should seek to learn from external sources, including other industries, both in this country and abroad, analysing and acting on the lessons learned.	We ensure that lessons are learnt from internal and external sources, both in the UK and abroad, through the operating experience feedback (OEF) process. The process involves capturing relevant information from events (and other operational experience) across the site, from other parts of the organisation, and from outside the company, nationally and internationally. The information is reviewed for learning points which are then communicated and acted on to prevent future events. We are a member of the IAEA International Low-Level Waste Disposal Network (DISPONET). We exchange information with other LLW disposal organisations, both in the UK and overseas. We record and review feedback and lessons learned. Findings are reviewed during our annual management review meeting and, if further action is required, are included in our Improvement Plan.	[2] §4.4 [5] §2.4
6.2.18	Learning should take place throughout the organisation. Staff at all levels should be encouraged to report any actual or potential problems and to make suggestions to avoid or overcome these problems and to achieve improvements generally.	Relevant information from events (and other operational experience) across the site, from other parts of the organisation, and from outside the company, nationally and internationally, is reviewed for communication to staff. All staff are encouraged to report any hazards, near misses, and actual or potential events and incidents. Each event is reviewed at a staff or managerial level, depending on severity, and corrective actions are agreed and implemented.	[2] §4.4, §5.4

GRA ID	GRA requirement	How addressed	In ESC
6.2.19	Lessons learned should be embedded through a structured system that is rigorously applied. Reviews should be carried out to confirm that the changes have been made and that they have brought about the desired improvements.	Based on our feedback process, an Improvement Plan is prepared annually by our Head of Safety, Regulatory Liaison and Governance in conjunction with the LLWR Ltd. Board and the EH&S Committee. EHS&Q requirements and improvements across the organisation are detailed and action is then instigated to implement the requirements of our Improvement Plan and achieve its objectives. EHS&Q performance against accountabilities and targets is monitored through the review of key performance indicators and at EH&S Committee and Board meetings.	[2] §4.4
6.2.20	Identify all the key areas in which competency is required, and develop a strategy for succession planning and knowledge management in all these areas.	It is the responsibility of the HRT Manager to ensure that there is adequate training of personnel within an intelligent customer capability and that there are arrangements for succession planning. The intelligent customer function also includes knowledge management in each area. Our Managing Director ensures that a deputy is identified for all key EHS&Q posts and roles and that long-term succession plans for these roles are maintained; the plans are reviewed during annual management review meetings.	[2] §4.3
6.2.21	Where appropriate, the approaches used to fulfil management system functions should be based on principles derived from national and international standards.	Our management arrangements are certified to BS EN ISO 9001:2008, BS EN ISO 14001:2004, and OHSAS 18001:2007. Our systems and processes are subject to periodic surveillance visits by Lloyds Register.	[2] §4.2, §7.1

GRA ID	GRA requirement	How addressed	In ESC
6.2.22	The management system needs to be effective in all work that supports the environmental safety case. This covers most of the things that the developer/operator does and includes, at least: investigating the site; designing and constructing the facility; emplacing the waste; closing the facility; and putting in place any arrangements for active institutional control. It also includes work to document these activities and to provide the environmental safety case.	The generic requirement for the management system to be effective in all work supporting the ESC is addressed by our Management System Manual and supporting documents that are applied to all of our work activities. The management of the work highlighted in the GRA text is described in the '*Management and Dialogue*' report [2]. Recording of the work has been achieved through the ESC documentation and Level 3 supporting reports.	[2] §5
6.2.23	The management system needs to be effective in work that supports the environmental safety case specifically during the period of authorisation. This includes demonstrating compliance with the operational limits and conditions that will be included in the authorisation under RSA 93 held by the facility operator. The operator, through the management system, should monitor and assess radioactive discharges from the facility and levels of radioactivity in the environment, to conduct prospective and retrospective dose assessments and report accordingly.	Our responsibilities and accountabilities with regard to the operational limits and conditions that are included in our environmental Permit are defined in Repository Site Procedure (RSP) 02.01 and the Environmental Clearance Certificate. For disposals, compliance with the Permit is ensured through our Waste Acceptance Criteria (WAC). For discharges, a single Site Environmental Clearance Certificate has been adopted, which details Operating Rules and documents the environmental equipment used at the LLWR and the maintenance activities required. We conduct environmental monitoring and the results are reported annually to the Environment Agency. We undertake retrospective assessments on the basis of our monitoring of discharges and prospective assessments to consider the impacts of discharges in the future.	[2] §5.1 [11] §5

GRA ID	GRA requirement	How addressed	In ESC
6.2.24	All work that supports the environmental safety case needs to be properly planned and controlled. Any changes need to be made within a well-defined change control procedure, described in the written management arrangements, that assures quality and includes decision-making, doing the work and recording what has been done.	The work needed to develop the 2011 ESC was split into four phases, which were planned and controlled by the ESC Project Manager and included in the LLWR Life Time Plan (LTP). Status reviews were held at the end of each phase to assess progress to date, review new information and identify any required changes to the programme. We control, assess and monitor change using a Management of Change process.	[2] §5.2, §4.2.4, §5.3
6.2.25	Planning considerations need to include protection against, and mitigation of the effects of, human error and unplanned events during construction, operation and closure (for example accidental flooding), where the environmental safety case might be affected.	Before a modification to existing buildings, plant or processes (including changes to a Safety Case) is made, an assessment of its effect on conventional, environmental, radiological and nuclear safety and environmental performance is carried out. This includes judgement of the most significant potential environmental consequences which may arise from fault or accident scenarios. To ensure that the ESC requirements for long-term performance are considered, the ESC Project Manager signs off all potential modifications. Following an unplanned event or human error, we identify whether an event is notifiable to the Environment Agency under the conditions of the environmental Permit, and whether the event is relevant to the ESC. If the latter, the ESC Project Manager is informed to enable the likely impact on the ESC to be assessed and actions to mitigate the impacts and recurrence agreed.	[2] §5.3, §5.4

GRA ID	GRA requirement	How addressed	In ESC
6.2.26	All work that supports the environmental safety case needs to apply sound science. Make informed judgements about the quality of the science being applied and make sure that timely scientific investigations are carried out to remedy any deficiencies in understanding of particular relevance. Maintain awareness of scientific developments, both within and outside the UK that may have a bearing on the environmental safety case for the facility.	Our staff are suitably qualified and experienced to make informed judgements about the quality of the science being applied in the ESC. We ensure that our conclusions are based on sound science by: – Ensuring that each member of our ESC Project Team is SQEP for their role and drawing on the best available expertise from specialist ESC contractors. – Ensuring a thorough process of technical review of reports and arguments made within the ESC. – Commissioning peer review using national and international peer review groups. – Drawing on experience obtained by ESC Project Team members through involvement with assessments undertaken in other programmes and international working groups. We have described our underpinning technical programme in the ESC.	[2] §6.2, §4.4 [6] §8 [7] §2.4

GRA ID	GRA requirement	How addressed	In ESC
6.2.27	All work that supports the environmental safety case needs to follow good engineering practice.	We are committed to ensuring the application of good engineering practice. Our integrated management system includes processes and procedures for engineering design that incorporate good practice at other sites in the UK and overseas. We apply the following processes, which are cognisant of the relevant British, European and International Standards: – identification of suitably trained, qualified and competent staff for each role; – optimisation of major decisions; – the use of construction quality assurance procedures; – the checking and approval of engineering designs by a chartered engineer; and – validation post-construction. Our use of good engineering practice is demonstrated in the '*Engineering Design*' [5] and '*Optimisation and Development Plan*' [10] reports.	[2] §6.1 [5] §2.4 [10]
6.2.28	Before the decision is made to use a novel technology, carry out trials to demonstrate that any uncertainties about the outcome of using the technology are kept to a minimum.	Our safety strategy and reference design is based on the use of robust technologies, many of them already used successfully at the LLWR. New approaches will be considered as part of future optimisation assessments. The process of selecting technologies, and any trials performed to support the choices, will be documented.	[2] §6.1 [5] §2.1 [1] §5
6.2.29	After the end of the period of authorisation, rely entirely on a combination of engineered measures that can contribute to passive safety (recognising the lifetime for which such features can be expected to remain effective) and natural features and processes.	The safety strategy and long-term radiological assessment demonstrate the incorporation of passive safety measures into the engineering design of the LLWR. Our assessment relies on a combination of these passive measures and natural features and processes. Our assessment demonstrates that safety after the Period of Authorisation (PoA) does not rely on human actions.	[2] §6.1 [5] §2.1 [12]

GRA ID	GRA requirement	How addressed	In ESC
6.2.31	All engineered measures will degrade with time and this should be recognised in the environmental safety case.	Degradation of engineered measures with time is recognised in the ESC and is accounted for in our safety assessment models used to evaluate the long-term performance of the disposal system.	[2] §6.1 [6] §7, §8 [12] §3.5, §5.3
6.2.34(a)	The developer/operator will be responsible for all information necessary to support the environmental safety case, and will provide it in a timely way within an agreed documentation structure so that its relevance to the environmental safety case is clear.	We have established a process for dialogue with the Environment Agency through which proposals concerning both the content of the ESC and the ESC programme of work, including the approach to peer review, have been presented, discussed and agreed. We are providing all of the information supporting the 2011 ESC to the Environment Agency on the timescale specified in Schedule 9 of our environment Permit. We are using a structure, as set out in the preface to this report, that has been discussed with the Environment Agency.	[2] §2, §8 Preface
6.2.34(b)	Technical information will need to be submitted in an agreed form that allows the regulator to understand fully the arguments put forward in the environmental safety case and to carry out its own environmental safety assessments to support its judgements.	The preface to this report sets out the structure of the ESC documentation. The structure of the ESC was presented to the Environment Agency by submission of the Technical Approach report, a list of the Level 3 supporting reports, and discussion at a monthly liaison meeting. Resulting comments were taken into account in developing the ESC. The data and models that underpin the ESC are set out in our Level 2 reports and Level 3 supporting reports. These data will allow the Environment Agency to carry out its own assessments.	[2] §8
6.2.37(a)	Set up and maintain a comprehensive system for recording information on all aspects of the project affecting the environmental safety case.	We maintain records in both paper and electronic form. These are, and will continue to be, managed according to RSP 5.01 (Records Management), using the ICEPAC document control information technology system. Records of radioactive waste disposals at the LLWR are provided to the Environment Agency on a monthly basis.	[2] §9

GRA ID	GRA requirement	How addressed	In ESC
6.2.37(b)	Record: decisions taken and the reasons for them, data and results from the site investigation and characterisation programme; design documents, drawings and engineering details of the facility as constructed; records of waste form and characterisation; records of waste emplacements and their location in the facility; other operational information; details of facility closure; and results of monitoring and assessment at all stages of the project.	In addition to the LLWR-wide records discussed above, the ESC Project records and controls project memos, letters, agendas, reports and other significant information for the ESC using a unique reference number. Our records include the information listed in the GRA requirement. The ESC Project Team includes an experienced information controller, who is responsible for controlling project documents and information, and maintaining and backing-up records. Individual project team members are responsible for ensuring information is recorded for activities for which they are responsible. The document record for each activity is reviewed as part of an activity completion checklist.	[2] §9
6.2.37(c)	Duplicates of the records will need to be kept at diverse locations and in durable form.	We have a records management service delivery contract in place to support local management of records. Where appropriate, records are sent for microfilming, and duplicate copies are produced. With regard to the ESC, we will review the requirements for back-up of records and will develop the system(s) needed as appropriate.	[2] §9
6.2.37(d)	At the end of the period of authorisation, make arrangement for the records to be included in the public archive.	The NDA plans for a National Nuclear Archive are currently under consideration. We will develop our plans to be consistent with these wider NDA plans, and to include the submission of records to public archive at such time as our environmental Permit is withdrawn.	[2] §9

GRA ID	GRA requirement	How addressed	In ESC
6.2.38	The quality management arrangements should be regularly audited internally and from time to time by an external auditor registered by the International Register of Certificated Auditors.	We implement and manage an internal audit and inspection programme to improve the effectiveness of the business processes and management arrangements. An independent site inspector prepares and conducts a rolling five-year inspection programme, and our systems and processes are subject to periodic surveillance visits by Lloyds Register. The ESC Project Team has conducted external audits of contractors engaged on the project, specifically focusing on the procedures and approaches applied to check and verify calculations.	[2] §7
6.2.39(a)	Ensure that quality management arrangements are in place to ensure that all information can be traced back to its source.	Quality management arrangements are in place to ensure that all information used to support the ESC can be traced back to its source. Management of key data used in assessment calculations is covered by the ESC Project 'Data Management QA Procedure', which required data management forms to be completed, checked and approved by our technical data managers. The approved data management forms are maintained in a master spreadsheet by our data manager.	[2] §7.2
6.2.39(b)	On request, allow access to the original data and information on how they were gathered, so that the regulator can examine the provenance and interpretation of the data.	The data that underpin the ESC are set out in our Level 2 and Level 3 supporting reports. Level 3 reports will be provided to the Environment Agency. Further information will be provided to the regulator on request, through the normal communication channels.	[2] §7.2

GRA ID	GRA requirement	How addressed	In ESC
6.2.40	Where appropriate, use peer review to supplement other approaches to quality management. The rigour with which peer review is carried out needs to be proportionate to the significance of the work being reviewed to the environmental safety case. The peer review process must not be inappropriately curtailed. There needs to be a clear-cut stage in which the originators of the technical work respond to the reviewers' comments. Provide the comments made by peer reviewers and the responses to those comments to the regulators.	As part of our programme of work leading to the production of an ESC in 2011, a Peer Review Group (PRG) was appointed to provide independent challenge of the ESC and constructive advice. Meeting records, PRG reports and our responses are available to the Environment Agency and other stakeholders. To complement the PRG, a review was also commissioned from an international team of peers with experience from other radioactive waste disposal facilities – the International Peer Review Group (IPRG).	[2] §4.4.3
6.3.1	**Requirement R5: Dose constraints during the period of authorisation.** During the period of authorisation, the effective dose from the facility to a representative member of the critical group should not exceed a source-related dose constraint and a site-related dose constraint.	Information from measured discharges and environmental concentrations provides direct evidence that we have used to show that the dose constraints have been met historically. Consideration of likely future discharges during the PoA coupled with assessment calculations show that future radiological impacts will be below the dose constraints even when cautious assumptions are made.	[11] §5
6.3.2	The following are the maximum doses to individuals which may result from a defined source, for use at the planning stage in radiation protection: – 0.3 mSv per year from any source from which radioactive discharges are made; or – 0.5 mSv per year from the discharges from any single site.	Our '*Environmental Safety During the Period of Authorisation'* report [11] summarises our assessment of peak annual doses to potentially exposed individuals for each possible exposure pathway. Estimated doses are below the source dose constraint even if the peak calculated annual doses are summed (and different exposure pathways lead to peak doses in different locations at different times).	[11] §5

GRA ID	GRA requirement	How addressed	In ESC
6.3.3	For the operational and active institutional control phases, consider HPA recommendations that a dose constraint of 0.15 mSv (annual dose) should apply to exposure to the public from a new disposal facility for radioactive waste.	Estimated doses during the operational and active control phases are below the recommended HPA dose constraint. A dose roughly equivalent to the HPA constraint could be received from direct radiation by a person living adjacent to Vault 9 during its operation. However, this location is currently uninhabited. In future direct radiation exposures will be monitored and managed by an appropriate waste emplacement strategy.	[11] §5 [15] §8.3
6.3.4	For comparison with the source-related dose constraint, the assessment of effective dose should take into account both direct radiation from the facility and radiation from current discharges from the facility. For comparison with the site-related dose constraint, the assessment of effective dose should take into account radiation from current discharges from the facility, together with radiation from current discharges from any other sources at the same site (i.e. sources with contiguous boundaries at a single location).	We have provided assessments of dose from direct radiation and from discharges. Even if the peak calculated annual doses from each possible exposure pathway are summed (and different pathways lead to peak doses in different locations and at different times), the total for the whole site remains below 0.3 mSv y^{-1}. There are no other contiguous sources of radioactivity. Therefore, the LLWR complies with both the source-related and site-related dose constraints.	[11] §5

GRA ID	GRA requirement	How addressed	In ESC
6.3.5	During the period of authorisation, have a management system in place that provides a level of control on operational discharges that is proportionate to the hazard. In accordance with the authorisation: – monitor and assess radioactive discharges from the facility and levels of radioactivity in the environment; – have plans for action if monitoring suggests an unexpected release from the facility; – put into action remediation plans if any adverse anomalies are identified as a consequence of monitoring; – carry out dose assessments based on the levels of radioactive discharge permitted by the authorisation (prospective assessments) and assessments based on the levels of radioactivity measured in the environment (retrospective assessments); – report this information to the regulator.	We use Operating Rules under our management system to ensure compliance with the operational limits and conditions included in our environmental Permit. We monitor discharges and concentrations of radionuclides and other potential contaminants in environmental media around the LLWR. Control levels for contaminant concentrations have been defined. Trends in the data are examined as part of an annual review process. Where control levels are exceeded or trends identified, appropriate technical review takes place and there is consideration of any need for further action. We undertake retrospective assessments on the basis of our monitoring of discharges, and prospective assessments to estimate the impacts of discharges in the future. We supply an annual monitoring report to the Environment Agency. We are working to improve and develop this report into a comprehensive annual review of the monitoring programme and its implications.	[2] §5.1 [9] §3, §4, §4.3.5 [11] §4, §5
6.3.7(a)	Show that the controls proposed for the period of active institutional control are sufficient to support the claims made for the period of control and that the arrangements for applying the controls can be relied on to be implemented as planned.	Arrangements are in place that restrict unsupervised access to the site by members of the public. Proposals for control after the completion of disposals for active institutional control will be finalised in consultation with stakeholders and the Environment Agency as site development and operation proceeds. Current plans are outlined in the ‘E*ngineering Design*’ [5] and ‘*Optimisation and Development Plan’* [10] reports.	[10] §6.2, §7.4 [5] §9.5, §9.6 [11] §4

GRA ID	GRA requirement	How addressed	In ESC
6.3.7(b)	A claim for active institutional control will need to be supported by detailed forward planning of organisational arrangements and a suitable demonstration of funding arrangements.	Arrangements for active institutional control are in place that restrict unsupervised access to the site by members of the public. Funding for these arrangements comes from our operational budget. Proposals for control of the site after the completion of disposals will be finalised in consultation with stakeholders and the Environment Agency as site development and operation proceeds. Organisational and funding arrangements will be determined before the finalisation and implementation of the proposals.	[1] §2.2, §3.4 [10] §7
6.3.8	Include provisions for site surveillance with scope for remedial work if needed, a programme of environmental monitoring, control of land use and arrangements for the preservation of records. It will need to be supported by evidence that these provisions can be relied on to remain effective throughout the claimed period of time.	Site surveillance and monitoring arrangements for the operational period are already in place and are described in the *'Monitoring'* report [9]. Arrangements for the post-closure period are still under consideration. Current plans include the items detailed in the GRA requirement and are outlined in the '*Optimisation and Development Plan'* report [10]. Necessary provisions will be finalised before closure.	[9] §5 [10] §6.2, §7 [1] §3.4
SUP6.1	Show that the radiation dose to members of the public through the groundwater pathway during the period of authorisation of the facility is consistent with, or lower than, a dose guidance level of 20 μSv y^{-1}.	At the present day, there are no wells utilised for the abstraction of drinking water from the area between the LLWR and the coast. We consider it unlikely that a well will be drilled before the end of the PoA. In any event, the impact calculated from drinking groundwater from a hypothetical well into the plume peaks at the present day with an annual dose of 3 µSv.	[11] §5.3
6.3.10	**Requirement R6: Risk guidance level after the period of authorisation.** After the period of authorisation, the assessed radiological risk from a disposal facility to a person representative of those at greatest risk should be consistent with a risk guidance level of 10^{-6} per year (i.e. 1 in a million per year).	We have made estimates of the radiation doses and risks to potential exposed groups after the PoA, taking account of uncertainties in the performance of the disposal system, including expected and less likely future conditions. These dose and risk estimates are consistent with the risk guidance level of 10^{-6} per year.	[12] §5 to §7, §10

GRA ID	GRA requirement	How addressed	In ESC
6.3.13	Radiological risk associated with a potential exposure situation corresponds to the product of the estimated effective dose that could be received, the estimated probability that this dose will be received and the estimated probability that detriment would occur as a consequence to the person exposed. For comparison with the risk guidance level, assessed risks must be summed over all situations that could give rise to exposure of the same person to radiation.	We use this approach, in particular for our treatment of the water abstraction well. To illustrate the performance of the disposal system, we use deterministic analyses for most assessment cases. We have undertaken probabilistic calculations for the groundwater pathway. We compare assessment results from each pathway, the timing and location of impacts, and hence whether an individual could be exposed via multiple pathways.	[12] §2.2, §2.4, §10 [1] §4.5
6.3.14	For situations in which only stochastic effects of radiation exposure need to be considered (i.e. when the estimated annual effective dose is less than 100 mSv and the estimated equivalent dose to each tissue is below the relevant threshold for deterministic effects), a risk coefficient of 0.06 per Sv should be used.	We calculate conditional radiological risk by multiplying the calculated annual dose by the HPA-recommended dose-to-risk factor of 0.06 per Sv.	[12] §2.4.3
6.3.16	If the estimated effective dose received over the period of a year or less is greater than 100 mSv it should not be combined with the probability of receiving the dose to give an estimated risk but the dose and probability should be presented separately.	No effective doses exceeding 100 mSv y^{-1} have been estimated.	[12] §2.4

GRA ID	GRA requirement	How addressed	In ESC
6.3.19	Demonstrate that the measure chosen for comparison with the risk guidance level is reasonable (e.g. expectation (mean) value of risk) and present information about the sensitivity of the chosen measure to important parameter values.	We have carried out deterministic calculations using reference parameter values and have compared the results with the risk guidance level. We have explored model sensitivity using deterministic calculations. We have used the results of sensitivity analysis to identify key parameters and to gain an understanding as to how calculated impacts may vary as a result of uncertainty in input parameters. We have undertaken a probabilistic calculation for the groundwater pathway, sampling the distributions for key parameters, and we present the mean risk from this pathway.	[12] §2.4.4, §2.5, §5.4.4
6.3.21	In setting up a risk assessment, aim for data and assumptions that represent realistic or best estimates of the system behaviour. However, where the data do not support this approach or where the assessment can usefully be simplified, conservative data and assumptions to be conservative can be chosen as long as the requirements are still shown to be met.	Our aim in our assessments is to adopt a cautiously realistic representation.	[12] §2.4.1, §2.5.2
6.3.22	In cases where the hazard presented by the waste warrants a detailed assessment of risks, present a probability distribution of dose covering the range of possible doses that a person representative of each potentially exposed group may receive and providing the probability that this person receives any given dose. The probability distribution will vary with time into the future.	We have presented information on the distribution of radiological impacts, based on a probabilistic calculation for the water abstraction well. ..	[12] §2.5, §10

GRA ID	GRA requirement	How addressed	In ESC
6.3.26(a)	Quantifiable uncertainties should be considered within a numerical risk assessment developed as part of an environmental safety case.	We have applied the conventional division of uncertainties in structuring and presenting our assessment, namely scenario, model and parameter uncertainty. We have presented an analysis of these uncertainties using a mixture of deterministic (scenario, model and parameter uncertainty) and probabilistic (parameter uncertainty) calculation cases.	[12] §2.5, §10
6.3.26(b)	Unquantifiable uncertainties (where, for example, it is not possible to acquire relevant data, or if acquiring enough data to evaluate the uncertainty statistically could only be done at disproportionate cost) need to be taken into account in developing the safety case, but should be kept apart from the quantifiable uncertainties and given separate consideration. Taking into account unquantifiable uncertainties will inevitably involve judgement, first identifying significant unquantifiable uncertainties and then considering 'balance of likelihood'.	We have defined three scenarios to be addressed in our long-term safety assessment: expected evolution; delayed coastal erosion; and inadvertent human intrusion. These capture unquantifiable uncertainties through expert judgement. For the assessment of coastal erosion, the Environment Agency has made the specific request that we calculate radiological impacts at times when wastes of potentially highest radiological impact are being eroded. In our decision-making, most attention is given to the analyses of expected evolution and inadvertent human intrusion. The analysis of delayed coastal erosion is considered unlikely and is included to indicate that performance is robust.	[12] §2.5, §3.5, §7.2, §10
6.3.28	For highly uncertain future events, consider whether it is appropriate to undertake numerical risk assessments for comparison with the risk guidance level (e.g. 'what-if' scenarios and human actions that affect the disposal system).	In our FEP analysis, the only highly uncertain future event identified for quantitative risk analysis is the drilling of a well between the LLWR and the coast, which is considered as part of the reference scenario in probabilistic analysis of the groundwater pathway. In our definition of scenarios, the delay of coastal erosion of the site is considered unlikely and is analysed to indicate robustness of performance. In addition, within the other scenarios in our long-term assessment, 'what if' calculation cases are defined to investigate the effect of particular uncertainties (behaviour of exposed individuals and construction of a building with a cellar that intercepts or makes a connection with the gas collection layer).	[12] §3.5, §7.3, §8.3

GRA ID	GRA requirement	How addressed	In ESC
6.3.30	Consider different groups of people that could be at risk of exposure (potentially exposed groups) in order to identify a person representative of those people at greatest risk at a given time.	We have defined a range of potentially exposed groups (PEGs) that make reasonable maximum use of the potentially contaminated local environments.	[12] §2.4
6.3.31(a)	Substantiate the choice of potentially exposed groups as being reasonable and suited to the particular circumstances. The location and characteristics of the groups considered should be based on the assessed releases of radioactivity and on assumptions about changing environmental conditions.	We have based our assumptions for future biosphere and human activities on those that are observed in the region today, e.g. through habit surveys and current land use, and extrapolation to those that can be imagined constrained by present day demographics, but including the effect of expected environmental changes. We have also considered local subsistence-based possibilities for occupancy and resource use, which tend towards cautiously maximising calculations of dose for a given concentration of radionuclides in the environment.	[12] §5.3, §6.3, §7.3, §8.3
6.3.31(b)	The habits and behaviour assumed for people in potentially exposed groups should be based on present and past habits and behaviour that have been observed and that are judged relevant. Metabolic characteristics similar to those of present-day populations should be assumed.	The past and present-day local population and land use are included as part of our system description and feed into our assessment model development. Our definition of PEGs is based on interpretation of the past and present-day observed habits in the region, together with consideration of local subsistence-based possibilities.	[3] §3.2.8 [12] §2.4
6.3.31(c)	Other parameters (i.e. non-behavioural and metabolic) used to characterise a representative member of a potentially exposed group should be generic enough to give confidence that the assessment of risk will apply to a range of possible future populations.	Characteristics of PEGs that are not specific to observed habits in the region have been derived on the basis of standard generic UK data.	[12] §5.3, §6.3, §7.3, §8.3

GRA ID	GRA requirement	How addressed	In ESC
6.3.32	If two or more separate disposal facilities present significant risks to the same potentially exposed groups, consideration should be given to the combined risks.	No other disposal facilities presenting significant risks to the same PEGs have been identified.	[3] §3 [9] §2.5
6.3.35	If there is a significant discrepancy between the results of a risk assessment and the risk guidance level, or if the probability distribution of dose at some future time is of concern, additional information should be provided to demonstrate that an appropriate level of environmental safety is assured.	Our estimates of the radiation doses and risks to PEGs after the PoA, taking account of uncertainties including expected and less likely future conditions, are consistent with the risk guidance level. However, in our ESC we still provide a range of additional information to demonstrate the environmental safety of the LLWR.	[12] §10 [1] §3, §4
SUP6.2	Show that the radiological risk to members of the public through the groundwater pathway after the period of authorisation of the facility is consistent with, or lower than, a risk guidance level of 10^{-6} per year.	The mean of the distribution of risks from a groundwater well peaks at 2 10^{-7} y^{-1} at about 150 years after closure. This is for an assumed probability of a well being present between the LLWR and the coast of 0.04.	[12] §5.4

GRA ID	GRA requirement	How addressed	In ESC
6.3.36	**Requirement R7: Human intrusion after the period of authorisation.** The developer/operator of a near-surface disposal facility should assess the potential consequences of human intrusion into the facility after the period of authorisation on the basis that it is likely to occur. The developer/operator should, however, consider and implement any practical measures that might reduce the chance of its happening. The assessed effective dose to any person during and after the assumed intrusion should not exceed a dose guidance level in the range of around 3 mSv y^{-1} to around 20 mSv y^{-1}. Values towards the lower end of this range are applicable to assessed exposures continuing over a period of years (prolonged exposures), while values towards the upper end of the range are applicable to assessed exposures that are only short term (transitory exposures).	We have undertaken an assessment of the potential impacts from inadvertent human intrusion in to the LLWR. We are confident that disposals to-date and future disposals can be managed such that assessed doses due to inadvertent human intrusion after the PoA will comply with the dose guidance levels. The primary engineering control to reduce the likelihood of disruption is the depth of waste beneath the ground surface. This is essentially related to the thickness of the final cap over the facility. Further, the many components of the cap will be distinctive and give warning of a man-made facility. Several layers will have considerable strength and could only be broken through by deliberate effort. There are expected to be few waste consignments that – if intruded into – could lead to radiological impacts that would exceed the dose guidance levels, and the potential impacts could be mitigated if we avoided emplacing these consignments at the top of a waste stack. We are, therefore, considering the establishment of an emplacement strategy for such wastes to mitigate the potential impacts from human intrusion.	[12] §8 [10] §5 [5] §8.5.5 [15] §6.4, §8.1, §8.3

GRA ID	GRA requirement	How addressed	In ESC
6.3.39	Assess potential exposures of possible intruders to the radiological dose that might arise from a range of possible exposure scenarios. These scenarios should consider the exposures that arise from the potential exposures from the inventory of waste to be disposed of including any gaseous emissions from the waste such as radon; this should not include exposures to naturally occurring radon. Due to the large uncertainties associated with exposures to radon the developer should present these both aggregated with other exposures and individually.	We have undertaken a qualitative evaluation of human intrusion events that could occur at the site after withdrawal of management controls. Human intrusion events specifically associated with activities that might occur in the period during which the site is being eroded by the sea have also been included. A set of events identified as most representative and likely were retained for quantitative assessment against the regulatory guidance levels. Doses have been calculated to those taking part in the intrusion event and to others exposed, for example, as a result of the distribution of waste at the surface or the use of recovered materials if they are contaminated. Calculated doses from radon are presented individually and aggregated with other exposures for relevant events.	[12] §8
6.3.40	Show that dose thresholds for severe deterministic injury to individual body tissues are unlikely to be exceeded as a result of human intrusion into a near-surface disposal facility.	We note that HPA has stated that, for near-surface disposal facilities, the annual dose range of 3-20 mSv y^{-1} will '*ensure that the doses from inadvertent human intrusion are well below the level that could give rise to severe deterministic effects.*' Therefore, we consider that the dose thresholds for severe deterministic injuries will not be exceeded by the doses we have calculated for human intrusion of the LLWR.	[12] §8
6.3.41(a)	Do not consider human intrusion where the intruders have full knowledge of the existence, location, nature and contents of the disposal facility.	Deliberate intrusion of the LLWR has been excluded from our evaluation of human intrusion events for assessment.	[12] §8
6.3.41(b)	Consider human intrusion in cases where there is no prior knowledge of the disposal facility or where there is knowledge of the existence of underground workings but no understanding what they contain.	We have considered the kinds of human intrusion events that could occur at the site after withdrawal of management controls. A set of events identified as most representative and likely were retained from this analysis for quantitative assessment against the regulatory guidance levels.	[12] §8

GRA ID	GRA requirement	How addressed	In ESC
6.3.44	Where barriers that provide environmental safety functions are natural, rather than engineered, consider how far from the disposal facility itself it is reasonable to apply the dose guidance level rather than the risk guidance level.	We have considered the dose guidance level as the performance measure only for inadvertent human intrusion of the facility itself. We have considered the risk guidance level as the performance measure for all other calculation cases.	[12] §10
6.3.45	Consider, and implement, any practical measures that might reduce the likelihood of human intrusion. Such measures should not compromise the environmental safety performance of the disposal system if human intrusion does not occur. The measures to reduce the likelihood of human intrusion should be considered as part of option studies under Requirement R8, Optimisation.	We have considered active control and passive design measures to mitigate against human intrusion as part of our optimisation studies. Active controls will include site management and monitoring. Preservation of information and installation of the cap will also reduce the likelihood of human intrusion.	[10] §5.2, §6.2, §7
6.3.47	Explore the timing, type and extent of human intrusion into a facility through one or more 'what-if' scenarios, separate from the scenarios representing evolution of the disposal system undisturbed by human intrusion.	We have analysed a set of human intrusion events identified as most representative and likely. Annual doses are calculated as a function of the time of event occurrence between the end of the PoA and either 3,000 years after present (reference case) or 10,000 years after present (delayed coastal erosion case).	[12] §8
6.3.48(a)	Human intrusion scenarios should be based on human actions that use technology and practices similar to those that currently take place, or that have historically taken place, in similar geological and geographical settings anywhere in the world. The assumed habits and behaviour of people should be based on present and past human habits and behaviour that have been observed and are judged relevant.	For our assessment of human intrusion, we have specified a stylised set of events with the event and assessment models based on present and past technology and practices, and human habits and behaviour. We have used the substantial body of work on potential future human actions undertaken in support of the 2002 Post-Closure Safety Case (PCSC), with consideration of additional human intrusion events that are specifically associated with activities that might occur in the period during which the site is being eroded by the sea.	[12] §8 [3] §3.2.8

GRA ID	GRA requirement	How addressed	In ESC
6.3.48(b)	Human intrusion scenarios should include all human actions associated with any material removed from the facility, including considering what is then done with this material. When considering optimisation, the number of people involved in actions associated with intrusion should be assessed, and may be assumed to be similar to the typical number involved in similar actions now or historically. Similarly, the number of people who might be exposed as a result of occupying the site or neighbourhood after the intrusion should also be assessed. Each scenario considered should be substantiated as being reasonable and suited to the particular circumstances.	In our assessment of human intrusion events, doses have been calculated to those taking part in the intrusion event and to others exposed as a result of distribution of waste at the surface and scavenging of contaminated materials during coastal erosion of the LLWR. The number of people who might be exposed as a result of each intrusion event has been considered in our qualitative analysis of possible events.	[12] §8

GRA ID	GRA requirement	How addressed	In ESC
6.3.49	Present assessments of radiation doses to individuals representative both of those undertaking intrusive activities and those who might occupy the site or the neighbourhood after intrusion. Explore the consequences of intrusion in a wider geographical sense and on the long-term behaviour of the disposal system. The assessments should take into account all radionuclides that may be present in the waste and all decay products making a significant contribution to dose. They should also take into account inhomogeneities in the waste.	In our assessment of human intrusion, a set of events has been identified as representative of the nature and consequences of possible events. For each, doses have been calculated to those taking part in the intrusion event and to others exposed as a result of distribution of waste at the surface and scavenging of contaminated materials during coastal erosion of the LLWR. Key radionuclides are distributed between different parts of the facility in a markedly heterogeneous manner. In certain cases, this heterogeneity is due to single waste streams rich in a given radioisotope arising over a short period (for example Tc-99), in others it is due to the phasing of decommissioning activities (for example C-14 or Cl-36 from decommissioning of power reactors). We have reviewed the distribution of the key radionuclides in the trenches and vaults, and considered heterogeneity in our assessment.	[12] §8 [4] §5.5
6.3.50	Present assessments of the radiation doses received by non-human organisms as a result of human intrusion into the facility and demonstrate that these are not at a level liable to cause significant harm to populations of such organisms.	We have not specifically assessed the impacts of human intrusion events on non-human biota, noting that such events would have only a very localised impact. Such events could lead to exposure to radionuclide concentrations only similar to or lower than those arising from cliff erosion, when dilution of exposed waste will be less. Our Level 2 report *Assessment of Impacts on Non-Human Biota* shows that the impacts to non-human organisms from coastal erosion are not significant.	[14] §6.2.5
6.3.51	Use the results from human intrusion scenarios as part of option studies under Requirement R8, Optimisation to reduce the radiological impacts resulting from human intrusion, subject to balancing all the other considerations relevant to optimisation.	We have used the results from our human intrusion calculations to consider options for management of past disposals, management of future disposals (waste acceptance, emplacement) and engineering design.	[10] §3, §4, §5

GRA ID	GRA requirement	How addressed	In ESC
6.3.52	Where potential doses around the dose guidance level may be possible for human intrusion scenarios as a result of long-lived radionuclides, use the results of the scenarios to propose facility-specific authorisation limits and conditions, such as inventory limits and allowable activity concentrations, supported with suitable arguments.	We have used the results from our human intrusion calculations, considering how the individuals in the assessment cases are potentially exposed to wastes, to derive potential radioactivity concentration limits. We will consider trigger levels that identify wastes that take up a significant fraction of these radiological limits. In terms of consignment activity limits, we will first ensure that the total volume of all waste streams that exceed the Sum of Fractions remains consistent with the basis for the ESC. Second, those waste streams that exceed the Sum of Fractions will be recorded to ensure that the objectives of any emplacement strategy for excluding such wastes from the upper levels of the vaults can be successfully implemented.	[15] §6.4, §8.1
6.3.54	Where there is a difference between practical measures to reduce the likelihood or consequences of disruption and what can reasonably be claimed in the ESC (because of uncertainties surrounding human intrusion), the operator/developer may be required to adopt practical measures that go beyond what is accepted as a substantiated claim in the ESC.	We take no credit in our ESC for any reduction in the likelihood of the human intrusion events we model as a result of passive control measures that persist beyond the PoA. However, the profile and highly engineered nature of the cap will provide a strong indicator of a significant facility, and this may give due warning against inadvertent human disturbance.	[5] §8.5.5 [10] §5.2.4
6.3.55	Show that intrusion by non-human species, including plant species (for example tree roots), is not a significant issue.	The cap is designed to prevent the possibility of intrusion by burrowing animals and deep-rooted plants.	[5] §8.3.5

GRA ID	GRA requirement	How addressed	In ESC
6.3.56	**Requirement R8: 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, both during the period of authorisation and afterwards, are as low as reasonably achievable (ALARA), taking into account economic and societal factors.	The optimised development of the facility through a series of option studies is summarised in our '*Optimisation and Development Plan'* report [10]. As noted by the 2002 PCSC review, two approaches of setting WAC based on ESC assumptions, and setting WAC via an optimisation process, are often used in combination. This is the approach we have used to derive and underpin proposed WAC for the LLWR.	[10] [15] §3.2
6.3.59	To succeed, optimisation requires good communication, both within the developer/operator's own organisation and with supplier organisations, as well as with the regulators and the local community.	Our optimisation work has involved both internal and external stakeholders, including waste consignors, regulators and the local community. Feedback has helped to guide and inform judgments made in the identification and comparison of options.	[10] §2.2.4, §3.2, §4.1, §5.2.2 [2] §2, §3
6.3.60	Where there are choices to be made among significantly different alternatives, carry out options studies. Present the results to the regulators and make them publicly available.	Our '*Optimisation and Development Plan'* report [10] summarises our options assessment work. This work has involved the regulators and other stakeholders, and has been made available *inter alia* through workshops, the Vault 9 planning process, and the Requirement 2 submission to the Environment Agency. Optimisation studies are ongoing, and publication of this ESC provides another vehicle for obtaining feedback on our work.	[10] [10] §2.2.4, §3.2, §5.2.2 [2] §2, §3

GRA ID	GRA requirement	How addressed	In ESC
6.3.62	Optimisation needs to be considered at each decision-making stage. Once a decision has been implemented, it forms part of the framework within which further decisions, and the optimisation considerations that go with them, must be made. Even when a decision has apparently been made, it continues to represent an uncertainty before it has been implemented. The end of the period of authorisation is the end of decision-making by the developer/operator.	Optimisation has been considered at the different decision-making stages in the development of the LLWR. Our overall approach to optimisation and the framework in which our decisions are made are set out in our '*Optimisation and Development Plan'* report [10]. Decisions about use of the LLWR – in part reflecting national strategy, and in part detailed engineering questions – are addressed in our 'E*ngineering Design*' report [5]. We recognise that not all decisions can be made now, and that further research, monitoring and analysis are likely to be required in order to refine optimisation of facility management in the future.	[10] §7 [10] §2 [5] §2.1
6.3.64	In the presence of uncertainties, make sure that an acceptable situation will result, not only in likely future circumstances, but also in circumstances that are possible but unlikely. Acceptability can be measured in terms of radiation dose or risk, but it will often be unnecessary to go as far as calculating these quantities to recognise a situation as unacceptable.	In our assessment, we have presented an analysis of the implications of uncertainties using a mixture of deterministic and probabilistic calculation cases. To check acceptability, we have included a delayed coastal erosion scenario in our assessment as a calculation for the unlikely circumstances of a delay in erosion of the site of over 10,000 years.	[10] §7 [12] §10 [1] §4
6.3.65	Once the main optimisation task has been fulfilled, follow the more usual path of finding the best way forward for each set of circumstances. At this stage, focus mainly on the likely circumstances. Unlikely circumstances should not have undue influence on design, construction or operation.	Our optimisation work underpins the definition and focus of our Site Development Plan, which encompasses our detailed strategic approach to controls on environmental safety. Our design follows from our optimisation work, being focused on likely circumstances and being kept as simple as possible within our strategic constraints. Our design is described in our 'E*ngineering Design*' report [5].	[5] [10] §7

GRA ID	GRA requirement	How addressed	In ESC
6.3.66	Favour a simple approach to optimisation rather than a more complex one, where either would deliver an adequate outcome. If a numerical approach is used to compare options, recognise that the size of the population at risk is a relevant issue as well as the magnitude of individual risks.	We have used a range of approaches to options evaluation. Whatever the approach to analysis, however, the aim in what is presented is to make visible the key underpinning evidence and logic that has led us to put forward a proposed set of management controls for future management of the LLWR.	[10] §2.3 [10]
6.3.67	At each decision-making stage, provide a written record of the consideration of optimisation. As part of the environmental safety case, provide a historical record of the decisions taken and implemented, and the optimisation considerations that related to those decisions when they were taken.	The '*Optimisation and Development Plan'* report [10] summarises options analysis and decisions for management of past disposals, management of future disposals, and pre-closure and closure engineering design. References are provided to the more detailed written records of the analyses and decisions.	[10]
6.3.69	Calculate collective doses and 'group' doses only for times where they can be a useful discriminator between different waste management options. This is likely to be of the order of several hundred years post-closure but the exact length of time will be dependent on the waste disposed of and type of facility and is not likely to be very long term in view of the large uncertainties.	Collective dose to the public was not considered to be a useful discriminator in the option studies undertaken.	[10]
SUP6.3	Give proper consideration to the input of radioactive substances to groundwater in optimising the design of the facility in relation to its geological environment, so that radiation doses to people are kept as low as reasonably achievable, subject to economic and societal factors.	Our reference design follows from extensive optimisation studies. These activities have included consideration of hydrogeological modelling to ensure that potential releases to groundwater comply with regulatory guidance and doses to people are as low as reasonably achievable.	[10] §5 [5] §7, §8

GRA ID	GRA requirement	How addressed	In ESC
SUP6.4	Manage radiological risks to non-human species together with any non-radiological hazards associated with radioactive waste such that the EPR10 provisions for Groundwater Activities are met.	We manage radiological risks to non-human species and non-radiological hazards to groundwater in compliance with regulatory (EPR10) provisions, as demonstrated here under GRA Requirements R9 and R10.	[13] §7.2.1, §7.3.1 [14] §7
6.3.70 7.3.35	**Requirement R9: Environmental radioactivity.** The developer/operator should carry out an assessment to investigate the radiological effects of a disposal facility on the accessible environment both during the period of authorisation and afterwards with a view to showing that all aspects of the accessible environment are adequately protected.	Radiological effects on the public are considered under GRA Requirements R5 through R7. We have used the concentrations of radioactivity in the environment calculated by the models under Requirements R5 to R7 to determine that radiological dose rates to non-human organisms are not significant. Generally, dose rates are calculated to not exceed the threshold dose rate of concern. A few organism types permanently residing on the cliff and beach during coastal erosion could receive slightly higher dose rates, but such organism types are relatively insensitive to radiation.	[14]
6.3.74	Carry out an assessment and draw conclusions about the effects of a disposal facility on the accessible environment using the best available information at the time of the assessment. Provide this assessment as an integral part of the environmental safety case and update it as new information becomes available and when other parts of the case are updated. The extent and complexity of the assessment should be proportionate to the radiological hazard presented by the waste in the facility.	We have presented an assessment of the effects on the accessible environment based on the radionuclide concentrations in the environment calculated using our site-specific models and the internationally-recognised ERICA Tool to determine doses to reference organisms from these radionuclide concentrations. This assessment can be updated as necessary, although calculated dose rates are generally very low compared to the threshold level for concern.	[14]

GRA ID	GRA requirement	How addressed	In ESC
6.3.75	The assessment of effects on the accessible environment should include an assessment of effects after human intrusion, making the same human intrusion assumptions as when assessing the effects on people.	We have not specifically assessed the impacts of human intrusion events on non-human biota, noting that such events would have only a very localised impact. Such events could lead to exposure to radionuclide concentrations only similar to or lower than those arising from cliff erosion, when dilution of exposed waste will be less. Our '*Assessment of Impacts on Non-Human Biota'* report [14] shows that the impacts to non-human organisms from coastal erosion are not significant.	[14] §6.2.5
6.4.1 7.3.36	**Requirement R10: Protection against non-radiological hazards.** The developer/operator of a disposal facility for solid radioactive waste should demonstrate that the disposal system provides adequate protection against non-radiological hazards.	The LLWR provides and will continue to provide levels of environmental protection against non-radiological hazards that are '*no less stringent*' than those applied elsewhere under nationally acceptable standards. Assurance is provided through monitoring, assessment calculations, design, and management of the LLWR.	[13]
6.4.2	A level of protection should be provided against non-radiological hazards that is no less stringent than would be provided if national standards for disposing of waste that presents non-radiological hazards but not a radiological hazard were applied.	Levels of protection required by non-radiological standards have been taken into account in our optimisation studies and the ESC 2011 reference design. Non-radiological standards have been considered to derive appropriate concentration measures for comparison with the results from our monitoring programme and assessment calculations. The review of our WAC includes consideration of non-radiological hazards based on their potential impact.	[13] §2.3, §3 [5] §2.3, §6, §8 [10] §5 [9] §3.8 [15] §7
6.4.4	Optimisation only applies to radiological risks, but adequate protection against non-radiological hazards needs to be maintained when optimising for radiological risks.	We consider that optimisation of the management, design and operation of the LLWR with respect to radiological hazards will also act to limit as far as practicable the potential impact of non-radiological hazards from the LLWR.	[13] §4

GRA ID	GRA requirement	How addressed	In ESC
6.4.5 SUP6.5	The environmental safety case should demonstrate that adequate protection against non-radiological hazards is achieved, using methods and approaches suited to the nature and proportionate to the magnitude of the hazards and suited to the characteristics of the disposal system.	Our '*Assessment of Non-Radiological Impacts*' report [13] describes the level of protection that is currently being achieved. Review of monitoring data indicates that the LLWR has not resulted in significant contamination of groundwater or surface waters by chemotoxic contaminants. We have undertaken calculations to evaluate potential impacts in the future, and have considered the limitation of non-radiological hazards in the design of the LLWR. During the PoA, monitoring will provide assurance that the facility is performing as desired.	[13] [9]
6.4.6	**Requirement R11: Site investigation.** The developer/operator of a disposal facility for solid radioactive waste should carry out a programme of site investigation and site characterisation to provide information for the environmental safety case and to support facility design and construction.	We have carried out an extensive programme of site investigation. Our characterisation and understanding of the site and its surroundings are summarised in the '*Site History and Description*', '*Hydrogeology*', '*Site Evolution*' and '*Monitoring*' reports [3,7,8,9]	[3] [7] §2.2, §2.3, §3, §4.3 [8] §2.2 [9] §4, §5.3 [1] §5
6.4.7	Establish a proportionate approach to site investigation that uses some or all of the results from site characterisation, modelling studies, design and construction to guide investigations. The site investigation should be presented as part of a structured programme that provides the requisite information for the environmental safety case.	We recognise the iterative nature of the development of an ESC through the various stages of repository development. The site investigation programme is constructed, in parallel with the site monitoring programme to progressively support the evolution of the ESC. We instigated a programme of site investigation to address uncertainties identified in the 2002 PCSC. We submitted a report on the site understanding in 2008 to meet the needs of Schedule 9 Requirement 2 of our environmental Permit. Since 2008, a programme of further investigation work has been carried out with the aim of delivering assessment models that could represent the behaviour of the hydrogeological system for 2011 ESC and that could provide an improved assessment of coastal erosion.	[7] §2.2, §2.3, §2.4 [3] §1.2 [8] §2.2 [9] §5

GRA ID	GRA requirement	How addressed	In ESC
6.4.8(a)	Show that the geological environment is characterised, understood and can be analysed to the extent necessary to support the environmental safety case. This will involve considering, for example, the lithology, the stratigraphy, the geochemistry, the local and regional hydrogeology, and the resource potential of the area.	The geological and hydrogeological conceptual models of the LLWR site and region have been built on a large amount of site characterisation information, including geology, hydrogeology and geochemistry. The resource potential of the area has been considered in developing our assessment of human intrusion.	[3] §3 [7] §3, §4.2, §5 [12] §5.3, §8.3
6.4.8(b)	Assess the potential for, and effects of, dynamic processes such as seismic events and ground subsidence.	The 2002 PCSC Engineering Performance Assessment explored the implications of disruption of the facility by credible natural hazards. This effectively screened out the need to further address disruptive events such as meteorite impact and tsunamis. Engineering studies associated with the 2002 PCSC confirmed the use of the standard UK nuclear provision to allow for accelerations of up to 0.25g, except where of no consequence. This remains the case for the 2011 ESC reference design, which is considered robust with regard to likely seismic and subsidence events.	[5] §2.4.4
6.4.9(a)	The biosphere is characterised, understood and capable of analysis to the extent necessary to support the environmental safety case. This may involve consideration of, for example, topography, soils, surface water systems, flora and fauna distributions and human settlement patterns and activities.	The '*Site History and Description'* report [3] provides a description of the biosphere at the LLWR. This has been used as the basis for modelling of the biosphere in our assessments. The '*Assessment of Impacts on Non-Human Biota'* report [14] also provides a description of the types of ecosystem at the LLWR.	[3] [12] §5.3 [14] §2.2

GRA ID	GRA requirement	How addressed	In ESC
6.4.9(b)	The investigation and characterisation of the biosphere should be sufficiently comprehensive to support calculations of dose during the period of authorisation and should be proportionate to the assumptions made in the environmental safety case for calculating risks after the period of authorisation.	Our characterisation of the present-day biosphere at the LLWR is sufficient to allow our environmental safety assessments to define and represent receptors and their interaction with potential exposure pathways.	[11] §3 [12] §2.4, §5.3, §6.3, §7.3, §8.3 [14] §2
6.4.10(a)	Show that the geological, hydrogeological and other characteristics of the region and the site under present and reasonably foreseeable future conditions will allow the environmental safety case for the facility to be made.	We have developed a thorough understanding of the evolution and performance of disposal system, including the geology and hydrogeology. This understanding has been used to develop the models used in our assessments and to optimise the design and management of the LLWR. Estimates of impacts from the LLWR using the assessment models are consistent with the regulatory guidance.	[12] §5.3
6.4.10(b)	Consider features and properties of the site related to release and transport of radionuclides in the gas phase.	For atmospheric discharges during the PoA, annual doses have been assessed to a permanent resident at the site boundary using conservative model assumptions and shown to be well below the regulatory dose constraint. The models, calculation cases and results for the assessment of the gas pathway after the PoA are described in our '*Assessment of Long-term Radiological Impacts'* report [12]. Waste forms and engineered barriers enable a substantial portion of the radon gas that is generated to decay before it is released. The caps include gas collection features that manage the point of release and the rate of release.	[11] §4, §5.1 [10] §5, §6 [12] §6 [13] §6.5

GRA ID	GRA requirement	How addressed	In ESC
6.4.11	Identify the presence of any actually or potentially valuable resources near the site and make an assessment of the extent to which the site and its surroundings might be disturbed as a result. Consider the implications for the integrity of the disposal system.	There are no valuable resources near the site. In the recent past, extraction of resources in the vicinity of the site has been limited to small scale water abstraction, primarily for agricultural purposes. There are currently no licensed abstractions in the vicinity of the site and no private water supplies down-gradient of the site. We will continue to monitor activity around the LLWR. Our long-term safety assessment considers the potential impacts of a water well downstream of the facility and inadvertent intrusion of the facility during site investigations (among other kinds of intrusion event considered).	[7] §3.3, §4.2 [3] §3.2.8 [12] §5, §8
6.4.13	Before carrying out any intrusive geological investigations, assess the extent to which these might disturb the site and any implications this might have for the environmental safety case.	All boreholes drilled as part of our site investigation and monitoring programmes do not disrupt the groundwater system, and they have been or will be decommissioned according to good practice to ensure that they do not have any implications for the ESC.	[7] §2.2

GRA ID	GRA requirement	How addressed	In ESC
6.4.14	Site characterisation should involve investigating specific properties of the site and its surroundings in sufficient detail to support the environmental safety case and may include the following: – Local and regional borehole investigations. – Characterisation of soil layers and quaternary deposits. – Characterisation of surface waters and sediments. – Characterisation of surface and sub-surface flora, fauna and ecosystems. – Development of regional and local geological, geotechnical, hydrogeological and geochemical understanding. – Development of the environmental baseline prior to facility construction. – Where relevant, consideration of the need to include a phase of underground investigation within the body of the host rock for the proposed disposal facility.	Our site characterisation work and understanding of the site is summarised in the '*Site History and Description'*, '*Hydrogeology'* and '*Site Evolution'* reports [3,7,8]. These reports also describe how the understanding has been used in the assessment modelling in the ESC. The '*Assessment of Impacts on Non-Human Biota'* [14] provides a description of the types of ecosystems at the LLWR. Data from the environmental monitoring programme summarised in the '*Monitoring' report* [9] have been used in the ESC and have been particularly important in providing inputs to and calibration for the 3-D groundwater flow model of the site and in considering environmental safety during the PoA. Underground investigation, i.e., creation of a cavern in the host rock, is not required for the design.	[3] §3 [7] §3, §4.3 [8] §4.2 [9] §4.2, §4.3 [14] §2.2
6.4.15	Depending on the hazard presented by the waste to be disposed of, adopt an iterative approach to facility design and development of the environmental safety case as results are progressively obtained from the site characterisation activities.	Our reference design incorporates our current best understanding and judgements. It is used as the basis for our detailed assessments of facility performance and radiological and non-radiological impacts within the 2011 ESC. It has developed in the light of the substantial existing knowledge of the site to date and monitoring thereof. However, it will be subject to ongoing review and may be amended in the light of construction and operating experience, monitoring, iterations of the ESC, and regulatory and planning decisions.	[5] §2.3

GRA ID	GRA requirement	How addressed	In ESC
SUP6.6	Undertake investigations which, as a minimum, examine the hydrogeological conditions, the purifying powers of the soil and subsoil and the risk of pollution and alteration of the quality of the groundwater.	A large amount of data on the hydrogeology, groundwater quality and soils has been collected, as summarised in our '*Hydrogeology*', '*Monitoring*' and '*Site History and Description*' reports [7,9,3]. The potential impact of the facility on groundwater quality is covered in our safety assessments.	[3] §3.2 [7] §3, §4.3 [9] §4.2 [11] §5.3 [12] §5.4
6.4.16	**Requirement 12: Use of site and facility design, construction, operation and closure.** The developer/operator of a disposal facility for solid radioactive waste should make sure 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.	Design, construction, operation and closure of the LLWR, including our WAC and associated waste control arrangements, ensure the safe operation, closure and long-term environmental performance of the site. Our Environmental Safety Strategy (ESS) has been developed and implemented taking account of this need.	[15] [5] [10]
6.4.17	The approach to the use of the site and to facility design, construction, operation and closure should be proportionate to the hazard presented by the waste that the facility is intended to receive.	The design, operations and future management of the LLWR are kept as simple as possible while ensuring environmental safety, and are described in the '*Engineering Design*' report [5].	[5] [10] [1] §2.1
6.4.18	Demonstrate that the proposed location of the facility within the site is large enough to accommodate the categories and quantities of waste to be disposed of, whilst being far enough away from geological media of less suitable characteristics.	Our reference design follows from extensive optimisation studies. Higher stacking and base lowering are proposed to best fit the available space. The design was informed by detailed hydrogeological modelling, taking due account of the geology and associated uncertainties. Our ESC reference design covers the northern 40 hectares of the site (RDA), and includes a variant case in which a further adjacent area (EDA) is developed for further disposals of LLW.	[5] §7 [7] §4 [1] §3.4

GRA ID	GRA requirement	How addressed	In ESC
6.4.19	Show that the methods of construction of the facility are consistent with the claims made in the environmental safety case, in that they do not unduly disturb the geological environment and the containment properties of the host rock.	Vault construction is based on well established engineering practice. The geological environment, as characterised and represented in the ESC models, has not been unduly disturbed by construction. Lessons learned from existing works, including construction of Vault 9, will be incorporated in the specifications and works for future vaults.	[5] §2.4, §5, §6.2, §8.3.1, §9.4.2
6.4.20(a)	Show that the geological conditions in each section of the disposal facility, as disturbed by construction, are suitable for the types and quantities of waste that it is proposed to dispose of in that section.	The geology and ground conditions have been extensively investigated over many years. All of the data have been incorporated in a 3-D Geological Model. The LLWR engineering components have been designed to suit the ground conditions.	[5] §2.2 [7] §3, §4.3, §5
6.4.20(b)	Where backfilling is used, show that methods and materials have been chosen that are compatible with the waste form and the geological setting, and that provide an overall system performance consistent with the claims made in the environmental safety case.	Vault 8 has voidage between half-height ISO containers of 5%. Infilling with free draining granular material is proposed to reduce this voidage. The containers in the other vaults will be packed as tight as possible to keep the voidage to within about 2%, in which case granular infilling is not expected to be required. The granular infill will not react with the waste form.	[5] §3.4, §8.4
6.4.21	In design and construction, take into account a number of effects that may arise from properties of the waste, including: – gas generation through microbial, chemical, or radiolytic action, or as a result of radioactive decay; – heat generation through microbial or chemical action, or as a result of radioactive decay; – criticality through concentration of fissile nuclides (for near-surface facilities, this can probably be dealt with by a simple analysis).	The potential impact of gas generation has been taken into account in the consideration of waste emplacement and closure design options. A passive venting arrangement is incorporated in the final cap, and this will facilitate monitoring of landfill gas and radio-labelled gas production during post-operational control of the site. Heat generation was discussed in the 2002 PCSC and is not considered to be a significant issue for the LLWR. Our WAC, both in the past and those proposed for the future, ensure that criticality has an extremely low probability of occurrence as a consequence of the presence of the small quantities of fissile material within wastes sent to the LLWR.	[10] §4.3, §5.2 [5] §8.3.11 [15] §6.6 [12] §9.2

GRA ID	GRA requirement	How addressed	In ESC
6.4.22	Gas generation within the disposal facility can lead to gas movement through and around the facility. Considerations will need to include any venting of gases, both those presenting a radiological hazard and those presenting other hazards such as explosions or asphyxiation, to the atmosphere that may occur and any implications this may have for people and the environment	The reference assumption for the ESC is that a passive venting scheme in the cap will be in place; however, a final decision does not need to be taken now. The final design will be informed by the outcome of discussions surrounding the significance of the assessment results.	[10] §5.2 [5] §8.3.11
6.4.23	Make plans for corrective action to deal with foreseeable geological or geotechnical problems which might arise during construction, operation or closure.	Vault 9 and future vaults have been or will be constructed to a rigorous system of Construction Quality Assurance (CQA) in accordance with current Environment Agency requirements. The CQA approach provides good evidence of achieving the design and construction requirements, and includes identifying problems and taking corrective action to deal with foreseeable geological or geotechnical problems.	[5] §6.2, §9.4.2, §2.4
6.4.24	At the design stage, and periodically during the lifetime of the facility, demonstrate that it is possible to close the disposal facility and, where relevant, seal any preferential pathways that will or may be introduced as a result of the siting, construction and operation of the disposal facility.	Our '*Engineering Design'* [5] gives a description of the proposed closure engineering, including the design functions and methods of construction of the final engineered cap and cut-off wall. The design and performance of the cap have been studied in considerable detail, including reviews of best practice and previous studies on the engineering design and construction methods. Staged installation of the cap provides for a longer period of monitoring of cap performance prior to final closure.	[5] §8, §9

GRA ID	GRA requirement	How addressed	In ESC
6.4.25	For facilities that are not regulated under the landfill regulations and not owned by a public sector body such as NDA, ensure that suitable financial provision has been and is being made such that the obligations (including any aftercare obligations) arising from the authorisation are being and will continue to be fulfilled.	Not relevant as the LLWR is owned by NDA.	Not needed
6.4.26 6.4.27	**Requirement 13: Waste acceptance criteria.** The developer/operator of a disposal facility for solid radioactive waste should establish waste acceptance criteria consistent with the assumptions made in the environmental safety case and with the requirements for transport and handling, and demonstrate that these can be applied during operations at the facility.	As part of developing the 2011 ESC, we have reviewed the WAC and considered the need for possible changes to continue to ensure the operational safety of workers, the safety of members of the public and protection of the environment during operations and post-closure. To ensure implementation of the WAC, we have a waste control system that manages the acceptance of wastes and records the wastes disposed of at the site. Following submission of the ESC, we will consult on changes to the WAC with the Environment Agency and the waste consignors.	[15]
6.4.28	Include in the acceptance criteria the factors that affect the performance of the waste before and after disposal, including the radionuclide content, the chemical and physical form and durability, the susceptibility to microbial action, the thermal and radiation stability, and the mechanical stability.	Our consideration of the WAC included controls on the radioactive and non-radiological components of wastes based on the impacts presented in the ESC. Our consideration also covered physical and biogeochemical factors that influence the release of contaminants. Our consideration of the WAC covered the factors highlighted in the GRA requirement.	[15] §4 - §7

GRA ID	GRA requirement	How addressed	In ESC
6.4.29(a)	Include requirements in the acceptance criteria that ensure as far as reasonably practicable that all waste accepted for disposal is passively safe. The chemical and physical form of the waste should limit detrimental chemical or microbial interactions, and should restrict the release of radionuclides into the disposal environment, in accordance with the assumptions of the environmental safety case. The radiation and heat resistance of the waste form should be in accordance with the assumptions of the environmental safety case. The waste package should have sufficient mechanical stability to withstand the conditions of transport and handling, and to meet any assumptions regarding structural integrity made in the case.	Development of our WAC considered factors that influence the release of contaminants and the assumptions in the ESC. For example, we are proposing restrictions on loose powders to prevent short-term release to either leachate or to the atmosphere, including under potential accident conditions. Our WAC include restrictions on material types that could cause or enhance the effects of fires, and limit the external radiation level on the surface of a container. Otherwise, resistance to heat and radiation is not considered to be a significant issue for LLW and is not a threat to the ESC. Our WAC stipulate packaging requirements to meet operational needs, including consideration of potential accident scenarios. Waste packages are able to bear loads associated with vault operations and subsequent capping. There are no other implications for the ESC from container strength considerations.	[15] §4, §5
6.4.29(b)	Demonstrate that the possibility of a local accumulation of fissile material, such as to produce a neutron chain reaction, will not arise.	Our WAC for fissile material, both in the past and those proposed for the future, ensure that criticality has an extremely low probability of occurrence as a result of either current LLWR operations or the future evolution of the LLWR after site closure. This is demonstrated in a criticality safety assessment conducted for the 2011 ESC.	[15] §6.6 [12] §9.2

GRA ID	GRA requirement	How addressed	In ESC
6.4.30	Make sure that the radionuclide content and composition, including the fissile content, of waste consignments received for disposal are sufficiently well characterised to comply with the conditions of the authorisation under RSA 93.	Our WAC are part of an overall waste acceptance procedure that describes the arrangements that must be followed to consign waste to the LLWR for treatment and or disposal. The procedure includes the following elements: waste forecasting, waste characterisation, waste assurance, waste enquiry, waste consignment and waste receipt. These are accompanied by process diagrams, guides, forms and templates to facilitate understanding and aid implementation of the process.	[15] §8.1
6.4.31	**Requirement 14: Monitoring.** In support of the environmental safety case, the developer/operator of a disposal facility for solid radioactive waste should carry out a programme to monitor for changes caused by construction, operation and closure of the facility.	A fully integrated environmental monitoring programme has been developed at the LLWR. We recognise the need for a programme of long-term monitoring that will continue throughout the PoA. The monitoring programme will be reviewed periodically and tailored so that it continues to be appropriate to the stage of facility development.	[9]
6.4.32	Establish a reasoned and proportionate approach to a programme for monitoring the site and facility. This monitoring should provide data during the period of authorisation to ensure that the facility is operating within the parameters set out in the environmental safety case. However, the monitoring must not itself compromise the environmental safety of the facility.	The monitoring programme was reviewed in 2008, and again in 2010 with a view to improving integration of monitoring activities. Activities within the monitoring programme are linked to 'drivers' and the need to satisfy various requirements of the ESC. We are committed to a review of the monitoring programme on a regular basis, including consideration of those measurements that should be undertaken in order to check that the system is evolving in a manner consistent with the ESC. In order to consider the potential implications of any monitoring data to the ESC, regular meetings are held between the ESC and monitoring teams. A factor specified in the design of our monitoring programme is that the monitoring must not compromise safety.	[9] §3

GRA ID	GRA requirement	How addressed	In ESC
6.4.33	Carry out monitoring during the investigation and pre-construction stages to provide a baseline for monitoring at later stages. The same measurements may form part of the site investigation programme. They should include measurements of pre-existing radioactivity in appropriate media, together with geological, physical and chemical parameters which are relevant to environmental safety and which might change as a result of construction and waste emplacement (for example groundwater properties such as pressures, flows and chemical composition).	Monitoring data have been collected from the site for many years. Results (e.g. leachate monitoring, mapping of the tritium plume and performance of the temporary trench cap) provide evidence of current performance of the site and preliminary closure engineering, which provides a basis for forward estimation of performance. The environmental monitoring programme at the LLWR has undergone significant development in a number of areas since 2008, resulting in a monitoring programme that is focused, fit for purpose and that provides the necessary data to support safety analyses and site management. We have been able to establish environmental baselines for the 2011 ESC by reference to monitoring data collected in recent years upstream and downstream of the LLWR site.	[9] §4, §5
6.4.34	Undertake radiological monitoring and assessment during the period of authorisation to provide evidence of compliance with authorised discharge limits and assurance of radiological protection of members of the public. In addition, during the construction stage and the period of authorisation, monitor non-radiological parameters to confirm understanding of the effects that construction, operation and closure of the facility have on the characteristics of the site. In particular, demonstrate that changes in, and evolution of, the parameters monitored are consistent with the environmental safety case.	During the PoA, monitoring provides assurance that the LLWR is performing as desired. Monitoring data also provide a direct demonstration that the relevant discharge limits and dose constraints are being met. Review of monitoring data to-date indicates that the LLWR has not resulted in significant contamination of groundwater or surface waters by chemotoxic contaminants. Concentrations of LLWR-derived radionuclides in groundwater around the site have decreased markedly since the installation of the temporary trench cap and the cut-off walls. Assessments based on measured discharges and environmental concentrations show that the dose constraints have been met historically.	[9] §5, §4.2 [11] §4, §5

GRA ID	GRA requirement	How addressed	In ESC
6.4.35	Carry out appropriate investigation and monitoring during the construction stage and period of authorisation to establish: the characteristics of the site; the behaviour of the disposal system; and the extent of disturbance caused by intrusive site investigation procedures and by construction, operation and closure of the facility.	Monitoring will continue throughout the PoA and is designed to provide: – sufficient reassurance to maintain confidence among local stakeholders; – information for long-term experiments that, for example, might be used to validate models of contaminant transport or the chemical evolution of the near field; – information on the near-field environment in order to take decisions about leachate management and to understand the performance and state of the closure engineering; – information on coastal evolution as an input to a better understanding of the timescales of coastal erosion and possible flooding of the LLWR. Baseline monitoring will be carried out in relation to any major new engineering works.	[9] §5.4
6.4.36	The monitoring programme should clearly set out the levels of specific contaminants that will trigger action. It should include an action plan to deal with possible contamination from the facility and an approach to confirming any apparently positive results to avoid inappropriate action being taken in the event of a false positive observation.	Control levels for significant changes or contaminant concentrations have been defined. Trends in the data are examined as part of an annual review process. Where control levels are exceeded or trends identified, appropriate technical review takes place and there is consideration of any need for further action.	[9] §3.8

GRA ID	GRA requirement	How addressed	In ESC
6.4.37	Assurance of environmental safety must not depend on monitoring or surveillance after the declared end of the period of authorisation. Subsequent monitoring that the developer/operator may wish to include is not ruled out, provided it does not produce an unacceptable effect on the environmental safety case.	Safety after the PoA does not depend on monitoring.	[9] §5.4
SUP6.7	Undertake whatever programme of continuing monitoring and investigation, both during and after the radioactive waste disposal activity, considered necessary by the regulator to establish the level of input of pollutants to groundwater and the impact on the environment.	We review our monitoring programme regularly. We will continue to develop our monitoring programme in dialogue with the Environment Agency. This programme includes monitoring of groundwater quality.	[9] §5.3
7.1.2	Provide an environmental safety case that responds to the guidance set out in a manner proportionate to the radiological hazard presented by the waste.	Our ESC 2011 addresses the regulatory guidance, as is demonstrated through the mapping in this table. Our ESC is proportionate, with our assessments and technology focused on the important features and hazards.	[1] All Level 2 reports
7.1.3	If the disposal facility is on a nuclear licensed site, provide a nuclear safety case for the facility that meets the requirements of ONR. The nuclear safety case will have different objectives from the environmental safety case. The arguments presented in the two separate safety cases will need to be compatible.	We hold a site licence from the ONR separately to the environmental Permit from the Environment Agency. The nuclear safety case for ONR is consistent with the 2011 ESC. Compliance with both our nuclear site licence conditions and the conditions of our environmental Permit and the GRA is overseen by our EH&S Committee and set out in our Management Prospectus.	[1] §4.2 [2] §4.2

GRA ID	GRA requirement	How addressed	In ESC
7.2.1(a)	The environmental safety case should demonstrate a clear understanding of the disposal facility in its geological setting ('the disposal system') as it evolves.	Our understanding of the site and its evolution is summarised in the '*Site History and Description*', '*Hydrogeology'* and '*Site Evolution'* reports [3,7,8]. Our understanding of the facility and its evolution is summarised in the '*Inventory*', '*Engineering Design'* and '*Near Field'* reports [4,5,6]. The evolution of the disposal system as a whole is described in the '*Assessment of Long-term Radiological Impacts'* report [12].	[3] [7] [8] [12] §3
7.2.1(b)	The environmental safety case needs to show how the various components of the disposal system contribute to meeting the requirements.	Our ESS identifies the management and engineering control measures we are implementing to ensure environmental safety. Our control measures are consistent with the goal of achieving radiation doses and risks, and more generally environmental impacts that are 'as low as reasonably achievable' (ALARA).	[1] §3.2, §4.5 [12] §3.6 [10] §5.2 [5] §2.1
7.2.2	The environmental safety case should include an environmental safety strategy supported by detailed arguments to demonstrate environmental safety. The environmental safety strategy should present a top level description of the fundamental approach taken to demonstrate the environmental safety of the disposal system. It should include a clear outline of the key environmental safety arguments and say how the major lines of reasoning and underpinning evidence support these arguments.	Our ESS is the guide by which we evaluate and select a set of controls to arrive at an optimised Site Development Plan, i.e. a Plan in which the environmental impact of disposals is optimised. Our ESS begins from high-level objectives that are then broken down into principles and control measures by which the objectives are realised. Our control measures are aimed at ensuring that the impacts that might result from the disposal of the wastes, including impacts resulting from radionuclides and chemotoxic components of the waste, are acceptably low. Measures include control of the source, and protection and containment of the source, with residual losses from the source being managed and monitored.	[1] §3.2

GRA ID	GRA requirement	How addressed	In ESC
7.2.3	The environmental safety case should demonstrate, using a structure based on clear linkages, how the environmental safety strategy is supported by the detailed arguments and how the arguments are supported by evidence, analysis and assessment. Internal consistency within the environmental safety case needs to be established and maintained.	Our detailed safety arguments are set out in our '*Main Report'* [1] and the underpinning evidence is summarised in our Level 2 ESC reports. There is clear linkage from the Level 1 report to the Level 2 reports and supporting Level 3 reports. All of the reports have been managed during development and reviewed by the ESC Project Team.	[1] §4 This report
7.2.4	The environmental safety case should explain how uncertainties have been considered and will be managed in the future and demonstrate that there can be confidence in the environmental safety case notwithstanding the uncertainties that remain. It should also demonstrate that potential biases and their effects on the environmental safety case have been identified and eliminated or minimised.	In our assessment of impacts during the PoA, we make use of existing monitoring data supplemented, where necessary, with broadly conservative models and data. Although there are uncertainties in the future disposals of wastes and the detailed function of closure engineering, we consider our assessment provides a well-based indication of the potential radiological significance of future activities during the PoA. In our assessment, we have applied the conventional division of uncertainties, namely scenario, model and parameter uncertainty, and we have analysed uncertainties in this context. We have identified outstanding uncertainties and open decisions with the potential to affect our assessment and related ESC arguments, and outlined the work needed to better understand the uncertainties or support future assessments and optimisation studies. This includes the development of a register of uncertainties [20].	[1] §4.5, 5 [11] §5.7 [12] §2.5, §10
7.2.5	Everything significant that is claimed or assumed in the environmental safety case should be supported by evidence that is adequate in content and is of appropriate type or types, detail and robustness.	Our detailed safety arguments are set out in our '*Main Report'* [1] and the underpinning evidence is summarised in our Level 2 ESC reports. There are references to more detailed evidence in Level 3 supporting reports as necessary.	[1] All Level 2 reports

GRA ID	GRA requirement	How addressed	In ESC
7.2.6(a)	The ESC should describe all aspects that may affect environmental safety, including the geology, hydrogeology and surface environment of the site.	Our understanding of the site is summarised in the '*Site History and Description*', '*Hydrogeology*', '*Site Evolution*' and '*Monitoring*' reports [3,7,8,9].	[3] §3 [7] §3, §4.3 [8] §4.2 [9] §4
7.2.6(b)	The ESC should describe all aspects that may affect environmental safety, including the characteristics of the waste (including any waste treatment and conditioning before disposal).	Our understanding of the waste and the uncertainties in the inventory are summarised in the '*Inventory*' report [4]. WAC and associated waste control arrangements are summarised in the '*Waste Acceptance*' report [15].	[4] §4 - §6 [15] §8
7.2.6(c)	The ESC should describe all aspects that may affect environmental safety, including the design of the facility and the techniques used to construct, operate and close it.	The design of the facility, the techniques used to construct the trenches and Vaults 8 and 9 and to be used for the construction of future vaults, and the closure design are summarised in the '*Engineering Design*' report [5].	[5] §3-§8
7.2.7	To an extent appropriate to the radiological hazard presented by the waste, the environmental safety case should make use of multiple lines of reasoning based on a variety of evidence, leading to complementary environmental safety arguments. The evidence may be both qualitative and quantitative, supported where appropriate by robust numerical analyses. The reasoning and assumptions should be clear and the evidence supporting them traceable.	Our '*Main Report*' report [1] presents both qualitative and quantitative arguments for the environmental safety of the LLWR. Our underlying Level 2 ESC reports present the evidence supporting these arguments, including quantitative assessment, monitoring data, and qualitative reasoning.	[1] §3, §4.5

GRA ID	GRA requirement	How addressed	In ESC
7.2.8(a)	The environmental safety case should include quantitative environmental safety assessments for both the period of authorisation and afterwards. These assessments will need to extend into the future until the radiological risks have peaked or until the uncertainties have become so great that quantitative assessments cease to be meaningful.	We have presented quantitative safety assessments that cover radiological and non-radiological effects on the public and the environment. For the post-authorisation period, the assessments have continued until the peak of the calculated impacts has been reached or passed, or the site has been disrupted by coastal erosion.	[11] [12] [13] [14]
7.2.8(b)	Show how radionuclides might be expected to move from the wastes through the immediate physical and chemical environment of the disposal facility and through the surrounding geological formations into and through the environment.	The evolution of the near field is described in the '*Near Field'* report [6]. Modelling of releases during operations and while active control of the site is maintained is described in the '*Environmental Safety During the Period of Authorisation'* report [11]. Modelling of radionuclide migration throughout the evolution of the LLWR is described in the '*Assessment of Long-term Radiological Impacts'* report [12].	[6] §6 [11] §5 [12] §5.4
7.2.8(c)	After the period of authorisation and while any significant hazard remains, the environmental safety case should explore the consequences not only of the expected evolution of the disposal system, but also of less likely evolutions and events.	In our assessment, we define a single expected evolution scenario that encompasses the broad expectation for evolution of the disposal system. Within this scenario, we expect the LLWR to be destroyed and dispersed by coastal erosion processes within a period of a few hundred to a few thousands of years. We also assess a scenario that we consider unlikely, that the site will not be eroded for at least 10,000 years. Human intrusion represents a special set of cases that we also assess separately.	[12] §3.5, §5 to §8

GRA ID	GRA requirement	How addressed	In ESC
7.2.9	The environmental safety case should describe the arguments for having confidence in the case including, for example, reference to: – the quality and robustness of the quantitative safety assessment and consideration of uncertainty; – the quality, robustness and relevance of the other arguments and evidence presented; – the developer/operator's environmental safety culture and the breadth and depth of expertise and experience of individuals involved in activities supporting the ESC; – the main features of the developer/operator's management system, such as planning and control of work, the use of sound science and good engineering practice, record-keeping, quality management and peer review.	The arguments for having confidence in our ESC are presented in our '*Main Report'* [1]. With regard to our assessments, we have developed a thorough understanding of the evolution and performance of the existing and planned disposal facilities. This understanding has provided us with the basis for developing a range of quantitative models to represent the disposal system, its important elements and their performance. The models and input have been developed and tested under appropriate quality assurance to ensure they are fit-for-purpose. Our ESC Project Team is suitably qualified and experienced and we have drawn on experience from our previous assessments of the LLWR and from assessments undertaken in other repository programmes. We have a positive safety culture, management system and organisational structure and resources sufficient to provide the functions required by the regulators and described in the GRA.	[1] §4 [12] §2.2 [2] §4
7.2.10(a)	The environmental safety case should describe and substantiate the level of protection provided by the disposal system both during the period of authorisation and in the long term. It should be sufficiently comprehensive and robust to provide adequate confidence in the environmental safety of the disposal system bearing in mind the radiological hazard presented by the waste.	Our environmental safety assessments describe and quantify the possible radiological and non-radiological effects of the LLWR on the public and the environment. The assessments presented in the 2011 ESC have been undertaken on the basis of the Site Development Plan, and we have thus demonstrated the environmental safety of the LLWR under the Plan. We have also calculated the radiological capacity of the LLWR and identified the conditions under which waste may be safely disposed of at the LLWR under the Plan.	[11] [12] [13] [14] [1] §3.4, §4.5

GRA ID	GRA requirement	How addressed	In ESC
7.2.10(b)	Be alert to possible future changes to standards and to basic data, and make the environmental safety case as robust as reasonably practicable in this respect.	We have taken account of all of relevant regulatory developments, such as the supplementary guidance to the GRA included in this mapping. Our ESC has been developed by specialists with state-of-the-art knowledge. We consider that the ESC is, therefore, robust to foreseeable changes. We are involved in a number of national and international initiatives on LLW management and disposal, and our forward programme will ensure that the ESC remains consistent with future developments.	[2] §6.2
7.2.12	Provide / update the environmental safety case at each step during the development of a disposal facility and at suitable intervals during the period of authorisation to inform and support regulatory decisions in a timely manner.	The development of our 2011 ESC responds to a Requirement in our current environmental Permit. Our forward programme and the timing of future iterations of the ESC will be agreed with the Environment Agency.	[2] §2.3 [1] §5
7.2.13 SUP7.2	Updates to the environmental safety case should reflect growing knowledge about the site and should increasingly reflect the disposal facility as built and wastes as disposed of rather than as anticipated. Updates should also take into account, for example, feedback from regulators and feedback from other relevant facilities, both nationally and internationally, together with developments in environmental safety assessment techniques, in radiological protection and in technical understanding more generally. The eventual aim will be to show that the disposal system as finally realised in practice will provide proper protection to people and the environment.	The safety cases prepared in 2002 were not accepted by the Environment Agency. Since that time, there have been significant developments (e.g. further optimisation work and construction of Vault 9, further site characterisation and monitoring, development of more detailed assessment models, new management of the LLWR), and we considered that a complete revision of the ESC based on new data and addressing the 2009 update of the GRA was necessary. This was agreed with the Environment Agency. Assuming that our 2011 ESC is agreed as a baseline by the Environment Agency, we will provide updates as required by the Environment Agency. Updates will include our increasing knowledge gained, for example through monitoring, feedback from the Environment Agency and feedback gained through our dialogue and involvement with other national and international waste management programmes.	[2] §2.3 [1] §6

GRA ID	GRA requirement	How addressed	In ESC
7.2.14	Consider how the safety case documentation will be structured and updated to promote traceability between steps and transparency. Maintain a detailed audit trail for changes to the environmental safety case and documentation.	Major changes between the 2011 ESC and previous work are summarised in the relevant Level 2 ESC reports. We review how we have addressed the core deficiencies identified by the Environment Agency in the 2002 safety case in our '*Main Report'* [1]. Following submission of the 2011 ESC to the Environment Agency, it will form a baseline with appropriate change control arrangements. These arrangements will include maintaining an audit trail of any future changes to the ESC.	[1] §6 [4] §5.5 [5] §2.5 [6] §6.1.3 [7] §2.4, §6 [8] §2.2, §3.4 [12] §2.1 §5 - §8, §10.1
7.2.15	Present the environmental safety case in a way that people will understand. Different styles and levels of documentation are likely to be needed to present the environmental safety case to different audiences, but these should be consistent in referring to the same fundamental arguments.	The '*Main Report'* [1] is intended to be complete enough to satisfy senior managers from the Environment Agency, Government ministries and local government representatives. The Level 2 ESC reports and Level 3 supporting reports are primarily addressed to the Nuclear Regulator and other technical staff in the Environment Agency. We will publish the ESC and a non-technical summary on our website and communicate the results to stakeholders according to our plan for stakeholder engagement, to help them understand the conclusions and implications of the ESC.	Preface [1] §4.2
7.2.16	Throughout the development and period of authorisation of the facility, preserve the environmental safety case documentation and all relevant records and provide access to these by interested parties.	Records of all information significant to the development of the ESC have been managed and retained using a project-specific document control system. We have a records management service delivery contract in place to support local management of records. With regard to the ESC, we will review the requirements for back-up of records and will develop the system(s) needed as appropriate.	[2] §9
7.2.17(a)	The environmental safety case should be used to help specify a forward programme of improvement work, both to the environmental safety case itself and more broadly.	Our forward programme considers the main decisions that remain to be made and the work that is required to support such decision making.	[1] §5

GRA ID	GRA requirement	How addressed	In ESC
7.2.17(b)	Operational decisions and practices should be consistent with the environmental safety case.	Our operational practices are consistent with our environmental safety strategy and are described in our '*Environmental Safety During the Period of Authorisation'* report [11] in terms of inventory and waste-form control, engineering, management controls, and surveillance. The safety and environmental impact of any modifications to the design and operation of the facility are formally reviewed. To ensure that the ESC requirements for long-term performance are considered, the ESC Project Manager signs off all potential modifications.	[11] §4 [2] §5.3 [15] §8
7.2.18(a)	The environmental safety case will provide an input to deriving facility-specific regulatory limits and conditions, and should help to underpin the developer/operator's waste acceptance criteria and emplacement requirements.	Our proposed controls on waste acceptance are consistent with the 2011 ESC. Implementation will be through our overall waste acceptance process, revisions to the WAC, and an emplacement strategy within the disposal vaults to manage specific waste streams and waste consignments. We intend to bring the necessary changes into operation in a planned and phased manner, with priority given to those aspects that if not enacted would have potentially significant environmental safety implications. A programme of work is being established for this and will be discussed with the Environment Agency and other stakeholders.	[15] §8
7.2.18(b)	The environmental safety case may help to guide the monitoring of discharges for compliance with the authorisation, and the environmental monitoring programme for the site and the surrounding area.	The environmental monitoring programme at the LLWR has undergone significant development since 2008. To develop the programme, two substantial reviews of the programme were undertaken (in 2008 and 2010) considering the technical needs and requirements of the ESC and other end users of the data. The 2011 ESC will be used in future review of the programme.	[9] §3 [11] §4

GRA ID	GRA requirement	How addressed	In ESC
7.3.2	The disposal system will consist of multiple components or barriers. There is a distinction between these components and the environmental safety functions they provide.	We have developed a complementary set of measures and controls by which the environmental safety of the LLWR is optimised. The key safety functions of the engineered barrier system are: isolation against disturbance so far as is practicable, reducing water flow through the system for as long as practicable, controlling the release of gas and leachate, and directing releases that may occur so as to reduce their impact.	[1] §3.2, §3.3, §4.4 [5] [10] §5.2 [11] §4
7.3.3(a)	The environmental safety case should include an explanation of, and substantiation for, the environmental safety functions provided by each part of the system. It should also identify which radionuclides each function is relevant to and the expected time period over which the function is effective.	The engineering of the LLWR and the safety functions it fulfils are described in our '*Engineering Design'* [5] and '*Optimisation and Development Plan'* [10] reports. The '*Near Field'* report [6] provides physical and modelling evidence for the duration of particular functions. The performance of each part of the disposal system with respect to individual radionuclides is described in the Level 3 reports supporting the Level 2 ESC reports on the radiological assessments.	[1] §3.2 [5] [6] §6, §8 [10] §5.2 [11] §4 [12] §5
7.3.3(b)	The environmental safety case for the period after closure of a disposal facility should not depend unduly on any single function.	Our ESC does not depend unduly on any one of the safety functions. During the PoA, key elements of the ESS are engineering to reduce direct radiation releases, site management controls to limit the potential for inadvertent exposure, monitoring and surveillance to provide information on the overall adequacy of the engineered barriers, and good management practices. In the long term, several aspects of the site engineering (vault design, cap design, cut-off wall design, waste form) act in concert to limit contaminant releases. The natural system (groundwater flow paths, sorption, dispersion during coastal erosion) also plays a role in ensuring environmental safety in the long term.	[6] §8 [11] §4 [12] §5

GRA ID	GRA requirement	How addressed	In ESC
7.3.4	Explore the contribution that each environmental safety function makes to the environmental safety case (for example, by sensitivity analyses). Explore the circumstances where more than one function is impaired.	Engineered structures provide environmental safety functions both by controlling the generation and release of leachate and gas, and by protecting the disposed wastes and providing a controlled environment. The natural system provides additional safety by delaying and diluting releases to the accessible environment and directing releases to the coastal zone where contaminants will be rapidly dispersed. The integrated performance of the disposal system is reflected in the development of our calculation cases, where the likelihood of circumstances whereby performance could be impaired was assessed. Our sensitivity analyses in our Level 2 ESC reports tend to focus on overall system performance. The contribution to performance or safety functions by individual barriers is explored in our Level 3 ESC assessment reports.	[6] §8 [11] §4 [12] §5, §6
7.3.5	Provide one or more quantitative assessments aimed at calculating risk, which can then be compared to the risk guidance level, as a key part of the environmental safety case for times after the period of authorisation.	Our '*Assessment of Long-term Radiological Impacts'* report [12] summarises calculations of radiation doses and risks to PEGs after the PoA, taking account of uncertainties in the performance of the disposal system, including expected and less likely future conditions. The dose and risk estimates are consistent with the risk guidance level and dose guidance level in the case of human intrusion.	[12]
7.3.6 7.3.19	Where environmental safety needs to be assured over very long timescales, use multiple lines of reasoning based on a variety of evidence, leading to complementary environmental safety arguments. In the overall environmental safety case, these complementary arguments need to be brought together in a structured way.	Our multiple arguments for environmental safety are brought together in our '*Main Report'* [1]. They include arguments based around our key principles of long-term safety independent of controls, the robustness of our engineering in terms of long-term performance, and meeting the radiological protection standards.	[1] §4

GRA ID	GRA requirement	How addressed	In ESC
7.3.7(a)	Examples of environmental safety indicators that might be used to strengthen the environmental safety case include radiation dose, radionuclide flux, radionuclide travel times, environmental concentration and radiotoxicity.	Our long-term assessment models provide calculations of dose, environmental concentrations, and radionuclide fluxes. We have not identified any other complementary safety indicators that we thought would help the presentation.	[12] §5.5
7.3.7(b)	Where the radiological hazard presented by the waste warrants it, provide a wide range of information, for example: – assessments of radionuclide release characteristics from the waste and from the various barriers that make up the disposal system; – assessments of the concentrations in the accessible environment of radionuclides released from the disposal system and comparison of these with naturally occurring levels of radioactivity in the environment; – where appropriate, assessment of collective radiological impact (as a measure of how widespread any significant increase in risk may be as a result of radioactivity released into the accessible environment); – unifying statements that aim to place in context the different items of information that contribute to assuring environmental safety.	Our '*Main Report'* [1] provides unifying statements that place in context the different evidence we present in our Level 2 reports demonstrating and assuring environmental safety. Radionuclide releases from the LLWR are calculated for the reference case and an alternative near-field case in our '*Assessment of Long-term Radiological Impacts'* report [12]. This also reports the radionuclide concentrations in the environment. Measured discharges and environmental concentrations are coupled with assessment calculations in our '*Environmental Safety During the Period of Authorisation' report* [11] to show that radiological impacts are below regulatory criteria for the PoA, even when cautious assumptions are taken. Collective dose was not considered to be a useful discriminator in the option studies we have undertaken.	[1] §4 [12] §5 [11] §5 [10]

GRA ID	GRA requirement	How addressed	In ESC
7.3.8	Account for uncertainties explicitly, analyse their possible consequences and consider where they may be reduced or their effects lessened or compensated for. 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.	We have taken uncertainties into account in our assessments and optimisation studies. For example, four cases for the future inventory have been considered, and two models for near-field releases have been evaluated in the ESC. We have identified uncertainties and open decisions that could affect any of the ESC arguments, and outlined the work needed to better understand the uncertainties or support future optimisation. This includes the development of a register of significant uncertainties.	[1] §4, §5 [11] §5.7 [12] §2.5, §3, §5 - §8
7.3.10	Demonstrate that the environmental safety case, for both the period of authorisation and afterwards, takes adequate account of all uncertainties that have a significant effect on the environmental safety case. This will mean establishing and maintaining: – a register of significant uncertainties; – a clear forward strategy for managing each significant uncertainty, based on considering, for example, whether the uncertainty can be avoided, mitigated or reduced, and how reliably it can be quantified.	As part of this ESC, we have: – identified and evaluated a small number of alternative scenarios, corresponding to alternative future evolutions of the system; – identified and evaluated alternative models of the system where appropriate; – identified key uncertainties relating to different parts of the system; – explored the implications of uncertainties in terms of estimated radiological impacts; – identified uncertainties that warrant further work. – established a database of features, events and processes (FEPs) considered in the ESC which includes a register of significant uncertainties that indicates how uncertainties have been addressed and the extent to which further data gathering or calculations are needed to support future optimisation.	[1] §4.5, §5 [2] §6.2
7.3.11	Provide explanations for interested parties of the significance of uncertainties important to the environmental safety case, by presenting these explanations in a way that people will understand.	Our '*Main Report*' [1] highlights key uncertainties, how we have addressed them, and our future programme to manage them. The report is written at a level intended to satisfy senior managers and government representatives. As such, it should be accessible to most stakeholders.	[1] §4, §5

GRA ID	GRA requirement	How addressed	In ESC
7.3.12	Account for both readily quantifiable and unquantifiable uncertainty types in the environmental safety case.	We have applied the conventional division of uncertainties in our long-term safety assessment, namely scenario, model and parameter uncertainty. Through this division, we have accounted for both quantifiable and unquantifiable uncertainty.	[12] §2.5, §5 - §8 [11] §5
7.3.14	Follow radiological protection advice generally accepted at the time of use for the assessment of dose and risk (e.g. dosimetric data and the applicable risk coefficient). Uncertainties in these areas are common to all radiological assessments and are normally left implicit. There is, therefore, no special reason to include them explicitly in assessments supporting the environmental safety case for a disposal system.	We have utilised the most recent internationally-accepted recommendations for conversion of radionuclide concentrations to effective dose to humans and to non-human organisms. We have compiled a '*Radiological Handbook*' [21], the aim of which is to provide a reference for common radiological data across the range of exposure calculations undertaken in support of the 2011 ESC and future iterations of the ESC.	[12] §4.2 [11] §5 [14] §4
7.3.15	Make clear which uncertainties have been quantified and applied to parameter values used in quantitative environmental safety assessments, and the methods used for carrying out the calculations.	Our reports on assessment modelling and our '*Near Field'*, '*Hydrogeology'*, and '*Site Evolution'* reports [6,7,8] cover supporting modelling, summarise key uncertainties. Four cases for the future inventory have been considered, and two models for the near field have been evaluated in the ESC. In addition, we have undertaken a probabilistic calculation case for the groundwater pathway assigning probability distribution functions to key parameters and undertaking a Monte Carlo simulation (see our '*Assessment of Long-term Radiological Impacts'* report [12] for a summary).	[4] §5 [6] §7, §8.2 [7] §4.4.6, §5.4 [8] §3.4, §4.3.6 [11] §5 [12] §5 [13] §6.7 [14] §3.4

GRA ID	GRA requirement	How addressed	In ESC
7.3.16	Show that any simplifications adopted in the environmental safety assessments either have an insignificant effect on the outcome of the assessments, or have a conservative effect (i.e. do not lead to impacts being underestimated).	Our Level 2 ESC reports on assessment modelling and supporting modelling of the near field, hydrogeology, and site evolution discuss the conservatism of our assessment results. Our aim in assessments is to adopt a cautiously realistic representation.	[6] §7 [7] §5.4 [8] §3.4, §4.4 [11] §5 [12] §2.5 [13] §6
7.3.17	If unquantifiable uncertainties are important to the ESC, they may be treated by a series of risk assessments, in each case making deterministic assumptions and exploring the effects of varying these assumptions.	We have defined three broad scenarios to be addressed in our long-term safety assessment: expected evolution, delayed coastal erosion, and inadvertent human intrusion. This range of scenarios captures unquantifiable uncertainties. Within each scenario, cases are defined to investigate the effect of particular model and parameter uncertainties. In our decision-making, most attention is given to the analyses of the expected evolution and inadvertent human intrusion scenarios. The analysis of the delayed coastal erosion scenario is considered very unlikely to occur and is included to indicate robustness of performance.	[12] §3.5, §10
7.3.18	In some circumstances, where few or no relevant data can be gathered, a 'stylised' approach to assessment may be adopted, in which arbitrary assumptions are made that are plausible and internally consistent but tend to err on the side of conservatism. Use of a stylised approach should not distort the modelling of the rest of the system such that important properties of other parts of the system are obscured in the overall model.	We have used stylised calculation cases to assess the impacts of inadvertent human intrusion. Otherwise, we have not adopted a stylised approach to our assessments. Rather, our aim in our assessments is to adopt a cautiously realistic representation.	[12] §8.3

GRA ID	GRA requirement	How addressed	In ESC
7.3.20	The environmental safety case will need to be updated as uncertainties related to the design, construction, operation and closure of a disposal facility are resolved as the programme develops.	The 2011 ESC is a major update to our understanding of environmental safety. Our forward programme considers the remaining key uncertainties and how they will be managed. The programme and the timing of future iterations of the ESC will be agreed with the Environment Agency.	[2] §2.3 [1] §5
7.3.21	Provide details of the models and methodologies used in the environmental safety assessment including any assumptions, as well as the results.	ESC Level 2 reports summarise our assessment models and assumptions, and our supporting models covering the near field, hydrogeology and coastal evolution. Details are provided in the referenced Level 3 supporting reports.	[6] §7 [7] §5 [8] §4.3, §5.2 [11] §5 [12] §5 - §8 [13] §6 [14] §4

GRA ID	GRA requirement	How addressed	In ESC
7.3.22(a)	Each specific set of modelling studies needs to have specific defined and documented objectives: – modelling objectives should take account of the decisions that the results are intended to support; – the selected approach should be driven mainly by the modelling objectives, and not by the availability of models or software or by considering what models or software were used previously (unless there is an overriding need for consistency); – modelling objectives should be defined in terms of what can be accomplished with the available data. Complex models should not be developed if there is not enough data to support them; – the objectives should be reviewed throughout the modelling process.	Modelling objectives and approach are set out in individual Level 3 supporting reports. The ESC Level 2 reports provide context and a brief description of the modelling, and summarise results. The history of model development is also summarised as appropriate to support understanding of how models have been reviewed and updated to meet objectives.	[6] §6 [7] §4, §5 [8] §4.3, §5.2 [11] §5 [12] §2 [13] §6 [14] §4
7.3.22(b)	In cases where there are likely to be extensive modelling studies, discuss the modelling objectives at an early stage with the relevant environment agency.	We have discussed our approach to modelling with the Environment Agency in many liaison meetings.	[2] §2.2

GRA ID	GRA requirement	How addressed	In ESC
7.3.23	Carry out a systematic programme of work to build confidence in modelling. This will include interpreting raw data and developing and testing conceptual, mathematical and computational models. The measures adopted in a confidence-building programme should include: – systematic approaches to model building and consideration of alternative models; – iteration between model building, quantitative assessments and data collection; – good communication between modellers (including those developing and using models), suppliers of data (including those planning research or data collection and those actually making observations) and those using modelling results; – continuing peer review of model development; – rigorous quality assurance of all modelling activities and associated data handling, including controls over changes to models and data and a detailed audit trail.	We have undertaken a systematic programme of modelling work, building on the work done for the 2002 safety cases and focused on additional characterisation and optimisation work for key FEPs and contaminants. Supporting work has been undertaken to build confidence in our modelling. Our work has been through extensive documented programme review and peer review, and the assessment modelling has been subject to rigorous quality assurance, which we have audited. Our modelling is summarised in the ESC Level 2 assessment reports and conceptual model reports. Our peer review and quality assurance processes are summarised in our '*Management and Dialogue'* report [2].	[2] §4.4, §7 [6] §6 [7] §4.4, §5 [8] §4, §5 [11] §5 [12] §2 [13] §6 [14] §4

GRA ID	GRA requirement	How addressed	In ESC
7.3.24	Models and associated parameter values should, to the extent possible at the time of the assessment, be site-specific. The use of generic or default data instead of site-specific data should be supported by considering the effect that this has on the ESC.	We have used site-specific models in our assessments, parameterised with site-specific data for significant parameters. Our models of the near field build on observations from the trenches and Vault 8. Monitoring of the LLWR site has provided a wealth of hydrogeological information which underpins the hydrogeological conceptual model and has been used to calibrate our hydrogeological models. We have undertaken a substantial programme of work to build an understanding of climate and landform changes as they may affect the LLWR. We have used our description of local land and resource uses and human habits to support characterisation of exposure pathways and critical groups or potentially exposed groups. Extrapolation of measured discharges and environmental concentrations have been coupled with assessment calculations to show that impacts during the PoA are below regulatory constraints.	[6] §3-§5 [7] §4.4 [8] §4.2, §5.1 [11] §5 [12] §3 [13] §5, §6 [14] §5.1

GRA ID	GRA requirement	How addressed	In ESC
7.3.25	Show that the environmental safety case is not unduly sensitive to alternative interpretations or conceptual models.	We have undertaken a rigorous analysis of uncertainties in our assessment using a mixture of deterministic and probabilistic calculations. Variant deterministic calculations with different parameters have been used to illustrate the sensitivity to different conceptual models for the system. Further, in the specific case of 'model uncertainty', we have evaluated alternative models for key parts of the system where appropriate, and presented evidence that our models are appropriate and cautious. Uncertainty in the near-field modelling has been addressed by considering two different models of radionuclide release and behaviour. Our hydrogeological modelling programme investigated potential sensitivities to alternative geological interpretations. Our non-radiological assessment considered the same uncertainties as the radiological assessment and included two models for contaminant release. Our non-human organism assessment reviewed available modelling approaches and selected the most appropriate. Our assessment of releases of gas during the PoA considered alternative models and their potential significance.	[6] §7.1 [7] §3.2, §4.4 [8] [11] §5 [12] §2.5 [13] §6.3 [14] §4
7.3.26	Provide the basis for the judgements to end the programme of building confidence in the modelling, area by area.	We have focused, and will continue to focus, our programme of model development and building confidence to support the main decisions that need to be made. Development of our work programme included evaluation of remaining uncertainties, their significance, and a judgement of whether further work is merited to support future optimisation studies.	[1] §4.5, §5

GRA ID	GRA requirement	How addressed	In ESC
7.3.27	Show that computational models have been used in an appropriate manner, giving the ranges of values for parameters outside which the results from a model cannot be relied on together with appropriate evidence.	Our modelling reports show that our models are fit-for-purpose and have been parameterised and developed appropriately for their range of application. These are objectives in our model calibration, verification, and confidence-building process throughout our ESC programme.	[6] §6, §7 [7] §4, §5 [8] §4, §5 [11] §5 [12] §2.2 [13] §6 [14] §4
7.3.28	Quantitative modelling projections should not be made for times so far into the future that uncertainties make the modelling results lose any meaning.	Our assessment models for the groundwater and gas pathways are concerned with the period until site disruption. We consider our quantitative modelling results to be informative for this period.	[12] §3 [6] §3.1 [7] §5 [13] §6.1.2
7.3.29	As far as possible, use standard approaches to establish the environmental safety case, thus relying on appropriate expert judgement in gathering and interpreting evidence and applying it to construct and use the qualitative and quantitative models.	Our staff are suitably qualified and experienced to make informed judgements about the quality of the science being applied in the ESC. ESC Technical Specialists were recruited to the ESC Project Team, and contracted-out work was procured through competitive ESC Framework Support Contracts with specialist providers of services related to developing repository ESCs. Further assurance concerning the application of sound science in our 2011 ESC is provided by peer review.	[2] §4.3, §4.4

GRA ID	GRA requirement	How addressed	In ESC
7.3.30	Where expert judgement that is not held in common is used to complement or interpret evidence or to compensate for data gaps, to an extent proportionate to the significance of the judgements to the environmental safety case: – explain the choice of experts and method of elicitation; – document explicitly expert judgements that have been made and the reasons given by experts to support their judgements; – take and document reasonable steps to identify and eliminate or minimise any biases resulting from the use of expert judgement and/or the elicitation methods adopted.	We have carried out a series of formal elicitations of expert judgement to parameterise key features of near-field evolution. Consideration of physical degradation of the engineering provided elicited distributions for hydraulic conductivities at 2180, 3180 and 7000. Solubility of Tc and U, sorption of Tc and U onto grout and soil, and the geometry of steel and graphite and the consequences for the release of C-14 and Cl-36 were considered in the elicitation process. Our work on coastal evolution involved workshops and combined qualitative and quantitative evidence sources to provide an integrated understanding of possibilities for the potential future development of the coastline in the vicinity of the LLWR site. Our approach to data elicitation complies with the GRA requirements and is described in a Level 3 supporting report.	[6] §3, §4, §7 [8] §2.2
7.3.31	Consider the issue of a criticality event, although a simple analysis should be sufficient to demonstrate that such an event will not occur.	Our WAC for fissile material ensure that criticality has an extremely low probability of occurrence as a result of either current LLWR operations or the future evolution of the LLWR after site closure. This is demonstrated in a criticality safety assessment conducted for the 2011 ESC.	[15] §6.6 [12] §9.2

GRA ID	GRA requirement	How addressed	In ESC
7.3.32	Take into account the potential for climate change. There is considerable uncertainty regarding the rate, amount and even the direction of possible climate change over different timescales, so consider a range of possibilities. The potential consequences of climate change include changes in rainfall patterns (which can affect watercourses and aquifers), changes in sea level, increased rates of erosion including coastal erosion, glacial cycling and glaciotectonic movements.	A series of studies has been undertaken for ourselves and the NDA. These have been integrated with the understanding gained from international studies on climate change, to develop projections of future climate and landscape evolution for the LLWR. These projections have been used in defining scenarios for our long-term assessment calculations. Groundwater behaviour has been simulated for a range of landscape evolutions and infiltration rates.	[8] §3.5, §4.3, §5.2 [12] §3.5 [7] §5.2
7.3.33	Consider human intrusion as part of the environmental safety case - because of the associated uncertainty, this is likely to involve using stylised calculations.	We have considered inadvertent human intrusion in a stylised fashion in our assessment of the period after authorisation, and in our consideration of radiological impacts on the environment.	[12] §8 [14] §6.2.5
7.3.34	Demonstrate in the environmental safety case that optimisation considerations have been applied in all relevant decisions and at all relevant steps. Relevant steps include 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.	Our '*Optimisation and Development Plan' report* [10] summarises options analysis and decisions for management of past disposals, management of future disposals including waste acceptance, and pre-closure and closure engineering design and management control. Our '*Waste Acceptance'* report [15] discusses WAC that make best use of the site, while ensuring safe operation and long-term environmental performance.	[10] [15] [1] §3.3
SUP7.1	The environmental safety case will need to substantiate that all necessary measures have been, or are being, taken to prevent or limit, as appropriate, the input of any pollutants into groundwater.	Our optimisation analyses, facility design, and management practices all take account of the need to limit input of pollutants into groundwater. Our ongoing monitoring provides assurance that we are meeting our commitments.	[5] §2.1.3, §2.2 [2] §5.1 [9] §5.3 [10] §6

3 References

1 LLWR, *The 2011 Environmental Safety Case – Main Report*, LLWR/ESC/R(11)10016, May 2011.

2 LLWR, *The 2011 ESC: Management and Dialogue*, LLWR/ESC/R(11)10017, May 2011.

3 LLWR, *The 2011 ESC: Site History and Description*, LLWR/ESC/R(11)10018, May 2011.

4 LLWR, *The 2011 ESC: Inventory*, LLWR/ESC/R(11)10019, May 2011.

5 LLWR, *The 2011 ESC: Engineering Design*, LLWR/ESC/R(11)10020, May 2011.

6 LLWR, *The 2011 ESC: Near Field*, LLWR/ESC/R(11)10021, May 2011.

7 LLWR, *The 2011 ESC: Hydrogeology*, LLWR/ESC/R(11)10022, May 2011.

8 LLWR, *The 2011 ESC: Site Evolution*, LLWR/ESC/R(11)10023, May 2011.

9 LLWR, *The 2011 ESC: Monitoring*, LLWR/ESC/R(11)10024, May 2011.

10 LLWR, *The 2011 ESC: Optimisation and Development Plan*, LLWR/ESC/R(11)10025, May 2011.

11 LLWR, *The 2011 ESC: Environmental Safety During the Period of Authorisation*, LLWR/ESC/R(11)10027, May 2011.

12 LLWR, *The 2011 ESC: Assessment of Long-term Radiological Impacts*, LLWR/ESC/R(11)10028, May 2011.

13 LLWR, *The 2011 ESC: Assessment of* Non-radiological *Impacts*, LLWR/ESC/R(11)10029, May 2011.

14 LLWR, *The 2011 ESC: Assessment of* Impacts on Non-human Biota, LLWR/ESC/R(11)10030, May 2011.

15 LLWR, *The 2011 ESC: Waste Acceptance*, LLWR/ESC/R(11)10026, May 2011.

16 LLWR, *The 2011 ESC: Assessment for an Extended Disposal Area*, LLWR/ESC/R(11)10035, May 2011.

17 LLWR, *The 2011 ESC: Addressing the GRA*, LLWR/ESC/R(11)10031, May 2011.

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

19 Environment Agency, *Interim Guidance Note for Developers and Operators of Radioactive Waste Disposal Facilities in England and Wales. Near-surface Disposal Facilities on Land for Solid Radioactive Wastes: Guidance on Requirements for Authorisation. Supplementary guidance related to the implementation of the Groundwater Directive*, July 2010.

20 LLWR, *2011 FEP List and Uncertainty Tracking System,* LLWR04127061103 1.0, April 2010.

21 Thorne MC, Balding D, Egan M and Paulley A, *LLWR Radiological Handbook,* LLWR/ESC/R(10)1033 Issue 1.3, April 2011.

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Appendix 1 List of Acronyms

ALARA	As low as reasonably achievable
CQA	Construction Quality Assurance
DAP	Duly Authorised Person
EDA	Extended Disposal Area
EH & S	Environmental, health and safety
EHS & Q	Environment, health, safety and quality
ESS	Environmental Safety Strategy
FEP	Features, events and processes
GRA	Guidance on Requirements for Authorisation for Near-Surface Disposal facilities on Land for Solid Radioactive Wastes
HPA	Health Protection Agency
IAEA	International Atomic Energy Agency
LLW	Low-level waste
LLWR	Low Level Waste Repository
ISO	International Organization for Standardization
PRG	Peer Review Group
NDA	Nuclear Decommissioning Authority
ONR	Office for Nuclear Regulation
PCSC	Post-closure Safety Case
PEG	Potentially exposed group
PoA	Period of Authorisation
PRG	Peer Review Group
RDA	Reference Disposal Area
RSP	Repository Site Procedure
SLC	Site Licence Company
SQEP	Suitably qualified and experienced person
WAC	Waste Acceptance Criteria
WCSSG	West Cumbria Sites Stakeholder Group