Nuclear Waste Services

ADDRESSING REGULATORY REQUIREMENTS AND FEEDBACK

2026 Environmental Safety Case for the LLWR

LLWR/ESC/R(26)10184, May 2026

Conditions of Publication

Preface

The Low Level Waste Repository (LLWR) is the United Kingdom's principal facility for the disposal of solid Low Level Waste (LLW). It is a near-surface disposal facility in which waste was disposed in trenches and is now being disposed in vaults excavated into the ground surface. The LLWR is owned by the Nuclear Decommissioning Authority (NDA) and operated on their behalf by a wholly-owned subsidiary division, Nuclear Waste Services Ltd.

We, Nuclear Waste Services, are committed to operating the LLWR as a safe and efficient facility that provides a continuing option for the disposal of LLW in the United Kingdom. This will be achieved consistent with good practice for the near-surface disposal of radioactive waste, in accordance with environmental, health and safety, and security regulation and guidance, and in compliance with the terms of our Nuclear Site Licence and Permit to dispose of radioactive waste. We are also committed to working with the NDA to ensure optimal use is made of the LLWR to support the NDA's mission, in accordance with government policy. This may involve the disposal of a broader range of wastes than just LLW as currently defined in the United Kingdom[1].

One of the means we use to operate the LLWR safely is to maintain and implement an Environmental Safety Case for the site. This is one of the reports presenting the 2026 Environmental Safety Case for the LLWR – the 2026 ESC. The 2026 ESC is a major update based on a comprehensive review of our previous 2011 ESC and subsequent developments. The 2026 ESC addresses both the environmental safety of the disposal facility and the rest of the site. It considers the disposal of both LLW and some less-hazardous Intermediate Level Waste (ILW). Assessing the disposal of some less-hazardous ILW does not imply any decision has been made to dispose of such waste at the LLWR. The work has been undertaken to understand the safety implications if such a decision were made and hence support consideration of the option by the NDA.

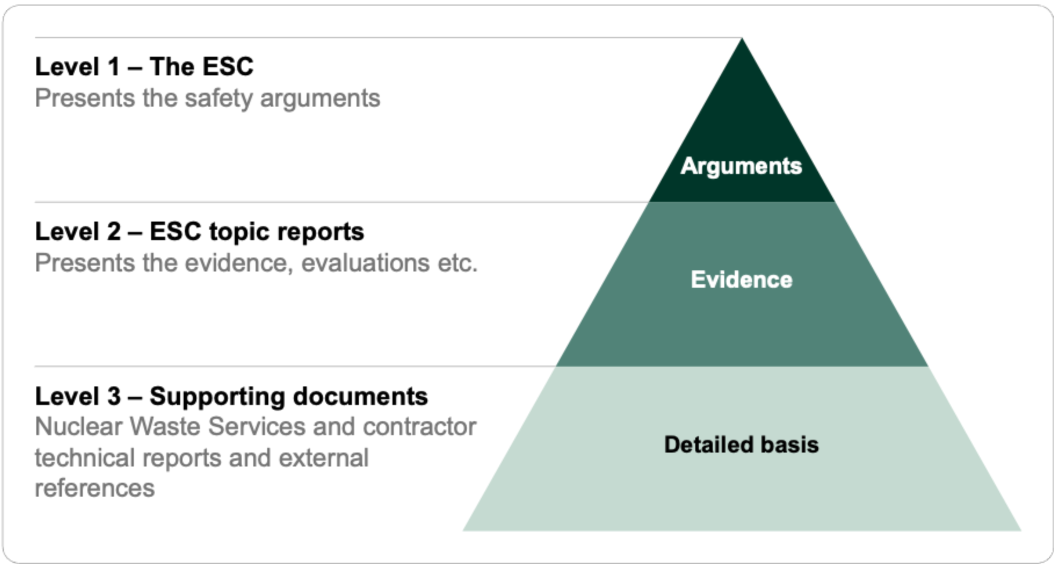
The 2026 ESC is issued under the authority of the Nuclear Waste Services' Executive Director of Sites and Operations.

The 2026 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 it 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, assessments and implementation.

[1] In government policy, LLW is defined as radioactive waste having a radioactive content not exceeding four gigabecquerels per tonne (GBq t^{-1}) of alpha or 12 GBq t^{-1} of beta/gamma activity.

This is the Level 2 report '*Addressing Regulatory Requirements and Feedback*'. The ESC Level 1 and 2 reports are listed in the table below, which also shows for the Level 2 reports the set of arguments for which each report mainly provides evidence. A brief description of the contents of each Level 2 report is also given. The ESC is supported by a large number of technical and scientific reports and references that we refer to as 'Level 3' documents. We have also produced a Guide to Key Points of the ESC, to help a wider group of stakeholders understand its nature, conclusions and implications.



Level 1	
Main Report [1]	
Level 2	
Management and dialogue	
Management and Dialogue [2]	Describes our environmental management systems and interactions with regulators and stakeholders
System characterisation and understanding	
Site History and Description [3]	Provides a history and description of the site
Disposal Facility Inventory [4]	Describes the wastes already disposed and wastes that may be disposed at the facility
Engineering Design [5]	Presents the engineering design of the current facility and proposed changes as further disposal vaults are built and the disposal facility is closed

Near Field [6]	Describes our understanding of the chemical and physical evolution of the engineered disposal system
Hydrogeology [7]	Describes our understanding of the geology and hydrogeology of the site
Site Evolution [8]	Describes our understanding of how the site will evolve, with a focus on coastal erosion
Monitoring [9]	Presents our programme of environmental monitoring supporting the ESC
Optimisation and Site Development Plan	
Optimisation and Site Development Plan [10]	Describes our approach to optimising the design and management of the disposal facility and wider site, and sets out our Site Development Plan
Waste Management Plan [11]	Presents our plans for managing the wastes produced by previous uses and operation of the site
Assessments	
Safety Functions [12]	Presents our understanding of how the different aspects of the repository system and its management contribute to the safety of the facility
Engineering Performance Assessment [13]	Presents our analysis of how the various components of the engineered disposal system will perform, which is an input into our impact assessments
Environmental Safety During the Period of Authorisation [14]	Presents evidence that the LLWR is currently being operated safely and will continue to be so during the period that the facility is permitted
Assessment of Long-term Radiological Impacts [15]	Presents evidence that, if the LLWR is managed in accordance with the Site Development Plan, the site will remain safe in the long term
Hydrogeological Risk Assessment [16]	Presents evidence that the disposal facility protects groundwater from both radiological and non-radiological contaminants in the disposed wastes now and will continue to do so in the future

Assessment of Radiological Impacts on Non-human Biota [17]	Presents evidence that the LLWR does not have adverse consequences for non-human biota populations now and will not in the future
Implementation	
Implementation [18]	Sets out how we use the ESC to manage the site, including setting Waste Acceptance Criteria and other controls on the types and quantities of waste accepted for disposal
Audit	
Addressing Regulatory Requirements and Feedback (this report)	Provides a cross-reference between the contents of the ESC and regulatory guidance and feedback

Executive Summary

Disposal of radioactive waste at the Low Level Waste Repository (LLWR) is permitted by the Environment Agency of England and Wales under the Environmental Permitting (England and Wales) Regulations 2016. Our Environmental Permit (Permit) requires us to maintain an Environmental Safety Case (ESC) and a Site-wide Environmental Safety Case (SWESC).

The content of the ESC is guided by the environment agencies' 2009 '*Near-surface Disposal Facilities on Land for Solid Radioactive Wastes Guidance on the Requirements for Authorisation*' (the GRA). The content of the SWESC is guided by the environment agencies' 2018 '*Management of radioactive waste from decommissioning of nuclear sites: Guidance on Requirements for Release from Radioactive Substances Regulation*' (the GRR). The GRA and GRR each consist of a small number of Principles and top-level Requirements, and together several hundred more detailed requirements.

Our 2026 submission to the Environment Agency is a SWESC that meets the requirements of the GRR. Our ESC for the disposal area that meets the requirements of the GRA is embedded within that submission. Our ESC dominates the overall content of our SWESC, which we consider to be proportionate, given the environmental hazard presented by the disposal facility compared with the rest of the site. Where it is necessary to do so, we consider it to be proportionate to assign primacy to the requirements of the GRA ahead of the GRR.

We submitted an ESC to the Environment Agency in 2011. The Environment Agency raised Forward Issues (FIs) and gave recommendations as a result of its review of the 2011 ESC. FIs are areas of work where the Environment Agency saw scope for continued improvement in the ESC and its implementation.

Improvement Condition 7 (IC7) of our Permit requires us to submit an update to the ESC by 1st May 2026. IC7 calls for the 2026 ESC to meet all the requirements of the latest version of the GRA and to address the findings of the Environment Agency's review of the 2011 ESC. Improvement Condition 8 (IC8) requires us to submit a SWESC to fulfil the requirements of the GRR by 1st May 2026.

This report has the following specific objectives in support of the 2026 ESC for the LLWR:

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

- To show how we have addressed the Environment Agency's Forward Issues and responded to the recommendations.

The purpose of this document is to show that we have fulfilled the requirements of our Permit by demonstrating that we have met all the requirements of the GRA and GRR. The report provides a short summary of how the requirements have been addressed and directs the reader to the relevant material within the ESC. It does not provide any detail on how the requirements have been addressed.

We manage the site in compliance with other regulations and good practice guidance, however, this report is concerned only with the regulatory requirements in the GRA and GRR as we consider those to be the most important.

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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 under the Environmental Permitting (England and Wales) Regulations 2016.

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) [19]. The GRA consists of five Principles, fourteen top-level Requirements, and several hundred more detailed requirements. A key requirement of the GRA is to develop and maintain an Environmental Safety Case (ESC). We understand that the GRA is being updated by the Environment Agency and we have responded to the consultation.

The Environment Agency, Natural Resources Wales, and the Scottish Environment Protection Agency (the environment agencies) jointly issued guidance in 2018: '*Management of radioactive waste from decommissioning of nuclear sites: Guidance on Requirements for Release from Radioactive Substances Regulation*' (the GRR) [20]. It applies to all nuclear sites and describes what operators must do over the lifetime of their site in order to achieve release from radioactive substances regulation. The GRR consists of five principles and fifteen specific requirements. The GRR requires operators to develop and maintain a Waste Management Plan (WMP) and a Site-wide Environmental Safety Case (SWESC) and to ensure the condition of their site meets regulatory standards for protection of people and the environment, now and into the future.

The GRR explains that a constructed disposal facility must meet the requirements of the GRA and will have its own ESC, which will define the Waste Acceptance Criteria for the facility. The ESC for the disposal facility will be a component of the SWESC, as shown in Figure 1.1. We have followed this approach by embedding the ESC for the dedicated disposal facility within a SWESC. However, the main purpose of the LLWR site has been and will continue to be the disposal of radioactive waste in a dedicated disposal facility. We therefore assign primacy to the requirements of the GRA and it addressed first in this document (Table 2.1).

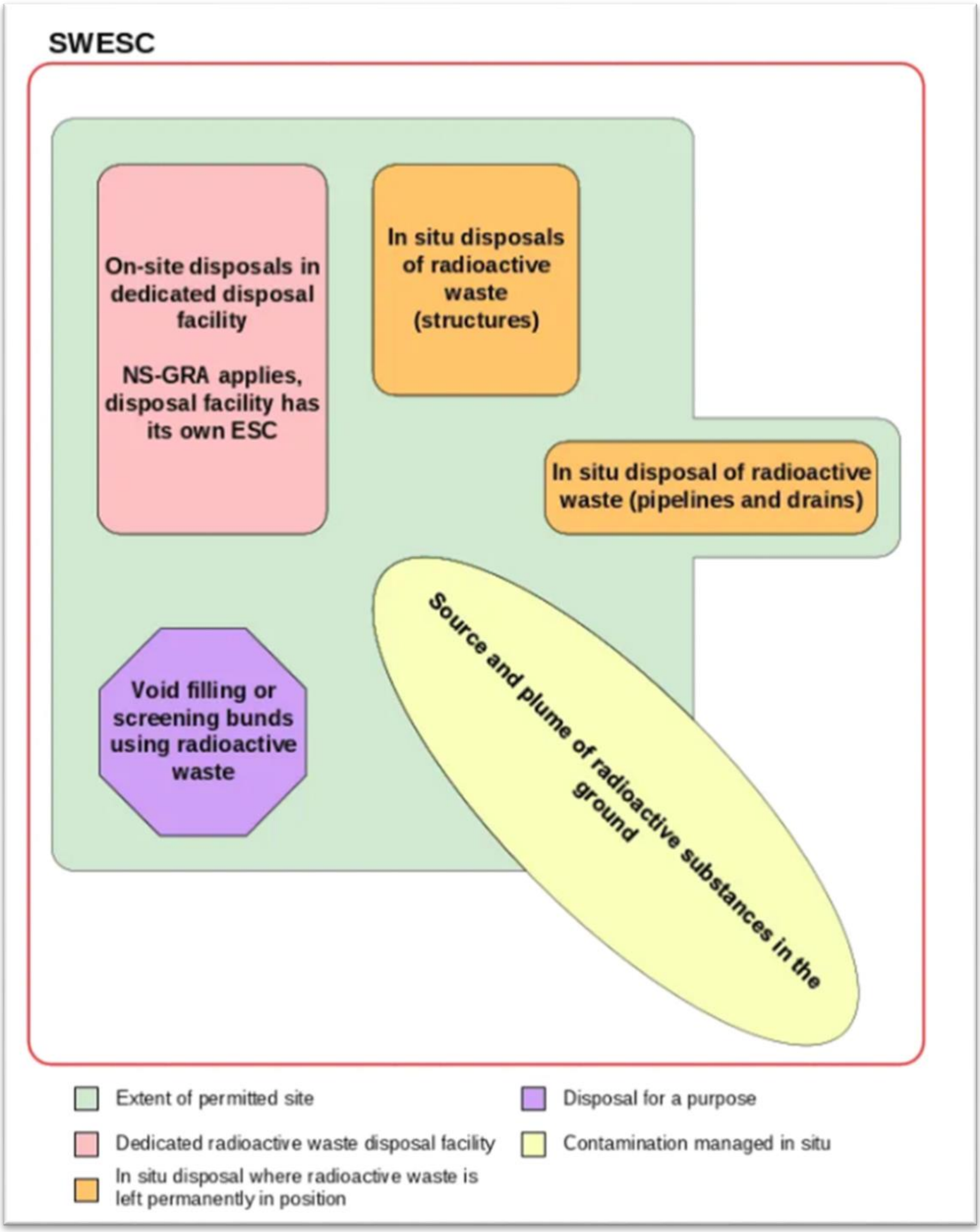

Figure 1.1: Relationship between SWESC and the GRA [20]

We submitted an ESC to the Environment Agency in 2011. The Environment Agency raised Forward Issues (FIs) and gave recommendations as a result of its review of the 2011 ESC. The Environment Agency recognised that the 2011 ESC was a complex submission involving a wide range of technical assessments that will evolve and improve in the future as technology and understanding advances. It also recognised that certain details will be developed further as the site advances, for example, toward construction of the final engineered cap over the waste. The FIs are areas of work where the Environment Agency saw scope for continued improvement in the ESC and its implementation [21].

Improvement Condition 7 (IC7) of our Permit requires us to submit an update to the ESC by 1st May 2026. IC7 calls for the 2026 ESC to meet all the requirements of the latest version of the GRA and to address the findings of the Environment Agency's review of the 2011 ESC. Improvement Condition 8 (IC8) requires us to submit a SWESC to fulfil the requirements of the GRR by 1st May 2026.

This report has the following specific objectives in support of the 2026 ESC for the LLWR:

- To provide mapping from the requirements set out in the text of the GRR and GRA to relevant sections of the ESC.
- To demonstrate that the relevant requirements of both the GRR and GRA 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.
- To demonstrate how we have addressed the Environment Agency's Forward Issues and Recommendations.

The purpose of this document is to show that we have fulfilled the requirements of our Permit by demonstrating that we have met all the requirements of the GRA and GRR. The report provides a short summary of how the requirements have been addressed and directs the reader to the relevant material within the ESC. It does not provide any detail on how the requirements have been addressed.

1.2 Scope

This report provides mapping to where material relevant to addressing a GRA or GRR requirement can be found in the ESC. It also sets out how we have addressed the FIs and recommendations that resulted from the Environment Agency's review of the 2011 ESC.

We manage the site in compliance with other regulations and good practice guidance, however, this report is concerned only with the regulatory requirements in the GRA and GRR as we consider those to be the most important.

Figure 1.2 sets out the relationships between the protection objective, principles and requirements for the GRA.

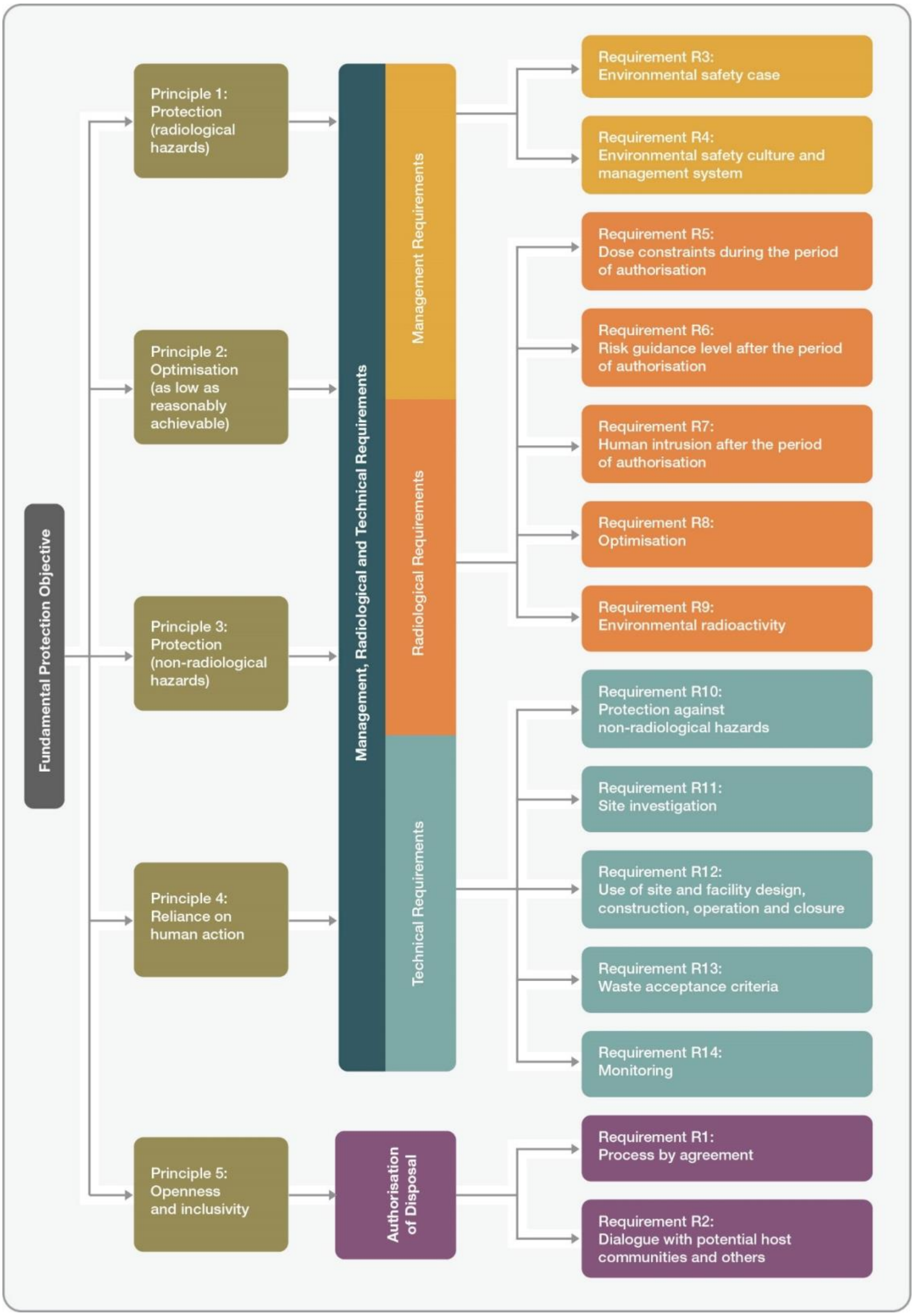

Figure 1.2: Relationship between the principles and top-level requirements in Part 1 of the GRA [19]

The GRA 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 1.2, 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.

The GRA requirements considered in this report have been extracted from Chapters 5 through 7. 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.

The GRR main document sets the context for the requirements by setting out expectations for: meeting the requirements (Chapter 2); the Waste Management Plan (Chapter 3); the Site-wide Environment Safety Case (Chapter 4); and other regulations affecting decommissioning nuclear sites (Chapter 5). Principles and requirements are then in a detailed Annex (Annex A), with underpinning information in Annex B (Basis for the environment agencies quantitative criteria). The GRR requirements considered in this document have been extracted from Annex A.

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 LLWR site has been used for disposal of radioactive waste for over 60 years. The disposal area presents the greatest environmental hazard on the site. We consider it to be proportionate to assign primacy to the requirements of the GRA where it is relevant to do so.

1.3 Structure

Section 2 of this report presents the mapping between the ESC and the regulatory requirements in the GRA (Table 2.1) and GRR (Table 2.2). The mapping is in the form of tables with the following columns:

- **Requirement ID**. This refers to the paragraph in the GRR or 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 GRR or GRA provide essentially the same requirement, a single entry in the table refers to both requirement IDs.

- **Requirement**. Note that the GRR or GRA text has sometimes been edited for brevity, or in order to express paragraphs as a specific requirement or need that is placed on the operator.
- **How Addressed**. A brief summary of how the requirement has been addressed in the 2026 ESC.
- Mapping to where the requirement is **addressed in the ESC**. This mapping is to the section level of the ESC reports.

Table 2.3 then documents how we have addressed the Forward Issues. Table 2.4 sets out the Environment Agency recommendations, noting how they have been addressed in the ESC or otherwise managed.

A general glossary for the ESC is appended to the '*Main Report*'.

2 Mapping Tables

2.1 GRA Mapping Table

Table 2.1 provides a mapping to where the GRA requirements are addressed in the 2026 ESC. The mapping generally points to the section of a Level 2 ESC report where the evidence can be found. For a few requirements, where a high-level argument is more appropriate, reference is to the '*Main Report*'.

Table 2.1: Summary of how the requirements of the GRA are addressed as necessary in the 2026 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.	After the review of the 2011 ESC, both we and the Environment Agency agreed that a more formal approach to recording reviews and positions would be beneficial for the next Major Review of the ESC. A 'process by agreement' is described in the GRA, which allows the regulator to provide advice prior to the start of a formal regulatory process. Although the LLWR is an operational site, to support the development of the 2026 ESC we agreed to follow such a process with the Environment Agency. We have engaged extensively with the Environment Agency in developing the 2026 ESC: we presented a forward programme of work, held structured liaison meetings, submitted technical documents for regulatory	Preface Main Report § 4.2 Management and Dialogue § 2.2

		assessment, and adjusted our methods (e.g. climate projections and representative-person framework) in response to feedback.	
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.	We have agreed the timing and scope of reviews with the Environment Agency; we will submit periodic reviews and updated versions of the ESC in line with our Permit obligations and NWSSOP 40.07.01 [22]. Specifically, the timing of the 2026 ESC submission was agreed with the Environment Agency; future iterations will likewise be agreed, and the ESC is operated under formal change control with Annual, Periodic and Major reviews, including earlier major reviews where significant new information arises. This approach ensures our reviews are planned jointly with the regulator and supported by a current, updated safety case.	Preface Management and Dialogue § 2.2 and 5.2
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, the closure design, its development and progressive implementation are built into the design of the repository that is considered in the 2026 ESC. Waste emplacement has been assumed in the 2026 ESC to occur up to 2135. Periodic reviews and future ESC iterations, including the post-operational ESC, will be managed and submitted under our formal change-control arrangements (NWSSOP 40.07.01 [22]) and forward programme	Main Report § 4.4 Optimisation and Site Development Plan § 5 Engineering Design § 3 Management and Dialogue § 4.6 and 5.2

		agreed with the regulator. Until revocation is sought, the site will remain under management and regulatory control, with the ESC treated as a live baseline and kept current through Annual, Periodic and Major reviews.	
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.	We recognise that revocation of the authorisation will require a final ESC demonstrating compliance with the principles and requirements of the guidance, and we will deliver it at the appropriate time. Periodic reviews and future ESC iterations, including the final ESC following any period of active institutional control, will be managed and submitted under our formal change-control arrangements (NWSSOP 40.07.01 [22]) and forward programme agreed with the regulator. Until revocation is sought, the site will remain under management and regulatory control, with the ESC treated as a live baseline and kept current through Annual, Periodic and Major reviews.	Main Report § 3.4 Management and Dialogue § 4.6 and 5.2
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.	Stakeholder dialogue associated with the development of the ESC is undertaken within our established organisational framework for communications and stakeholder engagement. We also have a dedicated stakeholder engagement and communications plan for the ESC. In practice, we engage regularly through the West Cumbria Sites Stakeholder Group (WCSSG) and the associated Working Group, monthly meetings with	Management and Dialogue § 3

		Drigg and Carleton Parish Council, community drop-ins and site tours, and targeted briefings; these fora are used to share ESC updates, explain the ESC's role in maintaining long-term environmental safety at the LLWR and address questions raised by local representatives, regulators and the public.	
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 undertake a significant programme of engagement activities to ensure all our stakeholders are aware of the activities on the LLWR site and to provide the information they require. These activities include: • attendance at the WCSSG and the NWS Working Group; • monthly meetings with Drigg and Carleton Parish Council; • community drop-in days; • site tours; • our website: repository community page; • our '*On the Level*' newsletter. We also provide targeted briefings for national stakeholders and non-governmental organisations. Engagement is also an important part of our optimisation process. In addition to regulatory engagement, wider	Management and Dialogue § 3 Optimisation and Site Development Plan § 2.5

		local stakeholder groups have also been specifically engaged, in particular for the optimisation processes ahead of the 2011 ESC that defined our current concept.	
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.	We undertake a significant programme of engagement activities to ensure all our stakeholders are aware of the activities on the LLWR site and to provide the information they require. Practically, we work with WCSSG, including its NWS Working Group, and have regular liaison with Drigg and Carleton Parish Council to ensure representation and awareness of our proposals. Members of the NWS Working Group include representatives from NWS, the NDA, the Office for Nuclear Regulation (the ONR), the Environment Agency, Cumberland Council and local town and parish councils, including Drigg and Carleton Parish Council and Seascale Parish Council. Our dedicated Community Engagement team have an 'open-door' policy where local residents are able to contact us directly with any queries.	Management and Dialogue § 3.1.6
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	We work with the Environment Agency to ensure that our discussions with the planning authority and local community are open, inclusive and constructive. We use established, public fora – WCSSG meetings (attended by the Environment Agency and local councils), monthly liaison with Drigg and Carleton Parish Council and	Management and Dialogue § 2 and 3

	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.	community drop-in days and site tours – to present and explain technical, social and economic matters (e.g. cap design, inventory and Waste Acceptance Criteria changes) and what we and the regulators are doing to address them. These fora are open to questioning and challenge, and stakeholder feedback is captured and responded to.	
6.2.1	**Requirement R3: Environmental safety case.** An application under RSA 93 [the Radioactive Substances Act 1993, which has now been replaced by the Environmental Permitting (England and Wales) Regulations 2016] relating to a proposed disposal of solid radioactive waste should be supported by an environmental safety case.	The Level 1 '*Main Report*' and the Level 2 reports make up the 2026 ESC.	All ESC Reports
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	The 2026 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.	Main Report § 4

	guidance and that the management, radiological and technical requirements set out in Chapter 6 are met.		
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 we are implementing a risk-informed approach in line with government policy. Proportionality has been taken into account in our optimisation studies and decision making.	Management and Dialogue § 4.5.1 Optimisation and Site Development Plan
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	We plan and control work for permit compliance and ESC development under documented arrangements (NWSSOP 40.07.01 [22]) and structured liaison with the Environment Agency. We apply sound science and good engineering practice through, for example, independent peer review, optimisation and controlled design and verification. We ensure timely provision of information to the regulator within an agreed documentation structure. We maintain robust documentation and record-keeping governed by our records policy and retention schedule. We operate formal quality management arrangements as part of our Integrated Management System. These assure oversight, review and continuous improvement.	Management and Dialogue § 4, 5, 6, 7, 8 and 9 Engineering and Design § 2.5.2

	record-keeping; (e) quality management.		
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.	A positive environmental safety culture is embedded in our management system. Expectations are set through documented environment, health, safety, security and quality (EHSS&Q) arrangements that reinforce acceptable behaviours. We have an established set of values, standards and expectations that are communicated to all employees. We ensure that suppliers meet the same standards by using our '*Contractor Lifecycle*' [23] and *'Management of Contractors*' [24] procedures and by assigning an Intelligent Customer to approve and oversee all ESC-related procurements. Learning and assurance is driven through OSHENS event capture and independent audits, so the culture is consistently reflected in, and strengthened by, the management system.	Management and Dialogue § 4.1, 4.4 and 4.8
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	We implement an Integrated Management System that provides effective leadership and governed arrangements for policy and decision making. Under NWSSOP 40.07.01 [22], we keep the ESC under formal change control and plan and control work for permit compliance and ESC development. We maintain a suitable range of competencies and provide sufficient resources through Intelligent Customer capability, Heads	Main Report § 4.2 Management and Dialogue § 4, 5 and 9

	succession planning and knowledge management.	of Function oversight and the use of trained, qualified and experienced (SQEP) contractors [25]. Continuous learning is maintained by event capture in OSHENS, learning and action reviews and periodic management reviews, and we maintain proper arrangements for succession planning and knowledge management by identifying deputies for key EHSS&Q roles, reviewing long-term plans annually and managing records to an agreed retention schedule [26].	
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 arrangements are subject to a formal annual management review, undertaken to ensure their adequacy, effectiveness and alignment to the direction of the organisation. The output of the review is submitted to the Nuclear Safety Committee. In addition to this, individual Process Owners undertake periodic reviews of their processes to ensure they are current, appropriate and adequate.	Management and Dialogue § 4.2
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	Our '*Environmental Management Topic Manual*' [27], forming part of the Environmental, Health and Safety section of the Integrated Management System and supported by the relevant '*Organisational Manual*' [28], provides the framework for managing environmental risks and ensuring compliance with applicable legislation, including environmental permits and, where required,	Management and Dialogue § 4.2 and 9

	in a living state through regular review, progressive updating and implementation of the management arrangements.	environmental enhancement obligations under the Energy Act. Underpinning the topic manual is a Permit Compliance Table [29], which documents the environmental permits applicable to our operations and supports compliance with relevant regulatory requirements, The management system is maintained through annual review and Process Owner reviews. The maintenance, version control and issue on the system are managed through a document control information technology system. Each management system document has a document owner who has responsibility for the review and amendment of the document through the lifetime of the business.	
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	We operate through an organisational structure built around a set of directorates that collectively deliver our core mission. The structure is underpinned by a comprehensive management system that provides clear governance arrangements, defined EHSSQ and Intelligent Customer accountabilities, and integration of environmental safety principles into all business processes. Key responsibilities for environmental safety and permit compliance are allocated through documented processes and our '*Management Prospectus*' [30] demonstrates that we maintain an adequate management structure,	Management and Dialogue § 4

	organisation the structure should remain a 'live' issue, so that it continues to match the business needs and maintains clarity about responsibilities.	capability and resource base to fulfil the obligations associated with operating the LLWR nuclear licensed and permitted site. The structure is subject to continuous improvement processes to ensure it remains aligned with current and foreseeable operational needs, including management, operation, and restoration activities at the LLWR site. Cultural reinforcement measures, such as leadership engagement and targeted training, further embed environmental safety values across the organisation, ensuring clarity of roles and responsiveness to regulatory expectations.	
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.	Our EHSSQ Policy states that '*above all, nothing is more important to us than protecting people and the environment.*' Our Board holds responsibility for strategic direction and ensuring compliance with environmental and regulatory obligations. The accountabilities of the Executive Directors are defined in the '*Management Prospectus*' [30], with particular emphasis on the roles and responsibilities that are critical to ensuring safe, secure and environmentally responsible delivery. The Board is supported by the Environment, Safety and Security Committee providing advisory input on safety and environmental matters.	Management and Dialogue § 4

		Our Integrated Management System embeds roles, standards, Permit-condition controls and assurance across all management levels. In practice, environmental safety messages originate from the top and are reinforced throughout the organisation via the '*Contractor Information and Standards*' [31], mandatory environmental-awareness training, and controlled processes for planning, change, communication and review.	
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 Integrated Management System provides a single, governed framework that secures environmental safety across the full facility lifecycle and establishes a continuous chain of accountability from the Board and Chief Executive Officer through senior management to operations. Within this framework, we define clear roles, responsibilities and accountabilities in the '*Management Prospectus*' [30] and '*Organisational Baseline Manual*' [32]. We embed performance standards via our Environmental Management System (ISO 14001) and Permit-condition controls. We manage change to key roles through a graded Management of Change process overseen by the Nuclear Safety Committee and the Management of Environment, Health and Safety Committee (MEHSC).	Management and Dialogue § 4.2 and 4.8

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.	Our Organisational Baseline represents the configuration of a fully capable organisation, encompassing the resources, competencies and structures required to deliver all operational, regulatory and strategic commitments effectively. We keep our Organisational Baseline under monthly review to ensure key EHSS&Q appointments and required training remain current; and we sustain a SQEP workforce through line management oversight, identified deputies for critical roles and targeted use of specialist contractors when needed. These written arrangements show how we achieve and maintain capability that matches the need over the facility's lifecycle.	Management and Dialogue § 4.8
6.2.14	The organisation may need to use contract resource to complement 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	SQEP contractors are engaged to support the work programme both to provide expertise in specialist disciplines and to address fluctuating resource requirements. We maintain sufficient in-house expertise across all relevant technical disciplines to act as an informed and Intelligent Customer for externally sourced technical services while using specialist contract resources in a controlled, proportionate way. Our Integrated Management System assigns an Intelligent Customer to all ESC-related procurements and applies NWSTM 27 ('*Contractor Lifecycle*' [23]) and RSP 8.02 ('*Management*	Management and Dialogue § 4.8

	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.	*of Contractors*' [24]) so that we remain in control of contract deliverables in the short and longer term. We keep an up-to-date '*Organisational Baseline*' [32] and succession plans to balance employee and contractor numbers through resource planning, and we retain sufficient scientific and technical expertise to oversee, verify and audit supplier goods and services so they meet the requirements of our authorisation and the ESC.	
6.2.15	Maintain relevant competencies over the lifetime of the facility, including any period of authorisation after closure.	We review and update our organisational baseline monthly; line managers identify deputies for all key EHSS&Q roles and keep longer-term succession plans under review. Where specialist skills are needed, we complement in-house expertise with SQEP contractors under controlled contractor-management procedures, maintaining sufficient in-house expertise across all relevant technical disciplines to act as an informed and Intelligent Customer for externally sourced technical services.	Management and Dialogue § 4.8
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	We ensure that policies and decisions affecting environmental safety are rational, objective, transparent and prudent by governing them through our Integrated Management System and formal change processes. Through these change processes the Nuclear Safety Committee would advise the Duty Holder on any significant decisions relating to changes to site	Management and Dialogue § 4.4, 4.6, 4.9.3, 5.2 and 7

	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.	operations that could affect either the disposal of waste or discharges to the environment, or that have the potential to affect environmental performance. In practice, we take all relevant considerations into account via documented change control (NWSSOP 40.07.01 [22] and related procedures), Periodic and Annual reviews and a live '*Issues Register*' that links new proposals explicitly to established policies and prior decisions. Rigorous questioning is embedded in our process through independent peer review, targeted bias-and-uncertainty audits, and data management quality assurance that requires provenance be recorded, checking and approval for all factual material and assumptions before use.	
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 regarding the development and operation of the LLWR to meet environmental safety objectives are captured in the Site Development Plan. In comparing options for the LLWR, our focus has been to make visible the key underpinning evidence and logic that has led us to put forward the proposed set of controls for future management of the LLWR. We apply documented change control processes and we have robust processes for producing high-quality technical reports that represent the ESC baseline and provide a complete record of decision making.	Optimisation and Site Development Plan § 3.2 and 9 Management and Dialogue § 4.5.1 and 7.2

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 actively seek, analyse and adopt lessons from international waste management organisations, through International Atomic Energy Agency (IAEA) networks (DISPONET; Legacy Trench Site Community of Practice), technical co-operation agreements (e.g. with Andra, ENRESA and ONDRAF) and site visits. These insights have informed optimisation decisions and engineering performance assessments particularly in relation to cap durability and closure engineering. This combination of structured review, independent peer challenge and applied external learning ensures we continually challenge established understanding, reduce uncertainty and update our practices in line with demonstrable improvements. Our '*Optimisation and Site Development Plan*' report shows how our optimisation process for the facility design has taken account of learning from our peers. By involving specialist contractors with experience from other clients, we ensure we adopt best practices and current safety case methods. We are committed to continuous learning and improvement of the ESC. After submitting the 2026 ESC, we will conduct a comprehensive lessons-learnt review, which we have scheduled in our future programme	Management and Dialogue § 4.9 and 6.2 Engineering Performance Assessment § 4 Optimisation and Site Development Plan § 3.7.2 Main Report § 3.3 and 6 Engineering Performance Assessment § 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.	We promote learning across the organisation by encouraging staff at every level to report hazards, near-misses and potential or actual events, and to offer improvement suggestions. Reports raised through our OSHENS 'Learning Reports' process are formally sentenced, reviewed at a Learning and Action Review meeting and, where required, translated into corrective actions that are tracked to completion. This structured cycle, spanning event reporting, managerial review and action tracking, ensures problems are identified promptly, lessons are captured, and improvements are implemented and shared, thereby embedding continuous organisational learning.	Management and Dialogue § 5.4.2
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.	In developing the 2026 ESC, we carried out a comprehensive lessons-learnt review of the 2011 ESC and 2002 Post-closure Safety Case and identified improvements relevant to the scope, structure and methods used in the current ESC. We also addressed the recommendations and explicitly tracked responses to Environment Agency Forward Issues and Recommendations via a formal '*Issues Register*'; this provides clear evidence that changes were made and tested for effect. In day-to-day operations, events and observations are sentenced through OSHENS and taken to a Learning and Action Review meeting where corrective actions are agreed, implemented and tracked	Management and Dialogue § 4.9

		to close, confirming that improvements have been achieved. Following submission of the 2026 ESC we intend to undertake a comprehensive lessons-learnt review.	
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.	We identify all key competency areas and maintain capability through our Organisational Baseline and competency tables, ensuring SQEP appointments across critical EHSS&Q roles (e.g. Intelligent Customers and Process Owners). We implement a structured succession and knowledge-management strategy: line managers identify deputies for all key posts, succession plans are maintained and reviewed through annual management reviews and changes to key roles are controlled under RSP 22.02 [33]. We preserve and transfer knowledge using formal processes, a central records management system with Information Asset Owner governance and our '*Record Retention Schedule*' [26], so competency is sustained and knowledge is captured, curated and handed over across the programme.	Management and Dialogue § 4.8
6.2.21	Where appropriate, the approaches used to fulfil management system functions should be based on principles derived from national and international standards.	We fulfil our management system functions on principles derived from recognised national and international standards: our Integrated Management System is certified to BS EN ISO 9001, BS EN ISO 14001 and BS EN ISO 45001 by Lloyd's Register Quality Assurance (UKAS-accredited), and our governance, management	Management and Dialogue § 4.2.1, 4.2.2 and 6.1

		review and quality assurance arrangements are explicitly aligned to these standards. We also apply good engineering practice cognisant of British, European and international standards, ensuring that design, construction and post-construction validation are independently checked and auditable. Regular internal and external audits and a documented management review confirm that these standard-based approaches are maintained and effective.	
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.	We apply a single, auditable Integrated Management System to all work that supports the ESC: site investigation and understanding, engineering design and construction, waste acceptance and emplacement, closure engineering, together with the documentation and provision of the ESC. The management system governs planning, control, change management and assurance via defined procedures (e.g. NWSSOP 02.01.02 [34] for permit compliance, NWSSOP 40.07.01 [22] for ESC, SWESC and WAC governance, RSP 1.27 [35] for plant modifications and construction quality assurance for engineered works), and is complemented by records and data controls that ensure traceability. Through this framework, we demonstrate that the management system is effective across the end-to-end lifecycle and that the ESC and its underpinning evidence are consistently produced, implemented and maintained.	Management and Dialogue § 4.2, 5 and 6.1

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.	We operate an Integrated Management System and will continue to work under such a system throughout the Period of Authorisation. We control compliance with operational limits and conditions under our Permit (which replaced the former RSA 93 authorisation), via NWSSOP 02.01.02 [34] and the site Environmental Clearance Certificate for waste acceptance, capacity management and change control through our Integrated Management System. Our Integrated Management System includes the processes for systematic monitoring and assessment of radioactive discharges and environmental radioactivity including retrospective dose assessments and formal reporting to the Environment Agency (quarterly discharge returns and the '*Annual Monitoring Report/Programme Review*'). These arrangements ensure that operational compliance, environmental monitoring, dose evaluation and regulatory reporting are governed, auditable and demonstrably effective throughout the Period of Authorisation. We undertake prospective dose assessments to consider the impacts of discharges in the future.	Management and Dialogue § 5.1 Monitoring § 3.3 Environmental Safety During the Period of Authorisation § 4
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-	We plan and control all work that supports the ESC through our Integrated Management System and defined procedures, ensuring decisions, execution and records are auditable. NWSSOP 40.07.01 [22] governs	Management and Dialogue § 5.2 and 5.3

	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.	development and review of the ESC and the WAC, requiring documented assessment of new information, independent review and change control (including notification to the Environment Agency). Operational changes are managed under RSP 1.27 [35] via the Plant Modification Proposal (PMP) process, which mandates impact assessment, categorisation, authorisation and Management of Environmental Health and Safety Committee endorsement. Certain categories of PMPs require regulatory involvement, with full documentation and traceable records in SharePoint. All changes to the management system or key roles that could affect permit compliance are managed through the Management of Change process. These arrangements, complemented by permit-compliance controls (NWSSOP 02.01.02 [34]) and records management, demonstrate that planning, decision-making, doing the work and recording are rigorously controlled for all ESC-supporting activities.	
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.	We have arrangements in place to identify and mitigate potential hazards and events; hazards are identified and managed via hazard and operability studies and external-hazard assessments (including for flooding). Such events are also considered in our design. Operational modifications are controlled under RSP 1.27 [35] using the PMP process (impact assessment, categorisation, authorisation, MEHSC endorsement and	Management and Dialogue § 5.3.1 and 5.4 Engineering and Design § 2.5.4

		regulatory involvement) and any implications for the ESC are governed under NWSSOP 40.07.01 [22] with documented assessment and change control. When events occur, we sentence reports in OSHENS, convene a Learning and Action Review to agree corrective actions, implement and track them to closure, and, where relevant, assess and update ESC-related procedures.	
6.2.26	All work that supports the environmental safety case needs to apply sound science. The developer needs to be able to 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; and to maintain awareness of scientific developments, both within and outside the UK that may have a bearing on the environmental safety case for the facility.	We apply sound science across all work supporting the ESC: our SQEP team and specialist contractors make informed judgements on scientific quality, our conclusions are subjected to independent peer review and bias and uncertainty audits, and we commission timely investigations through our work programme where understanding needs to be strengthened. We actively maintain awareness of national and international developments through participation in IAEA networks and overseas programmes, benchmarking our methods and designs and integrating proven advances into our assessments and engineering decisions.	Management and Dialogue § 6.2 and 4.9
6.2.27	All work that supports the environmental safety case needs to follow good engineering practice.	We apply good engineering practice across all work that supports the ESC by designing for long-term passive safety, employing proven technologies and executing engineering to British, European and international	Management and Dialogue § 6.1 Engineering Design § 2.5.2 and 2.6.2

		standards. Our Integrated Management System has arrangements for construction management and implements construction quality assurance, independent checking by chartered engineers and post-construction validation; we also incorporate passive and active environmental safety measures (e.g. final engineered cap, cut-off wall, basal liners and leachate management). In addition, the Permit requires pre-operational construction quality assurance validation before disposals commence, ensuring our designs are optimised, checked and auditable throughout construction, operation and closure.	
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 engineering design is based on the use of robust technologies, many of them already used successfully at the LLWR or elsewhere. There are no significant novel technologies planned. New approaches are considered as part of optimisation assessments; we use 'confidence in performance' as a discriminator in optimisation studies. Options that could, in principle, perform well but for which construction could prove challenging, or for which the outcomes are uncertain or unpredictable − for example, where solutions are novel and with limited provenance − are typically not favoured. The process of selecting	Engineering Design § 2.1.1 Optimisation and Site Development Plan § 3.7

		technologies, and any trials performed to support the choices, would be documented.	
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.	Our Environmental Safety Strategy sets out the principle of reliance only on passive engineering controls after the Period of Authorisation on which our engineering design is based. Our '*Safety Functions*' report demonstrates the incorporation of passive safety measures into the engineering design of the LLWR. Our '*Assessment of Long-term Radiological Impacts*' relies on a combination of these passive measures and natural features and processes. Our assessment demonstrates that safety after the Period of Authorisation does not rely on human actions.	Main Report § 3 Management and Dialogue § 6.1.2 Engineering Design § 2 and 7 Safety Functions Engineering Performance Assessment § 3.4 Assessment of Long-term Radiological Impacts § 12.2
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. The '*Engineering Performance Assessment*' report provides conceptual models of engineering evolution and barrier degradation, and parameter values to inform our long-term assessments.	Main Report § 3.4 Engineering Performance Assessment § 6.3 Near Field § 3.2 and 3.4.2
6.2.34(a)	The developer/operator will be responsible for all information	All information generated by the ESC team is managed using a specific document control system and all ESC-	Management and Dialogue § 8 and 9

	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.	related information is logged and tracked within this system. All information relating to the ESC will continue to be managed and is considered to be 'live' information until the end of its local retention period. Following the expiry of the local retention period, our long-term management and archival requirements for these records will be followed. Our ESC is structured around the presentation of our safety arguments and the evidence that supports them. The Preface to the ESC sets out the documentation structure for the 2026 ESC. The provision of periodic updates of the ESC to the Environment Agency forms a key element of our formal provision of information arrangements. These reviews provide assurance that the LLWR continues to operate within the safety envelope defined by the ESC and that the ESC baseline remains current and complete. The Environment Agency may request copies of any reports referenced in the Annual, Periodic or Major ESC reviews. We submit the required reports and notifications under our Permit and Compilation of Environment Agency Requirements and manage regulatory correspondence through defined procedures.	Preface
6.2.34(b)	Technical information will need to be submitted in an agreed form that allows	The Preface to this report sets out the structure of the ESC documentation. The ESC comprises a Level 1	Preface

	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.	report that sets out the safety arguments, supported by a suite of Level 2 reports that provide the underpinning evidence. The ESC is supported by a suite of technical and scientific reports and references, collectively referred to as Level 3 documents. This hierarchical structure is consistent with that presented in the 2011 ESC. The data that underpin the ESC are included in our formal ESC data management system or documented in the report associated with the calculation.	Management and Dialogue § 7.2 and 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.	All information generated by the ESC team is managed using a specific document control system and all ESC-related information is logged and tracked within this system. All information relating to the ESC will continue to be managed and is considered to be 'live' information until the end of its local retention period. Following the expiry of the local retention period, our long-term management and archival requirements for these records will be followed. In addition to the information generated by the ESC team, we also rely on information owned and produced by other teams within NWS. We have reviewed the requirements and defined a set of information that we need to retain throughout the operation of the LLWR and beyond the period of authorisation. Alongside the ESC	Management and Dialogue § 9

		documentation, this information set includes monitoring information, inventory data and engineering drawings.	
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.	Within NWS, records are documents or other items containing information created, received, and maintained to support business activities or statutory obligations. We have identified records that are required to be retained for legislation, regulation, contractual and business reasons. These are listed on our '*Record Retention Schedule*' [26]. All information relating to the ESC will continue to be managed and is considered to be 'live' information until the end of its local retention period. Following the expiry of the local retention period, our long-term management and archival requirements for these records will be followed. In addition to the information generated by the ESC team, we also rely on information owned and produced by other teams within NWS. We have reviewed the requirements and defined a set of information that we need to retain throughout the operation of the LLWR and beyond the period of authorisation. Alongside the ESC documentation, this information set includes monitoring information, inventory data and engineering drawings.	Management and Dialogue § 9

6.2.37(c)	Duplicates of the records will need to be kept at diverse locations and in durable form.	All information relating to the ESC will continue to be managed and is considered to be 'live' information until the end of its local retention period. Following the expiry of the local retention period, records that need to be retained are sent to the NDA archive at the Nucleus facility in Wick.	Management and Dialogue § 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.	All information relating to the ESC will continue to be managed and is considered to be 'live' information until the end of its local retention period. Following the expiry of the local retention period, records that need to be retained are sent to the NDA archive at the Nucleus facility in Wick.	Management and Dialogue § 9
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.	Management arrangements are subject to a formal annual management review to assess its continuing suitability, adequacy, effectiveness, and alignment with the strategic direction of the organisation. Outputs from the review are submitted to the Nuclear Safety Committee. Our arrangements are certified to BS EN ISO 9001, ISO 14001 and ISO 45001. External audit is provided by Lloyd's Register Quality Assurance. Surveillance audits are undertaken every six months to confirm the continuing application of the standards, and a full recertification audit is carried out on a three-year cycle.	Management and Dialogue § 4.2.1, 4.2.2 and 7

		In addition, the Environment Agency and the ONR conduct their own audits of relevant elements of the management system.	
6.2.39(a)	Ensure that quality management arrangements are in place to ensure that all information can be traced back to its source.	Our Data Management Procedure [36] (operated under NWSSOP 40.07.01 [22]) mandates standard Data Management Forms to capture provenance, interpretation, recommended values, uncertainty treatment and references for data that are used in more than one assessment or supporting calculation; each Data Management Form is independently checked and approved, then indexed in a master register maintained in the ESC document control system. The data that underpin the ESC are included in our formal ESC data management system or documented in the report associated with the calculation.	Management and Dialogue § 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 included in our formal ESC data management system or documented in the report associated with the calculation. If requested, we can provide this data to the regulator.	Management and Dialogue § 7 and 8
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	An independent Peer Review Group (PRG) was in place during development of the 2026 ESC to provide independent review and technical challenge of the	Management and Dialogue § 4.9.3 and 8

	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.	programme, reviewing both the adequacy of the overall work programme and individual technical reports. The PRG operated to agreed Terms of Reference. The PRG provided written comments on the documents they reviewed, and we formally responded to the comments to indicate how these comments had been considered. The PRG has published a review of the 2026 ESC submission and we have produced a companion report in response, which outlines how we intend to address the technical points raised by the PRG in our future programme. These reports will be Level 3 reports.	
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.	Present day doses and modelled doses after capping is completed are less than the source- and site-related dose constraints. Modelled doses during future operations are dominated by external irradiation. Our assessment indicates that wastes with higher external dose rates than are currently received may arise in future. We will ensure that there is appropriate emphasis on the external irradiation pathway for off-site receptors in future design optimisation work. If waste with higher external dose rates does arise in future, our monitoring arrangements will enable us to identify any adverse trends and we would implement any controls needed to ensure that doses were below the dose constraints and were as low as reasonably achievable.	Environmental Safety During the Period of Authorisation

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.	The '*Environmental Safety During the Period of Authorisation*' report summarises our assessment of peak annual doses to potentially exposed individuals from all pathways they could feasibly be exposed to and combinations of these pathways. Present day doses and modelled doses after capping is completed are below the source dose constraint. Our site monitoring and management arrangements will ensure that doses are below the source- and site-related constraints and as low as reasonably achievable even if wastes with higher dose rates arise in future.	Environmental Safety During the Period of Authorisation § 4
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 assessed dose from direct radiation and from discharges. We sum exposures for different pathways to local individuals based on their habits. Present day doses and modelled doses after capping is completed are less than the source- and site-related dose constraints. During future operations, potential impacts from LLW are assessed as being below 0.3 mSv y^{-1}. If a decision were taken to accept ILW for disposal or if our monitoring indicated an adverse trend in dose rates from LLW, we would take action to ensure doses to offsite receptors remained as low as reasonably achievable. There are some other sources of radioactive contamination on the site, but these are associated with low inventory and are not likely to affect our conclusion. Therefore, the LLWR	Environmental Safety During the Period of Authorisation § 4

		does now, and will in future, comply with both the source-related and site-related dose constraints.	
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	During the Period of Authorisation, we operate a management system that provides proportionate control of operational discharges through our Environmental Clearance Certificate, with programmes agreed with the Environment Agency to monitor and assess discharges and environmental radioactivity; we report liquid effluent results quarterly and the full programme annually, notifying any significant event without delay. We conduct retrospective dose assessments and contaminated land risk assessments to support remediation and control. 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 also have agreed statistical 'flags' for unusual monitoring results, which are reportable to the Environment Agency under the Compilation of Environment Agency Requirements and trigger additional investigation by the monitoring team.	Management and Dialogue § 5.1 Monitoring § 5.4.2.3 Environmental Safety During the Period of Authorisation § 4 Environmental Safety During the Period of Authorisation § 5 Monitoring § 4 Monitoring § 4.4.2 Monitoring § 3.6

	(prospective assessments) and assessments based on the levels of radioactivity measured in the environment (retrospective assessments); • report this information to the regulator.	Our permit does not include limits on radioactive discharges, so we do not carry out prospective dose assessments based on discharge limits. We carry out prospective dose assessments based on a combination of monitoring data, modelling and potential future inventory.	
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.	Proposals for active institutional control after the completion of disposals will be finalised in consultation with stakeholders and the Environment Agency as site development and operation proceeds. Current plans are outlined in the '*Optimisation and Site Development Plan*' report.	Optimisation and Site Development Plan § 7.3 and 9
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.	We outline our plans for active institutional control in our '*Optimisation and Site Development Plan*' report. 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. The LLWR is a public asset and hence funding will be underwritten by the UK government.	Optimisation and Site Development Plan § 7.3 and 9

		We will maintain a SQEP capability to implement the activities required during the active institutional control period. Existing NDA strategies and NWS plans and internal procedures are already in place to ensure capability maintenance and succession planning, and these will be subject to further development as appropriate until the end of active institutional control.	
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. The period of active institutional control, after waste disposal finishes and final closure engineering is emplaced, is expected to last for one hundred years. Detailed proposals for this period have not yet been developed. Current plans are outlined in the '*Optimisation and Site Development Plan*' report. This includes plans for access controls and surveillance, monitoring and knowledge management. Necessary provisions will be finalised before closure.	Monitoring § 3, 4 and 7 Optimisation and Site Development Plan § 7 and 9
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	We have made estimates of the radiation doses and risks to potential representative persons after the Period of Authorisation, taking account of uncertainties in the performance of the disposal system, including expected and less likely future conditions. These dose and risk	Assessment of Long-term Radiological Impacts

	should be consistent with a risk guidance level of 10^{-6} per year (i.e. 1 in a million per year).	estimates are consistent with the risk guidance level of 10^{-6} per year.	
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.	Our approach is based on this definition. For coastal erosion, we have assumed that the there is a probability of one that the exposure will occur. For the gas and well pathways, we have estimated this probability for different situations. We compare assessment results from each pathway, the timing and location of impacts, and hence whether an individual could be exposed via multiple pathways.	Main Report § 4.5 Assessment of Long-term Radiological Impacts § 5, 6, 7 and 11
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 a dose-to-risk factor consistent with Health Protection Agency (now UK Health Security Agency) recommendations.	Assessment of Long-term Radiological Impacts § 2.13.3

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.	Estimated effective doses do not exceed 100 mSv per year.	Assessment of Long-term Radiological Impacts § 5 and 6
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. We present the mean risk and the risk for a range of percentiles.	Assessment of Long-term Radiological Impacts § 5, 6 and 7
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,	Our assessment models aim for a realistic representation of the system. When there are limited data or it is necessary to limit the complexity of the assessment model, cautiously realistic assumptions are made.	Assessment of Long-term Radiological Impacts

	conservative data and assumptions to be conservative can be chosen as long as the requirements are still shown to be met.		
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.	Assessment of Long-term Radiological Impacts § 5
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.	Assessment of Long-term Radiological Impacts
6.3.26(b)	Unquantifiable uncertainties (where, for example, it is not possible to acquire relevant data, or if acquiring enough	We have defined three scenarios that allow us to explore uncertainties in climate evolution and sea-level rise on assessed impacts: a low greenhouse gas emissions	Assessment of Long-term Radiological Impacts § 2.9

	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'.	scenario; a reference greenhouse gas emissions scenario; and a high greenhouse gas emissions scenario. These scenarios are underpinned by our work exploring environmental processes and their impacts. In our decision-making, most attention is given to the analyses of the reference greenhouse gas emissions scenario. The analysis of the alternative emissions scenarios is used to indicate that performance is robust.	
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).	It is highly uncertain whether a water abstraction well would be drilled between the LLWR and the coast. It is also highly uncertain whether people will occupy different regions of the cap and as a consequence receive doses from radioactive gases. We have undertaken numerical risk assessments for both of these situations. We have analysed the effects of human intrusion on repository performance. We have considered a 'what if' case in our groundwater assessment in which the repository is not disrupted by coastal erosion and sea-level rise. This case is analysed to indicate robustness of performance.	Assessment of Long-term Radiological Impacts § 5, 6, 7 and 8.7

		Other 'what-if' cases are considered in the various assessments.	
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 cautiously realistic exposure groups that are based on a narrative description of potential future human behaviours. We term the representative member of that group a potentially representative person (PRP).	Assessment of Long-term Radiological Impacts § 2.8
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.	Assessment of Long-term Radiological Impacts § 5, 6 and 7
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	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 PRPs is based on interpretation of the past and present-day observed habits in the region, together with consideration of local subsistence-based possibilities.	Assessment of Long-term Radiological Impacts Site History and Description § 3.3.9

	those of present-day populations should be assumed.		
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.	When defining habits for PRPs we consider both local and national generic habits information but are not constrained by this information if it is inconsistent with the narrative description of the PRP.	Assessment of Long-term Radiological Impacts § 2.8
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.	For the gas and groundwater pathways we do not consider that there could be combined impacts in relation to the Calder Extension Segregated Area (CLESA) on the Sellafield site. It is unlikely that peak impacts from erosion of the two facilities would coincide and we expect that impacts from erosion of CLESA would be smaller than those from erosion of the LLWR.	Assessment of Long-term Radiological Impacts
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	Our estimates of the radiation doses and risks to PRPs after the Period of Authorisation, 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.	Main Report § 4 Assessment of Long-term Radiological Impacts

	appropriate level of environmental safety is assured.		
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 into 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 Period of Authorisation 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. The minimum depth is controlled by the thickness of the final cap and the underlying profile fill. 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. We also plan to implement passive institutional controls and methods for preservation of knowledge and records of the site. We have used the outputs of our human intrusion assessment calculations to derive sets of controls applicable to all wastes and controls applicable only to containers in upper stack locations.	Assessment of Long-term Radiological Impacts § 8 Optimisation and Site Development Plan § 5 and 7.3 Engineering Design § 3 Implementation § 6.4

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. Events specifically associated with activities that might occur in the period during which the site is being eroded by the sea have also been considered. 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 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. In a supporting Level 3 document we present calculated doses from radon individually and aggregated with other exposures for relevant events. We also calculate the assessed doses arising from radon exposure following construction of a house with a basement that penetrates the cap.	Assessment of Long-term Radiological Impacts § 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 the Health Protection Agency (now the UK Health Security Agency) has stated that, for near-surface disposal facilities, the annual dose range of 3 to 20 mSv per year 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	Assessment of Long-term Radiological Impacts § 8

		injuries will not be exceeded by the doses we have calculated for human intrusion of the LLWR. Our human intrusion assessment also includes an assessment of absorbed doses to specific organs for the events that lead to the highest effective doses, which concludes that severe deterministic effects are very unlikely to occur.	
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 into the LLWR has been excluded from our evaluation of human intrusion events for assessment.	Assessment of Long-term Radiological Impacts § 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.	Assessment of Long-term Radiological Impacts § 8
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 for inadvertent human intrusion into the facility itself and deliberate interaction with the waste (e.g. deliberate interaction with exposed waste in the cliff face). We have considered the risk guidance level as the performance measure for all other calculation cases.	Assessment of Long-term Radiological Impacts § 8

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.	Optimisation and Site Development Plan § 5, 7.3 and 9
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 after the end of the PoA. A range of timescales associated with the climate change scenarios being considered in the ESC are included in the assessment e.g. up to the year 5775 AD in the main assessment. A 'what-if' case where coastal erosion does not occur explores the evolution of the hazard up to 100,000 years after present.	Assessment of Long-term Radiological Impacts § 8
6.3.48(a)	Human intrusion scenarios should be based on human actions that use technology and practices similar to	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	Assessment of Long-term Radiological Impacts § 8

	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.	technology and practices, and human habits and behaviour. This included consideration of events such as scavenging and material recovery, that are specifically associated with activities that might occur in the period during which the site is being eroded by the sea. Although we do not consider these events to be human intrusion, because they involve a human interacting with the waste (i.e. excavating, moving or re-using the waste) but without knowledge of the nature of the facility, we apply the same assessment criteria as for human intrusion events.	Site History and Description § 3.3.9
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	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 exposed in each case is small.	Assessment of Long-term Radiological Impacts § 8

	scenario considered should be substantiated as being reasonable and suited to the particular circumstances.		
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, where appropriate, we have calculated effective doses to those taking part in the intrusion event and to others exposed as a result of distribution of waste at the surface. We also calculate effective doses to those scavenging contaminated materials during coastal erosion of the LLWR. We have qualitatively considered the consequences of intrusion on the long-term performance of the disposal system. We have reviewed the distribution of the key radionuclides in the trenches and vaults, and considered heterogeneity in our assessment. An assessment grid that reflects our knowledge of the larger-scale spatial variability in radionuclide activities and waste volumes has been used. In addition, waste heterogeneity has been considered at smaller scales by specifically considering sealed sources, Discrete Items and particles.	Assessment of Long-term Radiological Impacts § 8 and 10 Disposal Facility Inventory
6.3.50	Present assessments of the radiation doses received by non-human organisms as a result of human intrusion into the facility and	We have not quantitatively 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	Assessment of Radiological Impacts on Non-human Biota § 4.3.2.7

	demonstrate that these are not at a level liable to cause significant harm to populations of such organisms.	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 Radiological Impacts on Non-Human Biota*' shows that the exposure of non-human organisms to waste released during coastal erosion will not lead to significant detriment to populations of non-human organisms.	
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.	Optimisation and Site Development Plan § 5 and 6.3 Implementation § 6.4 Assessment of Long-term Radiological Impacts § 8
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 set out specific activity limits to identify containers that require management under our emplacement strategy to control the doses that might be received in certain human intrusion scenarios. If a decision were taken to accept ILW for disposal, we would use specific activity limits derived from human intrusion scenarios to determine whether a consignment (of LLW or ILW) could be accepted for disposal.	Implementation § 6.4.3
6.3.54	Where there is a difference between practical measures to reduce the	We take no credit in our ESC for any reduction in the likelihood of the human intrusion events we model as a	Engineering Design § 3

	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.	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.	Optimisation and Site Development Plan § 5
6.3.55	Show that intrusion by non-human species, including plant species (for example tree roots), is not a significant issue.	Intrusion by non-human organisms would likely only affect a few individual organisms and would likely involve mixing waste and clean material. Therefore, impacts from such intrusion will be bounded by impacts during erosion of the repository. Moreover, the cap is designed to prevent the possibility of intrusion by burrowing animals and deep-rooted plants.	Engineering Design § 3 Assessment of Radiological Impacts on Non-human Biota § 4.3.2.7
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),	The optimised development of the facility is summarised in our '*Optimisation and Site Development Plan*' report. As an existing facility, the focus is on operations at the repository, and its further development and closure of the facility. For pre- and post-closure engineering optimisation, we have developed an approach that takes forward the concept and process established for the 2011 ESC, appropriately modified for each options study. The process is focussed on demonstrating that impacts are	Optimisation and Site Development Plan Implementation § 9

	taking into account economic and societal factors.	as low as reasonably achievable and reflects an iterative approach ensuring that options for part of the repository are considered within the wider context of the whole system and the overall optimised concept. We have used optimisation considerations identified through appropriate processes for wider aspects including (for example) monitoring, WAC, and emplacement strategies.	
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. As part of this we have developed an integrated team that works across NWS functions to ensure consistency of approach and a common understanding of optimisation priorities.	Optimisation and Site Development Plan § 2.5 Management and Dialogue § 2, 3 and 4.5
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 Site Development Plan*' report summarises our options assessment work. This work has involved the regulators and other stakeholders and has been made available inter alia through the development of the 2011 ESC, the planning application process, and the submission of the Improvement Condition 9 submission to the Environment Agency. Optimisation studies are ongoing, and publication of the 2026 ESC	Optimisation and Site Development Plan Management and Dialogue § 2, 3 and 4.5

		provides another vehicle for obtaining feedback on our work.	
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 Site Development Plan*' report. Decisions about use of the LLWR – in part reflecting national strategy, and in part detailed engineering questions – are addressed in our '*Optimisation and Site Development Plan*' report. We recognise that not all decisions can be made now, and that further research, monitoring and analysis are likely to be required to refine optimisation of facility management in the future.	Optimisation and Site Development Plan
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.	Our optimisation process explicitly recognises the importance of criteria related to confidence in performance given the range of plausible system performances and wider uncertainties. In doing so, it takes account of the understanding arising from aspects of the ESC such as (for example) the geological and hydrogeological conceptual and numerical models; our near-field understanding; assessments for relevant pathways including bias and uncertainty audits; our Engineering Performance Assessment, and other	Assessment of Long-term Radiological Impacts Main Report § 4.5 Environmental Safety During the Period of Authorisation § 4.4.3 Engineering Performance Assessment § 4

		relevant sources of evidence on uncertainty. This understanding is key to ensuring the options identified through optimisation processes are robust to remaining uncertainties. In addition, our Site Development Plan is flexible to accommodate any changes required as further information is gained in the future and uncertainties are progressively reduced. An example is the gas venting design, where we have identified appropriate assumptions for the ESC, but will continue to monitor the facility and its evolution to inform final decisions on the venting approach, including the potential for closure of venting arrangements in the future.	Optimisation and Site Development Plan § 3.6.1
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 '*Engineering Design*' report.	Engineering Design Optimisation and Site Development Plan
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	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	Optimisation and Site Development Plan

	options, recognise that the size of the population at risk is a relevant issue as well as the magnitude of individual risks.	forward a proposed set of management controls for future management of the LLWR.	
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 Site Development Plan*' report 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.	Optimisation and Site Development Plan
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.	

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 biota are not significant. Generally, dose rates are calculated to not exceed a cautiously low screening value. Some assessed screening dose rates exceed this value for direct and scattered radiation from uncovered vaults and during coastal erosion. However, considering factors including the areas affected by these dose rates, the time-dependency of the dose rates and the radiosensitivity of the exposed organisms, we conclude that they will not result in detrimental radiological consequences to populations of non-human organisms and thus, that the environment is adequately protected.	Assessment of Radiological Impacts on Non-human Biota
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	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 low compared to the screening value.	Assessment of Radiological Impacts on Non-human Biota

	updated. The extent and complexity of the assessment should be proportionate to the radiological hazard presented by the waste in the facility.		
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 quantitatively 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 Radiological Impacts on Non-Human Biota*' report shows that the exposure of non-human organisms to waste released during coastal erosion will not lead to significant detriment to populations of non-human organisms.	Assessment of Radiological Impacts on Non-human Biota § 4.3.2.7
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.	Hydrogeological Risk Assessment
6.4.2	A level of protection should be provided against non-radiological hazards that is no less stringent than would be	We have optimised the management, design and operation of the LLWR with respect to radiological hazards. These optimised measures ensure that the level	Hydrogeological Risk Assessment

	provided if national standards for disposing of waste that presents non-radiological hazards but not a radiological hazard were applied.	of protection provided by the facility is no less stringent than that required by nationally acceptable standards for the disposal of waste that present non-radiological hazards. Assurance is provided through monitoring and assessment calculations. Non-radiological standards have been considered to derive appropriate concentration measures for comparison with the results from our monitoring programme and assessment calculations. Non-radiological hazards are also controlled through our WAC, including through the use of total inventory limits.	Engineering Design Optimisation and Site Development Plan Monitoring Implementation § 7 and 8
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.	Hydrogeological Risk Assessment Optimisation and Site Development Plan
6.4.5	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	Our Hydrogeological Risk Assessment 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. Our design has been optimised with respect to	Hydrogeological Risk Assessment Monitoring Optimisation and Site Development Plan Engineering Design

	hazards and suited to the characteristics of the disposal system.	radiological hazards and the resulting optimised design and Site Development Plan will ensure that we limit, as far as is practicable, non-radiological impacts from the wastes. Non-radiological hazards are also controlled through our WAC, including through the use of total inventory limits. During the PoA, monitoring will provide assurance that the facility is performing as desired.	Implementation § 7 and 8
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.	Site History and Description § 3.3 Hydrogeology § 2.2 Site Evolution Monitoring
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.	The site investigation programme combined with the on-going monitoring programme is considered to have provided sufficient information to develop geological and hydrogeological conceptual models to support the assessment of the safety of the site. 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.	Hydrogeology § 2.2 Monitoring

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.	Hydrogeology § 3.4
6.4.8(b)	Assess the potential for, and effects of, dynamic processes such as seismic events and ground subsidence.	Potential ground accelerations have been considered in the developing the designs. Effects of other hazards of this type with effects during operations are considered as part of the Nuclear Safety Case.	Engineering Design Engineering Performance Assessment § 2 and 3
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.	Information on the understanding of the biosphere is provided in Level 2 ESC reports as follows. • Hydrological information is in the '*Hydrogeology*' report. • Understanding of climate change and erosion is in the '*Site Evolution*' report. • Understanding of exposed groups and habits is in the assessment reports;	Hydrogeology § 4.1.2 Site Evolution Environmental Safety During the Period of Authorisation Assessment of Long-term Radiological Impacts Assessment of Radiological Impacts on Non-human Biota § 2

		• The LLWR ecosystems are discussed in in the '*Assessment of Radiological Impacts on Non-human Biota*' report. Our assessment reports each demonstrate that there are no gaps in input data and that parameter choice is well justified.	
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 based on data gathered from local Cefas habits surveys and local knowledge of occupancy and land use in the area. These data are sufficiently comprehensive to allow our environmental safety assessments to define and represent receptors and their interaction with potential exposure pathways. Information on the understanding of the biosphere is provided in Level 2 ESC reports as follows. • Hydrological information is in the '*Hydrogeology*' report. • Understanding of climate change and erosion is in the '*Site Evolution*' report. • Understanding of exposed groups and habits is in the assessment reports; • The LLWR ecosystems are discussed in in the '*Assessment of Non-human Biota*' report.	Environmental Safety During the Period of Authorisation § 3.3 Assessment of Long-term Radiological Impacts Site Evolution Hydrogeology Assessment of Radiological Impacts on Non-human Biota

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 hydrogeology. This understanding has been used to optimise the design and management of the LLWR and to develop the models used in our assessments.	Hydrogeology § 4.2.3 Engineering Performance Assessment
6.4.10(b)	Consider features and properties of the site related to release and transport of radionuclides in the gas phase.	Atmospheric discharges during the PoA could affect receptors off site as a result of inhalation and uptake of radionuclides in crops that are consumed. After the PoA, gaseous releases could affect receptors that occupy areas closer to the source term because the site perimeter is no longer maintained. Annual doses have been assessed to candidate (near term) and potential (long term) representative persons who could feasibly be exposed via these pathways using conservative model assumptions and contributions to dose are shown to be well below the regulatory dose constraint. We have given consideration to aspects of facility design that may be required to mitigate the impacts of releases of radioactive and bulk gases.	Environmental Safety During the Period of Authorisation § 4.1.2 Optimisation and Site Development Plan Assessment of Long-term Radiological Impacts Engineering Design
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	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. The LLWR site has a	Hydrogeology § 3.4

	surroundings might be disturbed as a result. Consider the implications for the integrity of the disposal system.	licensed abstraction on site to provide water for dust suppression during capping work but there are currently no other 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 assessment of potential impacts during the Period of Authorisation includes a 'what-if' case of a well being sunk between the LLWR and the coast and used for drinking water. Our long-term safety assessment considers the potential impacts of a water well downstream of the facility and inadvertent intrusion into the facility during site investigations (among other kinds of intrusion event considered).	Environmental Safety During the Period of Authorisation § 4.3.3 Assessment of Long-term Radiological Impacts
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.	The 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.	Hydrogeology § 2.2
6.4.14	Site characterisation should involve investigating specific properties of the site and its surroundings in sufficient detail to support the environmental	Our site characterisation work and understanding of the site is summarised in the '*Site History and Description*', '*Hydrogeology*' and '*Site Evolution*' reports.	Site History and Description § 3.3 Hydrogeology Site Evolution

	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.	The '*Assessment of Radiological Impacts on Non-Human Biota*' provides a description of the types of ecosystems at the LLWR. Data from the environmental monitoring programme summarised in the '*Monitoring*' report 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.	Monitoring § 3.6.3 Assessment of Radiological Impacts on Non-human Biota § 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 engineering 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 2026 ESC. It has developed in the light of the substantial existing knowledge of the site to date and monitoring thereof. The design is subject to optimisation and must be consistent with a set of requirements developed within a Requirements Management System. The approach to design is iterative, taking account of assessments, monitoring data and the requirements and a programme of optimisation.	Hydrogeology § 2.2 Engineering Design § 2.7 Optimisation and Site Development Plan Implementation § 3.2
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.	Main Report § 3 Engineering Design Optimisation and Site Development Plan Implementation § 8

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 is outlined in our '*Engineering Design*' report. The design, operations and future management of the LLWR are kept as simple as possible while ensuring environmental safety. The rationale is described in the '*Optimisation and Site Development Plan*' report.	Optimisation and Site Development Plan Engineering Design
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 engineering design follows from extensive optimisation studies. The design was informed by detailed hydrogeological modelling, taking due account of the geology and associated uncertainties. The ESC establishes the types and the volumes of waste that can be safely disposed at the LLWR.	Optimisation and Site Development Plan Engineering Design Hydrogeology § 5 Implementation Disposal Facility Inventory
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. The LLWR is a surface facility. The disposal vaults and cut-off wall do not intrude far into the ground. Lessons learned from existing works, including construction of Vault 9, will be incorporated in the specifications and works for future vaults.	Engineering Design § 5
6.4.20(a)	Show that the geological conditions in each section of the disposal facility, as	The geology and ground conditions have been extensively investigated over many years. All the data	Engineering Design

	disturbed by construction, are suitable for the types and quantities of waste that it is proposed to dispose of in that section.	have been incorporated in a 3-D geological model. The LLWR is a surface facility. The LLWR engineering components have been designed to suit the ground conditions.	Hydrogeology
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.	In Vault 8, voids between stacks of waste in the vaults will be filled with free-draining granular material. For other vaults, where voids are large enough, we will fill those voids with free-draining granular material. The granular material will be inert and will not react with the wastes. The void fill will provide preferential flow paths for water around the waste stacks and will provide lateral constraints between the stacks. Cementitious grout also used to fill voidage within the containers. The grout provides important functions in our ESC, helping to establish chemical conditions in the vaults which will limit the mobility of key contaminants and providing a sorption substrate.	Engineering Design § 5.1 and 5.2.2.7 Near Field § 3 and 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	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. If required	Optimisation and Site Development Plan § 5.4.1 Engineering Design § 3.2.6 Implementation § 6.6 and 8 Assessment of Long-term Radiological Impacts § 9

	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).	Heat generation 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.	Environmental Safety During the Period of Authorisation § 4.9
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 operational and closed at the end of the Period of Authorisation; however, a final decision on vent closure does not need to be taken now. The final design will be informed on the basis of assessment results and options evaluation.	Optimisation and Site Development Plan § 5.4.1 Engineering Design § 3.2.6
6.4.23	Make plans for corrective action to deal with foreseeable geological or geotechnical problems which might	Vault 9 and future vaults have been or will be constructed to a rigorous system of Construction Quality Assurance. This approach provides good evidence of achieving the design and construction requirements and includes	Engineering Design § 2.6

	arise during construction, operation or closure.	identifying problems and taking corrective action to deal with foreseeable geological or geotechnical problems.	
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*' report 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 decision to cease waste emplacement and implement the closure engineering can be taken at any time. The first strip of cap to be constructed over Vault 8 will include a leading edge seal which will also cover part of Vault 9 and the existing containers therein. 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.	Engineering Design § 3 Engineering Performance Assessment § 5.2 and 7.1 Optimisation and Site Development Plan § 5.4.1
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	Not relevant as the LLWR is owned by the NDA.	

	authorisation are being and will continue to be fulfilled.		
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.	Following the development of the 2011 ESC, and with the agreement of the Environment Agency, we implemented revisions to our WAC and introduced controls ensuring the total safe capacities for radionuclides and other materials are not exceeded. 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. During the development of the 2026 ESC, we have reviewed our waste acceptance controls and proposed further changes. We will consult on changes to the WAC with the Environment Agency and the waste consignors.	Implementation
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.	The derivation of our waste acceptance controls includes all aspects of the waste that might impact on performance, including those relevant factors highlighted in the GRA requirement.	Implementation
6.4.29(a)	Include requirements in the acceptance criteria that ensure as far as reasonably practicable that all waste accepted for	Our WAC address a range of waste characteristics to ensure that the wastes received are passively safe during operations and subsequently, and the release of	Implementation § 4, 5.1.8, 7.4 and 7.5

	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.	radionuclides (and other substances) will be restricted in accordance with the assumptions in our ESC. In addition, waste containers are usually grouted before final disposal. Our WAC include restrictions on material types that could cause or enhance the effects of fires. Limits are placed on the external radiation level on the surface of a container. These, along with operational and engineering measures, ensure impacts are ALARA. Otherwise, resistance to heat and radiation is not considered to be a significant aspect for the wastes disposed at the LLWR. 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. Our ESC contains proposals for improving the structural integrity of wastes during final capping.	Optimisation and Site Development Plan § 4.3, 7 and 9.2.1 Engineering Design § 5.2
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 2026 ESC.	Implementation § 6.6 Environmental Safety During the Period of Authorisation § 4.9 Assessment of Long-term Radiological Impacts § 9

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 and capacity management arrangements are part of an overall waste acceptance process 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. Risk-based audits of consignors are also undertaken.	Implementation § 8
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 is reviewed periodically and tailored so that it continues to be appropriate to the stage of facility development.	Monitoring
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	We have taken a reasoned and proportionate approach to establishing our monitoring programme. 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	Monitoring

	parameters set out in the environmental safety case. However, the monitoring must not itself compromise the environmental safety of the facility.	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. It is a requirement that the monitoring programme must not compromise safety.	
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).	No pre-construction environmental monitoring data is available. However, 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 and to assess the impact of construction. The environmental monitoring programme at the LLWR is reviewed on a regular basis to ensure it is focused, fit for purpose and that provides the necessary data to support safety analyses and site management. Screening criteria have been identified in order to assess the impact of LLWR site operations, including disposals, on river water, surface water and groundwater taking into account background concentrations.	Monitoring § 3.6
6.4.34	Undertake radiological monitoring and assessment during the period of authorisation to provide evidence of	During the PoA, monitoring provides assurance that the LLWR is performing as expected. Monitoring data also	Monitoring § 5

	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.	provide a direct demonstration that the relevant 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.	Environmental Safety During the Period of Authorisation § 4 Hydrogeological Risk Assessment § 5
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.	The environmental monitoring programme has the following objectives: • To confirm that the repository system is not giving rise to unacceptable environmental hazards by direct measurement of its impacts. • To assess whether the repository system is compliant with the relevant environmental standards. • To develop and build confidence in the models of the repository system by collecting data that may be used to refine conceptual models or in model parameterisation, calibration or validation.	Monitoring

		- To define baseline conditions before specific engineering developments or activities, such as the construction of a new repository component (for example, a vault) or the disposal of wastes at a particular location. - To confirm that construction activities are not giving rise to unacceptable environmental hazards by direct measurement of their impacts. - To provide reassurance to stakeholders that the system is safe and is evolving in a manner consistent with the models and assumptions in the ESC. - To monitor and identify any impact of land contaminated by historical operations on groundwater and surface water. - To provide information needed to support the development of a WMP and SWESC. - To work towards a programme that provides technical confirmation of towards the site reference state (e.g. include validation monitoring outline plans).	
6.4.36	The monitoring programme should clearly set out the levels of specific contaminants that will trigger action. It	In order to review and assess the significance of data collected as part of the environmental monitoring programme, the following steps are carried out:	Monitoring § 3.6

	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.	• ‘Unusual’ data are identified by comparison to Unusual Data Identification Levels (UDILs). • Trends in the data are used to identify gradual adverse changes. • ‘Unusual’ data and adverse trends are assessed against performance measures, where required, in order to assess the significance of these data. • Where data are identified as exceeding relevant screening criteria, or following an unusual trend, this does not necessarily mean that operations at the LLWR site are impacting on the environment. It does, however, allow the significance of the results to be assessed and further investigation instigated where appropriate. • Screening criteria have been identified in order to assess the impact of LLWR site operations, including disposals, on river water, surface water and groundwater taking into account background concentrations. The current Low Level Waste Repository Assessment Standards (LLWRAS) were introduced during 2019/20 and are reviewed regularly. • Monitoring Assessment Levels (MALs) are used to assess the non-radiological impact of the LLWR site operations, including disposals, on	

		groundwater. In general, MALs are set at the LLWRAS or the level discernible above the background, whichever is higher. The discernible level has been calculated at the 95th percentile of the background dataset. The use of MALs will result in a reduction in the number of false positives.	
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. We implement a range of passive control measures that will persist beyond the PoA.	Management and Dialogue § 6.1.2
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.	The 2026 ESC addresses the regulatory guidance, as is demonstrated through the mapping in this table. The ESC is proportionate, with our assessments and technology focused on the most important features and hazards.	Management and Dialogue § 4.5.1
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	We hold a site licence from the ONR separately to the Environmental Permit from the Environment Agency. Compliance with both our nuclear site licence conditions and the conditions of our environmental Permit and the	Management and Dialogue § 5.3.1 and 5.4.1

	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.	GRA is overseen by our Environment, Safety and Security board committee and set out in our Management Prospectus.	
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 '*Hydrogeology*' and '*Site Evolution*' reports. Our understanding of the facility and its evolution is summarised in the '*Disposal Facility Inventory*', '*Engineering Design*', '*Near Field*' and '*Engineering Performance Assessment*' reports. The evolution of the disposal system as a whole is described in the '*Engineering Performance Assessment*' report.	Hydrogeology Site Evolution Near Field § 3 Engineering Performance Assessment § 6 Disposal Facility Inventory Engineering Design
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 environmental safety strategy 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). We have undertaken a safety function analysis to demonstrate the contribution of different barriers to repository safety.	Safety Functions
7.2.2	The environmental safety case should include an environmental safety	Our environmental safety strategy is the guide by which we evaluate and select a set of controls to arrive at an	Main Report § 3

	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.	optimised Site Development Plan, i.e. a Plan in which the environmental impact of disposals is ALARA. The environmental safety strategy 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 inventory, and protection and containment of the source inventory, with residual releases from the source inventory being managed and monitored.	
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*' 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. The reports have been reviewed during their development with the intention of ensuring consistency. We also work to an Assessments Manual [37] to ensure a consistent approach to assessments and we have a data management system to ensure the consistency of data.	Main Report § 4 Addressing Regulatory Requirements and Feedback − 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, 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 use of a register of uncertainties. For each assessment, we have undertaken an audit of those biases and uncertainties that are not treated in the assessment and have estimated their potential impact. This provides a pointer to potential future work and builds confidence that we have not overlooked biases or that could have a significant impact on calculated results. Where possible we have used monitoring data as an input or check on our assessments.	Environmental Safety During the Period of Authorisation § 4.11 Assessment of Long-term Radiological Impacts § 2.5 and 12.4 Hydrogeological Risk Assessment § 4 Reference [38]
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*' 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.	All Level 2 reports

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.	Site History and Description § 3 Hydrogeology Site Evolution Monitoring
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 '*Disposal Facility Inventory*' report. WAC and associated waste control arrangements are summarised in the '*Implementation*' report.	Disposal Facility Inventory Implementation
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.	Engineering Design
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	Our '*Main Report*' 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.	Main Report § 4

	quantitative, supported where appropriate by robust numerical analyses. The reasoning and assumptions should be clear and the evidence supporting them traceable.		
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 impacts on the public and the environment. For non-radiological contaminants we have calculated concentrations in groundwater and compared them with limits that take account of potential impacts to humans 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.	Environmental Safety During the Period of Authorisation § 4 Assessment of Long-term Radiological Impacts Hydrogeological Risk Assessment § 4 Assessment of Radiological Impacts on Non-human Biota
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. 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. Modelling of radionuclide migration post- authorisation, is described in the '*Assessment of Long-term Radiological Impacts*' report.	Near Field § 4 and 6 Environmental Safety During the Period of Authorisation § 4 Assessment of Long-term Radiological Impacts § 5

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 explore performance using three natural evolution scenarios; a high carbon emissions scenario, a low carbon emissions scenario and a reference emissions scenario. Within the reference scenario, we expect the LLWR to be disrupted by coastal erosion within a period of several hundred to a few thousand years. We also explore 'what-if' scenarios of accelerated ice-sheet collapse, and a scenario where the site will not be eroded for at least 100,000 years. Human intrusion represents a special set of cases that we also assess separately.	Assessment of Long-term Radiological Impacts § 2.5 and 12.4
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	The arguments for having confidence in our ESC are presented in the '*Main Report*'. 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 team is qualified and experienced and we have drawn on experience from our previous assessments of the LLWR and from assessments undertaken in other	Main Report § 4 Assessment of Long-term Radiological Impacts § 2 Management and Dialogue § 4.1, 4.2, 4.3, 4.8.2, 4.9.2, 4.9.3 and 7 Hydrogeological Risk Assessment § 4

	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.	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. Our analysis of uncertainties and audit of biases provide confidence that we have not overlooked or accounted for significant uncertainties or biases.	
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 2026 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 and non-radiological capacity of the LLWR.	Environmental Safety During the Period of Authorisation § 5 Assessment of Long-term Radiological Impacts Hydrogeological Risk Assessment § 4 Assessment of Radiological Impacts on Non-human Biota Optimisation and Site Development Plan § 9

			Implementation
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 developed our 2026 ESC against the guidance set out in the February 2009 GRA, which is being revised. Our ESC has been developed by specialists with state-of-the-art knowledge. We are involved in several national and international initiatives on LLW management and disposal, and our forward programme will ensure that the ESC remains consistent with future developments. The ESC is operated under formal change control under NWSSOP 40.07.01 [22]. The procedure includes requirements to conduct Annual, Periodic and Major reviews of the ESC, including Major reviews at greater frequency if there is significant 'new information'.	Management and Dialogue § 2.4 and 5.2.2
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 the 2026 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.	Management and Dialogue § 5.2.2
7.2.13	Updates to the environmental safety case should reflect growing knowledge about the site and should increasingly reflect the disposal facility as built and	The 2026 ESC provides a comprehensive update to the ESC. It reflects changes and developments since the 2011 ESC in government policy and NDA strategy as they affect the use of the site, knowledge of the site and	Main Report § 5

	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.	engineering performance, optimisation and engineering design, assessment modelling and techniques, feedback from the Environment Agency and from peer review, and knowledge gained from other programmes.	
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.	The 2026 ESC provides a comprehensive update of the ESC. Major changes between the 2026 ESC and the 2011 ESC are summarised in the relevant Level 2 ESC reports. Management of the development of the 2011 ESC prior to this latest major review and revision is described in the '*Management and Dialogue*' report.	Main Report § 5 Optimisation and Site Development Plan § 8 Assessment of Radiological Impacts on Non-human Biota § 4.7 Site Evolution § 3.7 and 4.3.10 Near Field § 1.3

			Disposal Facility Inventory § 2.5 and 6.6 Environmental Safety During the Period of Authorisation § 4.13
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*' is intended to be complete enough to satisfy stakeholders 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 Environment Agency. We have also produced Guide to the Key Points for the ESC. We will publish the ESC and the Guide to the Key Points 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 Main Report Guide to the Key Points
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.	We preserve the ESC documentation and all relevant records throughout development and the Period of Authorisation by managing them within a governed EDRMS, applying metadata, retention schedules and periodic Information Asset Owner reviews and by arranging long-term preservation through transfer to the Nucleus national nuclear archive. We also provide access to interested parties via structured submissions to	Management and Dialogue § 9

		the Environment Agency and established public channels (e.g. WCSSG open meetings and publications).	
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. Further decisions that need to be made are summarised in our '*Implementation*' report.	Main Report § 6 Implementation § 9.4
7.2.17(b)	Operational decisions and practices should be consistent with the environmental safety case.	We ensure that operational decisions and practices are consistent with the ESC by integrating the ESC into our management system, controlling it under NWSSOP 40.07.01 and implementing operational controls that explicitly reference and enforce ESC requirements. In practice, we use the '*Environmental Clearance Certificate*' and Waste Acceptance Criteria to govern site activities; we require ESC Manager approval for any consignment variations.	Management and Dialogue § 5.1 Implementation
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.	Changes to the WAC consistent with the 2011 ESC were proposed and implemented, with the agreement of the Environment Agency. The Agency issued a revised environmental Permit in 2015 requiring that the stated radiological capacity of the repository should not be exceeded. This capacity was derived from results of calculations made using the data and models of the 2011 ESC. Controls on waste emplacement consistent with the	Implementation § 9

		2011 ESC were also implemented. Further revisions to the WAC, capacity management and waste emplacement are proposed in the 2026 ESC. These revisions will only be implemented with the agreement of the Agency.	
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.	A fully integrated monitoring programme has been developed at the LLWR, which includes monitoring of discharges and the site and surrounding area. The ESC is a key input to the ongoing development of the monitoring programme.	Monitoring
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 identified the key barriers and controls and explained their functions in the '*Safety Functions*' report.	Safety Functions
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.	We have identified the key barriers and controls and explained their functions in the '*Safety Functions*' report.	Safety Functions

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 objective has been to design the facility so that the ESC does not unduly depend on any one of the safety functions. As demonstrated in the '*Safety Functions*' report, many impacts are robust against the loss of a key barrier. In cases where there is reliance on a small number of controls, we have considered whether there are any reasonable further steps that can be taken to mitigate impacts and where such have been identified, they have been incorporated in our plans.	Safety Functions
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 of individual barriers is explored in our Level 3	Near Field § 4.3, 6.5 and 6.6 Environmental Safety During the Period of Authorisation § 4 Assessment of Long-term Radiological Impacts Engineering Performance Assessment Safety Functions

		ESC assessment reports and summarised in the '*Safety Functions*' report. We consider the potential effects of the loss of one or more barriers or safety functions.	
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.	The '*Assessment of Long-term Radiological Impacts*' report summarises calculations of radiation doses and risks to potential representative persons 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.	Assessment of Long-term Radiological Impacts
7.3.6	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*'. 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.	Main Report § 4
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	Our long-term assessment models provide calculations of dose, environmental concentrations, and radionuclide fluxes. These results may be of interest, but do not	Assessment of Long-term Radiological Impacts Monitoring

	times, environmental concentration and radiotoxicity.	provide any assurance of safety beyond the direct calculation of radiological impacts. For certain impacts during the PoA, direct measurements of concentrations of contaminants in relevant media provide data that support our safety arguments.	Environmental Safety During the Period of Authorisation § 4
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	Our '*Main Report*' 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. 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*' to assess potential radiological impacts. Collective dose was not considered to be a useful discriminator in the option studies we have undertaken. We have considered extensively the processes whereby radionuclides are released from the waste form and transported through relevant barriers.	Main Report § 4 Assessment of Long-term Radiological Impacts Environmental Safety During the Period of Authorisation § 4

	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.	We have calculated concentrations in relevant environmental media. However, in general the radionuclides that dominate radiological impact are different from the radionuclides that dominate in the natural environment so comparisons are of limited utility.	
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 investigated a range of different uncertainties through the choice of different cases or through probabilistic calculations. We have taken uncertainties into account in our assessments and optimisation studies. 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. Consistent with the register, we have set out a programme of future work, which would entail the reduction of certain uncertainties.	Main Report § 6 Environmental Safety During the Period of Authorisation § 4.11 Assessment of Long-term Radiological Impacts § 2.5 and 12.4 Hydrogeological Risk Assessment § 4.1.6
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:	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;	Environmental Safety During the Period of Authorisation § 4.11 Assessment of Long-term Radiological Impacts § 2.5 and 12.4

	• 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.	• 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 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. For each assessment, we have undertaken an audit of uncertainties and biases. This is to consider the magnitude of uncertainties and biases that have not been addressed in the assessment models and determine their potential impact.	Hydrogeological Risk Assessment
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*' 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 the Environment Agency and government representatives. As such, it should be accessible to most stakeholders. We have also produced a Guide to the Key Points for the ESC.	Main Report § 7 Guide to the Key Points

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 safety assessments, namely scenario, model and parameter uncertainty. Through this division, we have accounted for both quantifiable and unquantifiable uncertainty.	Assessment of Long-term Radiological Impacts § 2.5 and 12.4 Environmental Safety During the Period of Authorisation § 4.11 Hydrogeological Risk Assessment § 4.1.6
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 recently updated our '*Radiological Handbook*' [39], the aim of which is to provide a reference for common radiological data across the range of exposure calculations undertaken in support of the 2026 ESC and future iterations of the ESC.	Assessment of Long-term Radiological Impacts Environmental Safety During the Period of Authorisation § 4 Assessment of Radiological Impacts on Non-human Biota § 4.4
7.3.15	Make clear which uncertainties have been quantified and applied to parameter values used in quantitative environmental safety assessments, and	We explain our approach to dealing with uncertainties in each assessment report.	Near Field § 8 and 9.1 Hydrogeology § 5.3 Site Evolution § 4.3.4

	the methods used for carrying out the calculations.	Our reports on '*Near Field*', '*Hydrogeology*', '*Engineering Performance Assessment*' and '*Site Evolution*' cover supporting modelling and summarise key uncertainties.	Disposal Facility Inventory § 6.5 Environmental Safety During the Period of Authorisation § 4.11 Assessment of Long-term Radiological Impacts § 2.5 and 12.4 Hydrogeological Risk Assessment § 4.1.6 Engineering Performance Assessment Assessment of Radiological Impacts on Non-human Biota § 4.6
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 set out the assumptions that we have made. Our assessment models aim for a realistic representation of the system. When there are limited data or it is necessary to limit the complexity of the assessment model, cautiously realistic assumptions are made.	Near Field § 8 and 9.1 Hydrogeology § 5.3 Site Evolution § 4.3.4 and 5 Environmental Safety During the Period of Authorisation § 4.11

		For each assessment, we have undertaken an audit of uncertainties and biases. This is to consider the magnitude of uncertainties and biases that have not been addressed in the assessment models and determine their potential impact.	Assessment of Long-term Radiological Impacts § 2.5 and 12.4 Hydrogeological Risk Assessment § 4.1.6 Assessment of Radiological Impacts on Non-human Biota § 4.6
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.	In our assessment, we explore performance using three natural evolution scenarios; a high carbon emissions scenario, a low carbon emissions scenario and a reference emissions scenario. 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 reference emissions scenario and inadvertent human intrusion events. We also explore 'what-if' scenarios of accelerated ice-sheet collapse, and a scenario where the site will not be eroded for at least 10,000 years.	Assessment of Long-term Radiological Impacts § 2.5 and 12.4 Hydrogeological Risk Assessment § 4.1.6
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	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 assessment models aim for a realistic representation of the system. When there are limited data or it is necessary to limit the complexity of	Assessment of Long-term Radiological Impacts § 8

	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.	the assessment model, cautiously realistic assumptions are made.	
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 2026 ESC is a major review and update to our ESC. The update addresses how our understanding of environmental safety has developed since 2011. 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.	Management and Dialogue § 5.2.2 Main Report § 6
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 site evolution. Details are provided in the referenced Level 3 supporting reports.	Near Field § 6 and 7 Hydrogeology Site Evolution § 4.3.4 Environmental Safety During the Period of Authorisation Environmental Safety During the Period of Authorisation § 4

			Assessment of Long-term Radiological Impacts Hydrogeological Risk Assessment § 4 Assessment of Radiological Impacts on Non-human Biota
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	Modelling objectives and approach are set out in individual Level 3 supporting reports. The ESC Level 2 reports provide context and a 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.	Near Field § 6 and 7 Site Evolution § 4.3.4 Environmental Safety During the Period of Authorisation § 4 Assessment of Long-term Radiological Impacts § 5.3, 6.3, 7.3 and 8.3 Hydrogeology § 5.1 Hydrogeological Risk Assessment § 4 Assessment of Radiological Impacts on Non-human Biota § 4

	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.		
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 discuss modelling objectives at an early stage with the Environment Agency through the process by agreement, submitting documents for regulatory assessment of approaches, methods and options as they are developed, and holding topic meetings and briefings to obtain feedback. This early dialogue is supplemented by regular liaison meetings.	Management and Dialogue § 2.2
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:	We have undertaken a systematic programme of modelling, building on the work done for the 2011 ESC. 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.	Management and Dialogue § 4.5.1, 4.9.3 and 7 Near Field § 6 and 7 Hydrogeology § 5 Site Evolution § 4.3 Environmental Safety During the Period of Authorisation § 4

	• 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 implemented a data management procedure to ensure consistency of data used in more than one calculation.	Assessment of Long-term Radiological Impacts § 2 Hydrogeological Risk Assessment § 4 Assessment of Radiological Impacts on Non-human Biota § 4

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, in conjunction with local habits surveys, 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 assess potential impacts during the PoA.	Near Field § 4.2.1 and 4.5 Hydrogeology § 5 Site Evolution § 4.2 and 4.3 Environmental Safety During the Period of Authorisation § 3.3 and 4 Assessment of Long-term Radiological Impacts § 2 Hydrogeological Risk Assessment § 4 Assessment of Radiological Impacts on Non-human Biota § 4
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	Near Field § 6.6 Hydrogeology § 5.3 Site Evolution § 4.3.4 and 5

		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 in the context of the groundwater assessment. Our hydrogeological modelling programme investigated potential sensitivities to alternative geological and hydrogeological interpretations. Our non-radiological assessment considered the same uncertainties as the radiological assessment of the groundwater pathway and included two models for contaminant release. Our non-human biota assessment reviewed available modelling approaches and selected the most appropriate. Our assessment of potential impacts during the PoA considered alternative scenarios including climate scenarios, institutional control period and early vent closure.	Environmental Safety During the Period of Authorisation § 4.5.6 and 12.4 Hydrogeological Risk Assessment § 4.1.6 Assessment of Radiological Impacts on Non-human Biota § 4 Reference [38]
7.3.26	Provide the basis for the judgements to end the programme of building	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	Main Report § 6

	confidence in the modelling, area by area.	evaluation of remaining uncertainties, their significance, and a judgement of whether further work is merited.	
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 applications. These are objectives in our model calibration, verification, and confidence-building process. Our procedure for managing assessments is now formalised in our Assessments Manual [37], which ensures that the standard is applied consistently.	Near Field § 6 Hydrogeology § 5 Site Evolution § 4.3.4 Environmental Safety During the Period of Authorisation § 4 Assessment of Long-term Radiological Impacts § 2 Hydrogeological Risk Assessment § 4 Assessment of Radiological Impacts on Non-human Biota § 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, gas, human intrusion pathways and impacts to non-human biota are concerned with the period until site disruption. We consider our quantitative modelling results to be informative for this period. For the groundwater pathway and human intrusion we considered a 'what-if' case in which the repository is not eroded. These calculations are stylised in character and	Assessment of Long-term Radiological Impacts Hydrogeological Risk Assessment § 4 Assessment of Radiological Impacts on Non-human Biota § 2.3

		provide an indication of how the hazard may evolve over long timescales.	
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 qualified and experienced such that they are able to make informed judgements about the quality of the science being applied in the ESC. ESC specialists have been recruited to the ESC 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 the ESC is provided by peer review.	Management and Dialogue § 4.5.1, 4.8.2 and 6
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	We present our approach to elicitation in our '*Elicitation Manual*' [40]. Our approach is carefully structured to minimise unconscious biases. Aspects of this include providing suitable training to experts at elicitation workshops and the use of a consensus-based approach intended to reduce the risk of expert overconfidence. We have carried out expert elicitations to parameterise the performance of those engineering components that are expected to be most important for isolation and containment. In particular, we have expended significant effort to elicit probability density functions characterising key uncertainties for the final cap (frequency of defects, the timing of the onset of brittle failure in the	Engineering Performance Assessment § 4.5 and 5 Site Evolution § 4.3

	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.	geomembrane and the hydraulic conductivities of the bentonite-enhanced sand layer). The resulting probability density functions are recorded in our *'Engineering Performance Assessment'* report. Further details, including the reasoning to support expert judgements, are provided in supporting Level 3 reports.	
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 2026 ESC.	Implementation § 6.6 Assessment of Long-term Radiological Impacts § 9 Environmental Safety During the Period of Authorisation § 4.9
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	We embed the effects of climate change throughout the ESC as part of the expected evolution of the system, rather than considering the consequences of climate change on a static system. We consider a range of scenarios; a high carbon emissions scenario, a low carbon emissions scenario and a reference emissions scenario, based on scenarios developed by the IPCC. We have used the latest climate science to derive parameters and characteristics relevant to the ESC such as precipitation and sea level, and used these in our	Site Evolution § 3 Assessment of Long-term Radiological Impacts § 2.9 Hydrogeology § 5 Environmental Safety During the Period of Authorisation § 4.5.6

	aquifers), changes in sea level, increased rates of erosion including coastal erosion, glacial cycling and glaciotectonic movements.	assessments. Glaciation will not occur prior to coastal erosion of the LLWR. In our PoA assessment, we use the high carbon emissions scenario in our reference case and assess the reference and low carbon emissions scenarios as alternative scenarios.	Hydrogeological Risk Assessment § 4
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.	Assessment of Long-term Radiological Impacts § 8
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 Site Development Plan*' report 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 '*Implementation*' report discusses WAC that make best use of the site, while ensuring safe operation and long-term environmental performance.	Optimisation and Site Development Plan Implementation

2.2 GRR Mapping Table

Table 2.2: Summary of how the requirements of the GRR are addressed as necessary in the 2026 ESC and supporting work programme

GRR ID	GRR requirement	How addressed	In ESC
A3.2	**Requirement R1: Optimisation of waste management options** Operators should use a proportionate process to select options, for managing radioactive waste arising from decommissioning and clean-up, that are optimised. This process shall ensure that the radiological risks to individual members of the public and the population as a whole are kept as low as reasonably achievable (ALARA) taking account of economic and social factors. The process should also consider the need to manage radiological risks to other living organisms and to manage the non-radiological hazards associated with radioactive waste.	We employ a proportionate, systematic process to optimise waste management over the lifetime of the site. Our processes consider when and how to clean-up radioactive contamination and the non-radioactive properties of radioactive waste. Our options assessment process considers all relevant factors across the waste lifecycle, working within the constraints of past land use and disposal decisions. It balances many considerations including worker safety, minimising waste generation and environmental effects. The process ensures that radiological risks to individual members of the public and the population as a whole are kept ALARA. Radiological risks to other living organisms are also considered. Our Waste Management Plan describes the processes and procedures that we implement to ensure optimal management of all site wastes.	Main Report Optimisation and Site Development Plan § 2 and 3 Waste Management Plan

A3.3	Employ a systematic process to select optimised waste management options for radioactive waste over the lifetime of the site. Considerations of contamination should be integrated into the wider optimisation process. Chosen options must enable the site to be released from RSR in accordance with GRR requirements.	We employ a systematic process to select optimised waste management options for radioactive waste over the lifetime of the site. The overarching framework for this process is set out in the '*Optimisation and Site Development Plan*' report, with details and examples in the '*Waste Management Plan*' report. Consideration of contamination is integrated into the wider optimisation process. Our work to enable the site to be released from RSR is explained in the '*Waste Management Plan*' report.	Optimisation and Site Development Plan § 2 and 3 Waste Management Plan
A3.4	Consider the non-radioactive properties associated with radioactive waste as part of the optimisation process, and address radioactive and non-radioactive hazards in an integrated manner when assessing radioactive waste management options.	We gather information on the non-radioactive properties of radioactive waste during the waste acceptance process. For in situ structures or contamination, we gather information on non-radioactive properties as part of site characterisation activities. Our monitoring programme also gathers relevant data on non-radioactive substances. Using this information, we consider the non-radioactive properties of radioactive waste as part of the optimisation process and address radioactive and non-radioactive hazards in an integrated manner when assessing radioactive waste management options. We achieve this through using a structured optioneering process within a multidisciplinary, integrated team.	Optimisation and Site Development Plan § 3 Waste Management Plan
A3.5	The optimisation process in the later stages of decommissioning has to work within the constraints of past decisions	Our optimisation process considers all relevant factors across the waste lifecycle and works within the constraints of past land use and disposal decisions.	Site History and Description § 2

	regarding design, construction and operation of nuclear sites. Developers of a new nuclear facility should ensure their plans take account of decommissioning, clean-up and waste management at all stages of the facility's lifecycle.	Future plans for site development, including potential new facilities are coordinated within the Site Development Plan.	Waste Management Plan § 4 Optimisation and Site Development Plan § 9
A3.6 – 3.7	Optimisation must balance many considerations, ensuring there are choices to be made between sufficiently different alternatives. The results should be presented to Regulators and made publicly available.	Our arrangements ensure a wide range of factors are considered and balanced throughout the optimisation process. The overarching framework for this process is set out in the '*Optimisation and Site Development Plan*' report, with details and examples in the '*Waste Management Plan'* report. We engage with stakeholders including regulators and the public and we make our assessments publicly available. Through the application of our processes, and our stakeholder engagement, we have established a well-founded SWESC.	Optimisation and Site Development Plan § 2, 3 and 4 Waste Management Plan Management and Dialogue § 2, 3 and 8 Main Report
A3.8 – 3.10	Consider all relevant factors in relation to the generation, treatment, packaging, storage, retrieval, and disposal of radioactive waste. Assess the impacts of different options, both local to and remote from site (e.g. doses to the	Our arrangements ensure a wide range of factors are considered and balanced throughout the optimisation process. These include consideration of: • the extent and manner of decommissioning and clean-up;	Optimisation and Site Development Plan § 4 and 9 Waste Management Plan

	workforce from handling waste for off-site disposal).	• the timing and sequencing of decommissioning and clean-up activities; • the resulting management requirements for radioactive and directive wastes; • whether wastes are to be disposed of on-site or consigned for disposal elsewhere. The overarching framework for this process is set out in the '*Optimisation and Site Development Plan*' report, with details and examples in the '*Waste Management Plan*' report. The impacts of different options are assessed whether local to, or remote from the site.	
A3.11 - 12	Implementation of decommissioning decisions should flow from an overall plan, which includes the WMP, for managing decommissioning, clean-up and site restoration.	Decommissioning, clean-up and site restoration decisions flow from an overall plan, which includes consideration of the WMP. We have developed an optimised Site Development Plan for the LLWR. The Site Development Plan helps to ensure that the site meets the government's policy objectives and the NDA's strategic objectives. The ESC demonstrates the safety of the Site Development Plan. The ESC also played an important role in the development of an optimised Site Development Plan. For example, the designs of the engineered disposal vaults and the final capping of the disposal facility were developed under the Environmental Safety Strategy for the LLWR set out in the ESC, along with the Site Development Plan. Optimisation is central to	Optimisation and Site Development Plan § 9 Waste Management Plan § 3 Management and Dialogue § 2.1

		decommissioning, clean-up and site restoration decisions; each will be set out in the Waste Management Plan and assessed in the context of the ESC, working iteratively with the Site Development Plan.	
A3.16 – 3.24	**Requirement R2. Waste management plan** Operators should prepare a waste management plan (WMP) to manage the programme of disposals of radioactive waste from their nuclear site, and implement the plan to achieve the site reference state.	Our '*Waste Management Plan*' report provides a structured account of current waste and contamination issues, the management arrangements in place, and the evidence base used to demonstrate environmental protection and Permit compliance. The Waste Management Plan is a 'live' product in that it signposts to maintained inventories, registers and monitoring systems that are updated on an ongoing basis. The Waste Management Plan includes our current understanding of: • existing waste; • waste anticipated to arise (including any waste generated from clean-up of ground and/or groundwater contaminated by radioactive substances); • waste in situ. It also includes procedures for updating our records as more knowledge is gained (e.g. through ongoing site characterisation activities) and forms an important part of the iterative process of progressive development, ongoing throughout the life of the LLWR.	Waste Management Plan

A3.25	**Requirement R3. Early engagement**. Operators should engage as early as possible with the relevant environment agency.	As an operating site for the disposal of Low Level Waste, we have a well-established process for regulatory interaction at the LLWR. After the review of the 2011 ESC, both we and the Environment Agency agreed that a more formal approach to recording reviews and positions would be beneficial for the next Major Review of the ESC. A 'process by agreement' is described in the GRA (Requirement R1), which allows the regulator to provide advice prior to the start of a formal regulatory process. Although the LLWR is an operational site to support the development of the 2026 ESC we agreed to follow such a process with the Environment Agency. We have engaged extensively with the Environment Agency in developing the 2026 ESC: we presented a forward programme of work, held structured liaison meetings, submitted technical documents for regulatory assessment, and adjusted our methods (e.g., climate projections and representative-person framework) in response to feedback.	Management and Dialogue § 2.2
A3.29	**Requirement R4. Engagement with local communities and others**	Stakeholder dialogue associated with the development of the ESC is undertaken within our established organisational framework for communications and stakeholder engagement. We also have a dedicated	Management and Dialogue § 3

	Operators should engage with local communities, ONR, the planning authority, other interested parties and the public on their developing WMP and SWESC.	Stakeholder Engagement and Communications Plan for the ESC. In practice, we engage regularly through the WCSSG and the associated Working Group, monthly meetings with Drigg and Carleton Parish Council, community drop-ins and site tours, and targeted briefings; these fora are used to share ESC updates, explain the ESC's role in maintaining long-term environmental safety at the LLWR and address questions raised by local representatives, regulators and the public.	
A3.30	Operators to engage widely in discussion of their plans to achieve the site reference state and their developing WMP and SWESC.	We undertake a significant programme of engagement activities to ensure all our stakeholders are aware of the activities on the LLWR site and to provide the information they require. These activities include: Attendance at the West Cumbria Sites Stakeholder Group and the NWS Working Group; Monthly meetings with Drigg and Carleton Parish Council; Community drop-in days; Site tours; NWS website: repository community page; Our 'On the Level' newsletter.	Management and Dialogue § 3 Optimisation and Site Development Plan § 2.5 Waste Management Plan § 4.4

		We also provide targeted briefings for national stakeholders and Non-governmental Organisations. Engagement is also an important part of our optimisation process. In addition to regulatory engagement, wider local stakeholder groups have also been specifically engaged, in particular for the optimisation processes ahead of the 2011 ESC that defined our current concept.	
A3.31	**Requirement R5. Environmental safety culture and management system** Operators should maintain a positive environmental safety culture appropriate to the activities being undertaken on-site 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) commissioning of appropriate research and development; (d) provision of information; (e) documentation and record-keeping (see	We plan and control work for permit compliance and ESC development under documented arrangements (including NWSSOP 40.07.01 [22]) and structured liaison with the Environment Agency. We apply sound science and good engineering practice through, for example, independent peer review, optimisation and controlled design and verification. We commission timely investigations through our work programme where understanding needs to be strengthened. We ensure timely provision of information to the regulator within an agreed documentation structure. We maintain robust documentation and record-keeping governed by our records policy and retention schedule. We operate formal quality management arrangements as part of our Integrated Management System that assures oversight, review and continuous improvement.	Management and Dialogue § 4, 5, 6, 7, 8 and 9 Engineering and Design § 2.5.2

	also Requirement R6); and (f) quality management.		
A3.32	Maintain a positive environmental safety culture, reflected in and reinforced by the management systems.	A positive environmental safety culture is embedded in our management system. Expectations are set through documented EHSS&Q arrangements that reinforce accountable behaviours. We have an established set of values, standards and expectations that are communicated to all employees. We ensure that suppliers meet the same standards by using our '*Contractor Lifecycle*' [23] and '*Management of Contractors*' [24] procedures and by assigning an Intelligent Customer to approve and oversee all ESC-related procurements. Learning and assurance is driven through OSHENS event capture and independent audits, so the culture is consistently reflected in, and strengthened by, the management system.	Management and Dialogue § 4.1, 4.4 and 4.8
A3.33	Management systems to be progressively adapted throughout the full lifecycle of the nuclear site, to ensure suitable corporate governance of the organisation until release from RSR.	Our management arrangements are subject to a formal annual management review, undertaken to ensure the adequacy, effectiveness and alignment to the direction of the organisation. The output of the review is submitted to the Nuclear Safety Committee. In addition to this, individual Process Owners undertake periodic reviews of their process to ensure they are current, appropriate and adequate.	Management and Dialogue § 4.2

A3.34	Management arrangements to show how environmental safety is directed and controlled, and how arrangements are kept 'live'.	Our '*Environmental Management Topic Manual*' [27], forming part of the Environmental, Health and Safety section of the Integrated Management System and supported by the relevant '*Organisational Manual*' [28], provides the framework for managing environmental risks and ensuring compliance with applicable legislation, including environmental permits and, where required, environmental enhancement obligations under the Energy Act. Underpinning the topic manual is a Permit Compliance Table [29], which documents the environmental permits applicable to our operations and supports compliance with relevant regulatory requirements. The management system is maintained through annual review and Process Owner reviews. The maintenance, version control and issue on 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.	Management and Dialogue § 4.2 and 9
A3.35	The management system should provide a level of control that is proportionate to the hazard and are fit for purpose across the lifecycle.	Our management system is structured as a hierarchy, where governance flows from high-level organisational standards through to site specific implementation. Our management arrangements are subject to a formal annual management review, undertaken to ensure the adequacy, effectiveness and alignment to the direction of the	Management and Dialogue § 4.2, 4.5.1 and 5.3

		organisation. The output of the review is submitted to the Nuclear Safety Committee. In addition to this, individual Process Owners undertake periodic reviews of their process to ensure they are current, appropriate and adequate. 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 we are implementing a risk-informed approach in line with Government Policy. Proportionality has been taken into account in our optimisation studies and decision making. As part of our management system, we apply a graded, risk-based approach to change control, tailoring the depth of assessment and approval to potential environmental and safety impact.	
A3.37 - 43	**Requirement R6. Preservation of knowledge and records at the time of release from RSR** Operators shall manage and retain adequate records of their site's journey	All information generated by the ESC team is managed using a specific document control system and all ESC-related information is logged and tracked within this system. In addition to the information generated by the ESC team, we also rely on information owned and produced by other teams within NWS. We have reviewed	Management and Dialogue § 9

	to completion of all planned work involving radioactive substances and also, where necessary, provide adequate records of the controls applied up to the site reference state being achieved along with the required validation monitoring data. Operators should provide these records in a form suitable for long-term preservation and access, and should propose arrangements for the long-term safe-keeping and management of the records.	the requirements and defined a set of information that we need to retain throughout the operation of the LLWR and beyond the period of authorisation. Alongside the ESC documentation, this information set includes monitoring information, inventory data and engineering drawings. Within NWS, records are documents or other items containing information created, received, and maintained to support business activities or statutory obligations. We have identified records that are required to be retained for legislation, regulation, contractual and business reasons. These are listed on the NWS Record Retention Schedule. All information relating to the ESC will continue to be managed and is considered to be 'live' information until the end of its local retention period. Following the expiry of the local retention period, records that need to be retained are sent to the NDA archive at the Nucleus facility in Wick.	
Technical Requirements			
A4.2 – 4.5	**Requirement R7. Site-Wide Environmental Safety Case**	Our ESC sets out claims concerning the environmental safety of the LLWR site, which we have substantiated by a structured collection of arguments and evidence. We believe it to be technically sound, comprehensive, robust,	Main Report Waste Management Plan

	Operators should maintain a site-wide environmental safety case (SWESC) to demonstrate that people and the environment will be adequately protected from ionising radiation and any associated non-radiological hazards, both before and after their site is released from RSR.	and also proportionate to the magnitude of the radiological and associated non-radiological hazards. The ESC in its entirety covers radioactive substances potentially remaining on and adjacent to the site and includes any ground or groundwater affected by contamination. It demonstrates that people and the environment will be protected from the radiological hazard and any non-radiological hazards associated with both radioactive waste and contamination. It addresses the present condition of the site and considers future evolution of the site without operator control, under a range of future climate scenarios. We have developed the ESC in close connection with the WMP and will maintain consistency between them. Our processes will ensure that we maintain the ESC and will provide it to regulators when required.	Management and Dialogue § 4.5
A4.6	The SWESC should specify the nature and duration of the validation monitoring that is needed after all planned work involving radioactive substances is complete.	Validation monitoring will be a targeted, confirmatory programme undertaken during Phase 3 (Active Institutional Control), building on the operational monitoring baseline and designed to obtain the evidence needed to confirm key SWESC claims and demonstrate the Site Reference State; it will continue until sufficient evidence has been gathered to support Permit surrender (i.e. evidence-led rather than time-fixed).	Waste Management Plan § 4.5 and 4.6 Monitoring

A4.7	The SWESC should demonstrate that members of the public and the environment will be adequately protected while work involving radioactive substances is still being done including events and faults.	The effects of events and faults that result in exposures during the PoA are addressed in the site's Nuclear Safety Case, as discussed in the '*Environmental Safety During the Period of Authorisation*' report. We also consider reasonably foreseeable events during surcharging and potential impacts from discharge to the Drigg Stream in an extreme storm event in the '*Environmental Safety During the Period of Authorisation*' report.	Nuclear Safety Case Environmental Safety During the Period of Authorisation § 4.2.3 and 4.10
A4.8	The SWESC need not be a stand-alone document, but can make reference to any documentation that provides evidence to support the case. However, there needs at least to be a top level, or signposting, document that provides a focus for the SWESC.	We have adopted an integrated approach in which the SWESC and the ESC are presented in an integrated manner within the '*Main Report*' (titled 'ESC' because the main focus of our presentation is the disposal facility) and eighteen Level 2 documents. The '*Main Report*' and this document provide signposting to the arguments and evidence that address regulatory guidance. As set out in this table, a Waste Management Plan has been added to the ESC document suite.	Main Report Addressing Regulatory Requirements and Feedback − this report
A4.9	The SWESC must support any application from the operator to make an on-site disposal of radioactive waste or to seek release from RSR.	No application for on-site disposal or for release from RSR is being made at this time. We propose to develop the SWESC iteratively, with detailed decisions that can support permit surrender at an appropriate point.	Waste Management Plan
A4.11	A constructed disposal facility must meet the requirements of the NS-GRA and will have its own environmental	Table 2.1 sets out how the requirements of the GRA have been met for the disposal facility. As explained previously, we have adopted an integrated presentation of the	Table 2.1 of this report Main Report

	safety case (ESC), which will define the waste acceptance criteria for the facility. The ESC for the disposal facility will provide a component of the wider SWESC for the site as a whole.	SWESC and ESC. How we implement waste acceptance criteria for the dedicated disposal facility is set out in the '*Implementation*' report.	Implementation
A4.12-13	**Requirement R8. Site characterisation and monitoring** Operators should carry out a programme of site characterisation and monitoring to provide information needed to support the WMP and SWESC. The programme shall include appropriate validation monitoring to provide technical confirmation that progress towards the site reference state is as expected or to validate that the site reference state has been achieved.	We have carried out an extensive site characterisation programme over many years and continue to collect data as part of site development and inform the WMP. The monitoring programme will be adapted through the facility lifecycle to provide sufficient validation monitoring to confirm the Site Reference State has been reached, consistent with SWESC assumptions.	Hydrogeology § 2.2 Waste Management Plan § 4.6 Monitoring
A4.14	Site characterisation and monitoring should establish sufficient understanding of the nature of the site and the hazards presented.	The site investigation programme combined with the on-going monitoring programme is considered to have provided sufficient information to understand the nature of the site and the hazards presented. Our programme of site characterisation supports our WMP by progressively identifying and characterising contaminated land and materials on the wider site that require management.	Hydrogeology § 2.2 Monitoring

A4.15	Site characterisation programme to also gather sufficient information to provide estimates of background radioactivity present at the site.	Since disposals were started before monitoring was undertaken, up-gradient monitoring has been used to establish background conditions. The focus of the Monitoring report is the dedicated disposal facility, however, the up-gradient background measurements are generally applicable across the whole site.	Monitoring § 3.6.3
A4.16	Operators should show that the biosphere is characterised, understood and capable of analysis to the extent necessary to support the SWESC.	Site understanding has been built up over decades of site monitoring (e.g. site ecological surveys, site weather station data, aerial photography). Site specific topography and hydrology have underpinned our assessments models.	Site History and Description § 3.3 Hydrogeology
A4.17	Knowledge of the site characteristics relevant to the SWESC is expected to increase progressively with time. Proportionate assessment of site characterisation and monitoring will be carried out in the context of an evolving SWESC.	We already hold extensive information relevant to the SWESC but recognise that optimisation is an iterative process founded on an increasing knowledge base. The environmental monitoring programme is reviewed annually to meet the needs of the SWESC. The WMP identifies knowledge gaps that guide future site investigation studies and monitoring coverage, ensuring characterisation and monitoring remain proportionate and aligned with an evolving SWESC.	Waste Management Plan § 3.2 Monitoring

A4.18-20	Establish a monitoring programme to provide data during the period of RSR and to support the SWESC. Provide evidence of compliance with the limits and conditions of the RSR permit and assurance of radiological protection of members of the public. Changes to the parameters monitored should be reflected in the SWESC.	The environmental monitoring programme is reviewed annually to ensure it continues to meet the needs of the ESC/SWESC, and that new monitoring information is assessed through established ESC reporting and review processes to determine whether updates (including to the WMP/SWESC) are required. It is further supported by Section 4.5 'LLWR Lifecycle Phases and the WMP' and Section 4.6 'Validation Monitoring', which confirm that monitoring continues through operations and the Period of Authorisation, including validation monitoring to confirm SWESC claims and support permit surrender. The detailed monitoring programme that provides evidence of RSR permit compliance and assurance of radiological protection of the public is presented in the Level 2 '*Monitoring*' report.	Monitoring Waste Management Plan § 3.2, 4.5 and 4.6
A4.21	The monitoring programme must set out clearly the levels of specific contaminants that will trigger action and adequate processes to subsequently follow. The monitoring programme must be reviewed in the event of any changes to decommissioning plans or subsequent change of uses of the site.	Assessment procedures are set out in the '*Monitoring*' report and include screening criteria, plus identification of unusual data and trends. Actions to take are described in our procedures and include notification requirements in compliance with our environmental permits (e.g. water discharge permit). The list of the current of LLWR Assessment Standards (LLWRASs) are provided in the '*Hydrogeological Risk Assessment'* report. The LLWRASs are reviewed annually and updated as required.	Monitoring § 3.6.3 and 2.1.2

		The environmental monitoring programme is reviewed annually to ensure it continues to meet the needs of the ESC/SWESC taking into account any planned changes to the site.	
A4.22	Assurance of environmental safety should not depend on monitoring or surveillance after release from RSR.	Environmental safety at the point of Permit surrender / release from RSR is demonstrated by achieving the Site Reference State, defined as meeting GRR risk/dose guidance levels without the need for ongoing controls/monitoring; monitoring during institutional control (including validation monitoring) is used only to confirm the safety case prior to surrender, not to provide continuing assurance thereafter.	Waste Management Plan § 4
A4.23-24	**Requirement R9. Dose constraints during the period of RSR** During the period of radioactive substances regulation the effective dose, from the authorised site to a representative person, shall not exceed a source related dose constraint and a site-related dose constraint.	The disposal area dominates the environmental hazard presented by the site, therefore, our SWESC is dominated by our ESC, which fulfils the requirements of the GRA. Dose constraints during the period of RSR are addressed in Table 2.1, under GRA Requirement 5: Dose constraints during the period of authorisation.	Table 2.1 (6.3.1 to 6.3.35) of this report
A4.25	The dose constraints place upper bounds on optimisation that apply during the period of RSR.		

A4.29	Operators, in accordance with their permit, should: • monitor and assess radioactive discharges from the site and levels of radioactivity in the environment; • have plans for action if monitoring suggests an unexpected release from the site; • 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).		

A4.30 - 32	**Requirement R10. Risk guidance level after release from RSR** Operators should demonstrate through the SWESC that, after release from RSR, the assessed risk from the remaining radiological hazards to a representative person should be consistent with a risk guidance level of 10^{-6} per year (that is, a risk of death or heritable defect of 1 in a million per year due to exposure to ionising radiation).	The disposal area dominates the environmental hazard presented by the site, therefore, our SWESC is dominated by our ESC, which fulfils the requirements of the GRA. Dose constraints after release from RSR are addressed in Table 2.1, under GRA Requirement 6: Dose constraints after the period of authorisation. We have not completed the site-wide optimisation that would determine what may be proposed to remain on site but these requirements from the GRR have been captured in our management system. Any residual radiological hazards remaining after release from RSR will be consistent with the risk guidance level.	Main Report Waste Management Plan
A4.33	The risk guidance level applies to assessed risks from radioactive substances dispersed in the accessible environment (arising from radioactive waste or radioactive contamination) due to the migration or uncovering of radioactive substances by natural processes. The period for assessing these risks should be chosen to ensure that peak risks are considered.	The disposal area dominates the environmental hazard presented by the site, therefore, our SWESC is dominated by our ESC, which fulfils the requirements of the GRA. We have not completed the site-wide optimisation that would determine what may be proposed to remain on site but these requirements from the GRR have been captured in our management system. See Table 2.1 for information on how we have addressed similar requirements derived from the GRA in assessing the impact of our disposal area. The WMP sets out our current understanding of the site but no proposals for leaving any radioactive waste in situ or for leaving contamination in place are being made at this time.	Main Report Waste Management Plan
A4.34	The assessed 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.		
A4.35	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 tissue reactions), a risk coefficient of 0.06 per Sv should be used. The risk coefficient is only appropriate when considering risk to populations not individuals. This corresponds to recommendations set out in advice given by PHE in its publication on the disposal of solid radioactive waste (HPA, 2009).		

A4.40 A4.37 – A4.41	*Risk Assessment* Risk assessments should generally be realistic or represent best estimates of the system behaviour. However, where the data do not support this approach or where the assessment can usefully be simplified, operators may choose some data and assumptions to be conservative as long as the requirements are still shown to be met.	The disposal area dominates the environmental hazard presented by the site, therefore, our SWESC is dominated by our ESC, which fulfils the requirements of the GRA. We have not completed the site-wide optimisation that would determine what may be proposed to remain on site but these requirements from the GRR have been captured in our management system. See Table 2.1 for information on how we have addressed similar requirements derived from the GRA in assessing the impact of our disposal area. Any residual radiological hazards remaining after release from RSR will be consistent with the risk guidance level.	Main Report Management and Dialogue § 4.5.1 and 6.2 Waste Management Plan
A4.42 - 48	*Uncertainties*		
A4.49-50	*Representative persons*		
A4.51	If two or more separate nuclear sites present significant risks to the same representative persons, consideration should be given to the combined risks to those representative persons. The operators of such separate sites should communicate and cooperate as SWESCs and WMPs are developed. This will require careful co-ordination and forward-thinking, especially in circumstances where operations	In preparing our first iteration of the SWESC, no proposals for leaving any radioactive waste in situ or for leaving contamination in place are being made. The disposal area of the LLWR dominates the environmental hazard presented by the site, therefore, we have conducted our assessments in line with the requirements of the GRA. This requirement from the GRR has been captured in our management system. At the point when we are planning for any on-site disposals (outwith the dedicated disposal facility), proposing to leave contamination in situ or	Management and Dialogue § 3 and 4.9 Waste Management Plan

	involving radioactive substances at one site may be ongoing, whilst such operations may have been completed at a nearby site. An unacceptably large total for the assessed risks from different nuclear sites affecting the same representative person at the same time could indicate an unacceptably large assessed risk from one or more of the sites taken individually.	applying for surrender of the permit, we will assess combined risks as appropriate.	
A4.56	**Requirement R11. Inadvertent human intrusion dose guidance level after release from RSR** Operators should assess the potential consequences of inadvertent human intrusion into any local concentrations of radioactive substances on the site after release from radioactive substances regulation. The assessed effective dose to a representative person during and after the assumed intrusion should not exceed a dose guidance level in the range of around 3 millisieverts per year (3 mSv/y) to around 20 millisieverts in total (20	The disposal area dominates the environmental hazard presented by the site, therefore, our SWESC is dominated by our ESC, which fulfils the requirements of the GRA. We have not completed the site-wide optimisation that would determine what may be proposed to remain on site but these requirements from the GRR have been captured in our management system. See requirement R7 of Table 2.1 for information on how we have addressed a similar requirement from the GRA in assessing the impact of our disposal area. Assessments of the consequences of inadvertent human intrusion into any local concentrations of radioactive substances on the wider site after release from RSR will be made at the appropriate time. We expect the impacts to be low.	Management and Dialogue § 4.9, 5.3, 6 and 8 Waste Management Plan § 4

	mSv). Values towards the lower end of this range are applicable to prolonged exposures, while values towards the upper end of the range are applicable only to transitory exposures.		
A4.75	Assessing the consequences of inadvertent human intrusion on people. For each defined location of radioactive waste or contamination remaining after RSR, operators should assess the potential exposures to people that might arise from a range of possible inadvertent human intrusion scenarios.		
A4.79	Present assessments of radiation doses to representative individuals both undertaking the intrusion and occupying or using the site or its locality afterwards. Also explore the consequences of intrusion in a wider geographical sense and on the long-term behaviour of the site after disturbance in this manner.		
A4.80	Assessments should also take into account radioactive articles that people		

	might encounter as a result of inadvertent human intrusion. Consider the possibility of ingestion or inhalation as appropriate.		
A4.81	Assessments should show that dose thresholds for tissue reactions are unlikely to be exceeded as a result of inadvertent human intrusion.		
A4.82	Use the results from the inadvertent human intrusion scenarios above as part of optimising on-site disposals and clean-up of contamination.		
A4.84-91	**Requirement R12. Natural disruptive processes after release from RSR: application of risk guidance level and dose guidance level** Operators should show in the SWESC that people will be adequately protected in the case of natural disruptive processes which expose radioactive waste or contamination, or impair protective barriers after the site is released from RSR.	The disposal area dominates the environmental hazard presented by the site, therefore, our SWESC is dominated by our ESC, which fulfils the requirements of the GRA. We have not completed the site-wide optimisation that would determine what may be proposed to remain on site. At the point when we are planning for any on-site disposals beyond the dedicated disposal facility, proposing to leave contamination in situ or applying for surrender of the permit, we will assess the impacts from natural disruptive processes. These requirements from the GRR have been captured in our management system.	Main Report Management and Dialogue § 4.5, 5.4 and 6 Waste Management Plan

A4.92-96	**Requirement R13. Optimisation of on-site disposals** Operators shall, through a process of optimisation, ensure that the radiological risks to individual members of the public and the population as a whole, from the on-site disposal of radioactive waste, are kept as low as reasonably achievable (ALARA) taking into account economic and social factors. Radiological risks shall be optimised throughout the period of radioactive substances regulation and afterwards, as far as can be judged at the time when relevant actions are taken. The process should also consider the need to manage radiological risks to other living organisms and to manage the non-radiological hazards associated with radioactive waste.	The only disposal being undertaken or proposed at this time is within the dedicated disposal facility so GRR Requirement R13 does not apply at this time. If in the future on-site disposal is proposed, optimisation will be applied as set out in R13. This requirement from the GRR has been captured in our WMP and management system.	Waste Management Plan
A4.97-101	**Requirement R14. Protection of the environment** Operators shall assess the radiological effects of the site on the environment	See Table 2.1, Requirement R9 which maps to our assessment of impacts to non-human biota arising predominantly from the disposal facility. We have not assessed impacts from contaminated land and other	Table 2.1 (Requirement R9) of this report Main Report

	with a view to showing that all aspects of the environment are adequately protected, both during the period of, and after release from, RSR.	potential on-site wastes to non-human biota. The methodology in our '*Assessment of Radiological Impacts on Non-human Biota*' report will be relevant to such assessments when they are undertaken. We expect impacts from the wider site to be low compared with the impacts arising from wastes disposed to the dedicated disposal facility.	Assessment of Radiological Impacts on Non-human Biota
A4.102	**Requirement R15. Protection against non-radiological hazards** Operators shall bring their site to a condition at which it can be released from radioactive substances regulation, through a process that will protect people and the environment against any non-radiological hazards associated with the radiological hazards both during the period of, and after release from, radioactive substances regulation. The level of protection should be consistent with that provided by the national standard applicable at the time when relevant actions are taken.	No proposals for leaving any radioactive waste in situ or for leaving contamination in place are being made at this time. At the point of making site-wide optimisation decisions, the non-radiological hazards associated with the radiological hazards both during the period of, and after, release from RSR, will be considered. Our site characterisation processes already capture relevant information, as does the site monitoring programme. This requirement from the GRR has been captured in our WMP and management system.	Main Report Waste Management Plan Monitoring Hydrogeology Management and Dialogue § 4.2.1.3 and 5.4

2.3 Forward Issues Mapping Table

The principal source of information on how each Forward Issue has been addressed can be found in the corresponding Forward Issue Proformas, which summarise each response and signpost to the relevant underlying documentation.

Table 2.3: Forward Issues raised by the Environment Agency following their review of the 2011 ESC

Reference	Title and Summary of FI	How addressed
ESC-FI-001	**Cap settlement issues:** Develop and implement a work programme to identify an optimised cap design and container stack heights.	We have developed an optimised cap design and are implementing it in line with our repository capping programme. Container stack heights and cap settlement issues were addressed within reference [41].
ESC-FI-002	**Tritium monitoring and establishment of trigger and action levels:** Continue to monitor tritium throughout the period of authorisation in line with our requirements outlined in this FI.	Tritium is monitored as part of the ongoing monitoring programme. We continue to analyse monitoring results to better understand the trench inventory and its fate and transport in the environment.
ESC-FI-003	**Revised borehole fire assessment:** Present a 'what if' assessment of a deep-seated fire occurring during the construction or operation of a borehole drilled into trench waste.	We have considered establishment of new monitoring points into the trenches, concluding that we will not drill into the waste and have maintained some probe-holes as monitoring points. If we reconsider this decision in the future, further consideration of fire risk will be undertaken. Further work has also been done to address this Forward Issue for the post-PoA period [42].

ESC-FI-004	**Forward programme:** Further develop and update the forward programme of work to make sure there is continued improvement of the ESC.	To address this Forward Issue, we submitted our Technical Development Programme to the Environment Agency in February 2019. The following two references supported the Technical Development Programme as submitted: [43, 44]. Our management arrangements ensure we have systems in place to apply continual improvement to the ESC (e.g. assessment of new information forms, R&D work). Our management and development process for the ESC [22] allows us to respond effectively to lessons learnt. Whenever we receive new information or insights, such as significant changes in monitoring results or repository site data, we assess their implications and integrate them into our development programme where appropriate.
ESC-FI-005	**Use of monitoring to reduce uncertainties in the ESC:** Collate and integrate monitoring objectives, strategies and procedures in a single document, so as to provide evidence of how the forward monitoring programme will be implemented and developed throughout the PoA and linked to the ESC to reduce uncertainties.	We have collated and set out our monitoring objectives and strategies, with signposting to our monitoring procedures, which form part of our management system. We make clear how the ongoing monitoring programme is to be implemented and acted upon throughout the PoA. The monitoring programme is an important part of the ESC and helps to reduce uncertainties. Our management and development process for the ESC ensures we respond effectively to lessons learnt. Whenever we receive new information or insights, such as significant changes in monitoring results or repository site data, we assess their implications and integrate them into our development programme where appropriate.

ESC-FI-006	**Non-radioactive groundwater assessment reporting:** Update the hydrogeological risk assessment for the LLWR for issue by December 2017.	We updated the Hydrogeological Risk Assessment as required by the Forward Issue [45]. This Forward Issue was closed by the Environment Agency in March 2024. A further updated Hydrogeological Risk Assessment forms part of the 2026 ESC.
ESC-FI-007	**Inaccessible voidage minimisation procedures and emplacement strategies:** Have appropriate procedures in place to make sure that potential container settlement remains within acceptable limits and that placement is optimised.	Container settlement and optimised placement were addressed for this Forward Issue. The formal response to the Agency is reference: [46]. Voidage within waste consignments is a parameter that is controlled by our waste acceptance procedure. In our optimisation and engineering design, we have considered the potential for voidage and the necessity of expressing voidage prior to installation of the final cap over committed wastes.
ESC-FI-008	**Management of uncertainty:** Further develop the FEPs and uncertainty tracking system (or alternative tools) as a tool to manage uncertainty in the ESC and feed into the forward programme.	Each of the assessments used in the development of the 2026 ESC have included a FEP audit, as well as a bias and uncertainty audit. We have also developed a Register of Significant Uncertainties, which is maintained as a tool to manage key uncertainties in the ESC. It informs our forward work programme to address uncertainties.
ESC-FI-009	**EDTA analysis to support the complexant assessment:** Undertake further work to underpin	In response to this Forward Issue, the following references were submitted to the Environment Agency: [47, 48].

	the conclusions of assessment of complexants such as EDTA. Continue to improve knowledge of complexants leaching from the trenches and the vaults and the risk thereof via the groundwater pathway.	We have included the effects of complexants on contaminant mobility in our assessment of radiological and non-radiological impacts via the groundwater pathway.
ESC-FI-010	**Waste heterogeneity in Vault 8 and future vaults:** Undertake further work to understand the distribution of key radionuclides and key materials in Vault 8 and future vaults. Demonstrate via the ESC understanding of the distribution of these species and materials in the vaults.	In response to this Forward Issue, the following was submitted together with the 2026 ESC: [49]. The following assessment investigates the distribution of key radionuclides and materials in Vault 8 and explores the consequences of sub-vault heterogeneity on human intrusion doses assessed: [50].
ESC-FI-011	**Forward review of the extended disposal area:** Fully integrate the EDA assessment into the ESC at the next periodic review of the ESC.	This Forward Issue was closed by the Environment Agency in March 2020. The EDA is no longer part of the facility design. We have made considerable effort in improving the alignment of the major review of the ESC with UKRWI information and understanding the nature and timing of wastes destined for the LLWR. Environment Agency noted in its response that significant uncertainties associated with waste generation and decommissioning timings remain in the UK nuclear industry. The 2026 ESC includes an assessment of future waste inventory applicable to LLWR site disposal.

ESC-FI-012	**Use of probabilistic calculations in derivation of radiological capacity:** Consider update of the probabilistic groundwater pathway assessment model and as appropriate recalculate radiological capacity calculations based on the expectation value of the model output.	We have updated our groundwater assessment model taking into account developments in our understanding of the near field and hydrogeological conditions at the LLWR. We have carried out probabilistic calculations using the updated assessment model. These probabilistic calculations have been used to demonstrate the robustness of system performance with respect to parametric uncertainty. We have calculated radiological capacities using the expectation value of the assessed risks.
ESC-FI-013	**Assessment of discrete items in stored and disposed waste:** Review the disposed records for stored waste located in Vault 8. LLW Repository Ltd should provide a BAT case for disposal of these items within Vault 8.	This Forward Issue was closed by the Environment Agency in March 2024, following submission of references [51, 52].
ESC-FI-014	**Impact of changing waste composition:** Assess the implication of future waste treatment processes on the settlement of the engineered cap and on the performance of the near field.	This Forward Issue was closed by the Environment Agency in March 2024. Material composition information is gathered as part of our Waste Acceptance Process, and controls are applied to avoid receipt of materials not meeting the WAC. The WAC places restrictions on Total Potential Voidage to ensure that cap settlement remains within acceptable limits. We maintain a pro-active and responsive approach to identifying and managing changes to forecast waste compositions, waste treatment practices and their effects on near-field

		assumptions in the ESC. The basis for our assumptions on future waste compositions is, and will continue to be, the latest version of the UK Radioactive Waste Inventory (UKRWI). Our near-field modelling applies our best understanding of waste composition, and the Engineering Performance Assessment explores the evolution of the facility.
ESC-FI-015	**Monitoring of colloids:** Implement a proportionate colloidal material monitoring programme, to ensure that the conclusions reached in the 2011 ESC will remain valid.	Our response is set out in reference [53].
ESC-FI-016	**Discretisation of the Generalised Repository Model (GRM):** Assess the sensitivity of the outputs from the GRM to the discretisation of the model grid.	Since the 2011 ESC, near-field modelling has moved from the GRM to PFLOTRAN. The updated model suite for the 2026 ESC near field modelling includes a site-scale model, vault-scale models and a package-stack model. This sequence of models will allow much finer scale discretisation than was possible with the 2011 GRM assessment, allowing processes at different scales to be examined. We sent a response to this Forward Issue in February 2025.
ESC-FI-017	**Radiological capacity calculations:** Explore the relationship between disposed inventory and dose or risk to determine the suitability of the linear relationship assumption. Particular emphasis should be placed on C-	In response to this Forward Issue, the following was submitted to the Environment Agency: [54]. This work demonstrated that it is appropriate or cautious to assume a linear relationship between the disposed inventory to the LLWR and the associated impacts. One potential nonlinearity was identified regarding the risks from the groundwater pathway in relation to solubility-limited radionuclides. However, any optimistic bias in the calculation of radiological capacity is avoided by assuming

	14. If required, outputs should be fed into the WAC.	that there is no solubility limit. We also noted potential nonlinearities regarding the association of radionuclides with different types of waste, most significantly for C-14-bearing wastes, where an assumed distribution of C-14 between different wasteforms is used to calculate the radiological capacity.
ESC-FI-018	**Near field vault and trench experimental programme:** Propose and implement a near field experimental and monitoring programme capable of providing sufficient understanding of the vault and trench near field environments to support the ESC throughout the PoA.	In response to this Forward Issue, the following was submitted to the Environment Agency: [55]. The scope of the experimental programme has since changed due to technical and practical reasons, but we have undertaken a programme of small-scale trials, and we are in the process of refining the design of an experimental system that will run for approximately two years.
ESC-FI-019	**Monitoring of coastal erosion:** Develop and implement a coastal evolution monitoring programme. The company should use the output to check assumptions made within the 2011 ESC and to inform continued development of the ESC.	In response to this Forward Issue, the following was submitted to the Environment Agency: [56] We have undertaken coastal inspections as part of our monitoring programme.
ESC-FI-020	**Development of a new Low Level Waste Tracking System (LLWTS):** Develop a new waste tracking	We have established a new waste tracking system, which: • enables accurate tracking of waste disposals;

	system that is fit for purpose for future waste tracking.	• improves the management of waste acceptance; • addresses limitations in the legacy tracking systems, which were prone to errors and inefficiencies. The Environment Agency officially closed ESC-FI-020 in March 2024, indicating that the development objectives had been met or sufficiently addressed.
ESC-FI-021	**Learning from development of the ESC:** Undertake a review of learning from the development of the 2002 and 2011 ESCs, so as to inform future major reviews of the ESC.	To address this Forward Issue, we submitted the following to the Environment Agency: [57] Relevant learning has been implemented as part of our development programme. A similar exercise to review learning from the development of the 2026 is included in our forward programme.
ESC-FI-022	**Active management of ESC records:** Ensure all ESC-related records are actively managed.	Records are maintained according to a defined retention schedule, agreed with the Environment Agency, and are considered active until their local retention period expires. After this period, records may be destroyed, retained further, or archived for long-term preservation, with those required for over seven years sent to the NDA archive at the Nucleus facility. This includes all ESC-related records including monitoring data, inventory, and engineering drawings. Once the 2026 ESC is submitted, the retention schedule will be updated to include the 2026 Level 1, Level 2, key Level 3 reports.
ESC-FI-023	**Leachate management strategy:** Produce a leachate management strategy that demonstrates the application of BAT to the	These requirements have been addressed through optimisation, design and engineering performance assessment activities. This has included development and testing of operational leachate management arrangements, including pumping trials and the development of a gravity-based drainage concept,

	management of leachate during the PoA. Investigate long-term leachate drainage performance, degradation and failure mechanisms.	together with associated updates to monitoring arrangements. For post-closure performance, options considered drainage-related aspects of vault design, including container void fill, profile fill and materials selection [58]. Design and optimisation information is presented in the '*Engineering Design*' report and the '*Optimisation and Site Development Plan*' report, with associated requirements captured in the Requirements Management System. Long-term post-closure leachate management performance is analysed in the '*Engineering Performance Assessment*'.
ESC-FI-024	**Gas management strategy:** Establish and implement a programme of work to develop a gas management strategy and infrastructure, including collection of necessary monitoring data, for the PoA.	We acknowledge the need for additional data and assessment to underpin the gas management strategy. The response outlines ongoing and planned activities, including • Review and optimisation of the current vent design, with consideration for alternative vent geometries and gas release pathways; • Further gas modelling to address uncertainties in gas generation rates; • Use of monitoring data from the trenches and vaults, including new data expected from future cap installations, to validate and refine modelling assumptions; • Close liaison with the monitoring team to ensure future monitoring programmes meet data requirements for both the trenches and Vault 8.
ESC-FI-025	**Protection of waste prior to final capping:** Develop and implement a programme of work to develop an optimised container design and	These issues have been considered in detail by successive optimisation studies since the 2011 ESC. Key outcomes are reflected, for example, in the approach to closing Vault 8 including the use of surcharge; proposals for strengthened containers and

	restoration sequence that provides adequate protection to waste containers and minimises discharges to the environment.	reinforced container protection units to protect their lids from load, to be adopted for future wastes pending continued design and optimisation; and the proposed use of interim storage warehouses to provide protection of future disposals prior to capping.
ESC-FI-026	**Engineering delivery:** LLW Repository Ltd should develop and implement the engineering forward programme to finalise the as-built design so as to allow further construction to begin. This programme should include: • an engineering R&D programme; • an engineering performance monitoring programme; • the scoping of a proportional Engineering Performance Assessment framework for use in future updates to the ESC.	Starting with the 2011 ESC, we have implemented a systematic and iterative programme of engineering optimisation, assessment and design development. A key part of this has been the iterative development of the Engineering Performance Assessment (EPA). This has provided a framework for developing and capturing an integrated understanding of the evolution of the engineering system both as a whole, and at the level of individual components. The outcomes are then reflected in the Requirements Management System. We are committed to continuing and further developing this integrated approach to engineering optimisation, design, assessment and requirements capture.
ESC-FI-027	**Cap performance assessment:** Undertake further assessment of the performance of the capping	We have assessed cap resilience to potential failure mechanisms. This has included the development of a structured and iterative Engineering Performance Assessment (EPA) alongside, and informed by, iterations of cap resilience

	system, including consideration of potential failure scenarios. Where appropriate, incorporate the outcome of the investigations into the repository engineering design and updates to the ESC.	assessment. These approaches were also integrated with aspects such as the final cap BAT, and the subsequent detailed design and specification approach, including establishing a set of requirements implemented via a Requirements Management System.
ESC-FI-028	**Improved understanding of the repository erosion process:** Seek to improve its conceptualisation and understanding of the repository erosion sequence.	We have improved our understanding of repository erosion processes including better understanding waste degradation once the wastes are exposed to coastal processes. This includes updating our understanding of the likely timing and mode of erosion, cap performance, biogeochemical conditions in the near-field and the rates of key degradation processes such as corrosion. This includes assessment of how degradation processes and rates change once wastes and engineering materials are exposed in the cliffs and then on the storm beach. We have considered how exposure to wave attack changes as the coast continues to erode, and waste and engineering materials become exposed further down the coastal profile. We have used analogues to understand the durability and break-up of different materials in the coastal environment and have considered the effects of infiltration once coastal erosion reaches the LLWR.
ESC-FI-029	**Management of elicited data:** Develop documented procedures for the future management of elicited data.	We have developed an elicitation manual to set out our approach to the elicitation of data: [40] This document captures learning from previous elicitations for the LLWR, the UK Geological Disposal Facility (GDF) programme and good practice guidance.

		All elicited data are managed in accordance with our *'ESC Data Management Procedure'* and are captured in our ESC data management system.

2.4 Recommendations Mapping Table

The Environment Agency made recommendations following their review of the 2011 ESC. These recommendations were grouped by the Environment Agency using the following categories.

- ASS – Assessment.
- INF – Inventory and Near Field.
- O&E – Optimisation and Engineering.
- SCM – Safety Case Management.
- SUE – Site Understanding and Evolution.

Table 2.4 provides a record of how we have addressed these recommendations and maps to where these areas are addressed as necessary in the 2026 ESC.

Table 2.4: Recommendations from the Environment Agency following their review of the 2011 ESC

Reference	Description of FI or Recommendation	How addressed	Responded to in
ASS1	A future PoA assessment should include a more thorough assessment of scenario,	Our approach to treatment of scenario, conceptual and parameter uncertainties is set out in the Assessments Manual [37]. The assessment of environmental safety during	Environmental Safety During the Period of Authorisation § 4.11 Management and Dialogue § 4.5.1 and 7.2

	conceptual and parameter uncertainties.	the PoA also includes an audit of bias and uncertainty.	
ASS2	We recommend that future versions of the ESC seek to fully integrate the assessments for the PoA and the post-closure period.	We are now using a fully integrated groundwater assessment model that integrates the PoA and post-PoA. Similarly, the models used in the gas assessment for radon and C-14-bearing gases integrate the PoA and post-PoA. In 2011 we had separate groundwater assessment models for the PoA and the post-PoA. In the 2026 ESC we use a groundwater assessment model which covers the full timespan of the assessment.	Environmental Safety During the Period of Authorisation § 4.3 Assessment of Long-term Radiological Impacts § 5 and 6 Hydrogeological Risk Assessment § 4
ASS3	We recommend LLW Repository Ltd undertakes a reassessment of doses and risks against the most recent version of the UKRWI as part of the company's submission for the next major ESC update.	Assessment calculations for the 2026 ESC are based on the most recent inventory available at the time of the data freeze for the assessments (the 2022 UKRWI).	Environmental Safety During the Period of Authorisation Assessment of Long-term Radiological Impacts Disposal Facility Inventory
ASS4	We recommend that LLW Repository Ltd assesses the implications of changes to the non-radiological component of the 2013	Non-radiological components and materials are documented in the '*Disposal Facility Inventory*' report. Assessment of non-radiological components of the radioactive	Disposal Facility Inventory § 5 Hydrogeological Risk Assessment § 4 Waste Management Plan § 9

	UK national inventory on the 2011 ESC.	waste and contamination is addressed in the 2026 ESC.	
ASS5	We recommend that LLW Repository Ltd considers a sensitivity study of the effects of inventory heterogeneity and configuration of the groundwater model on the assessment results in future assessments.	We examined this in work following the 2011 ESC and concluded that the effects of inventory variability are limited on the effects to assessed groundwater impacts [59]. We have developed a dual porosity model which explicitly models stacks of waste and the gaps between the stacks of waste. This model has allowed us to explore the effects of physical heterogeneity on assessed impacts.	Hydrogeological Risk Assessment § 4 Assessment of Long-term Radiological Impacts § 5
ASS6	We recommend that LLW Repository Ltd further explores the effect of cliff recession on the geosphere-biosphere interface in future ESCs. This should take into account the uncertainty associated with projected groundwater flow pathways in terms of pathway length, spatial variability and location of discharge to the beach.	We have considered issues associated with erosion and cliff recession and the geosphere-biosphere interface in reference [60]. We have considered the impacts of heterogeneity in hydrogeological properties and summarise our work in the '*Hydrogeology*' report.	Assessment of Long-term Radiological Impacts § 7 Site Evolution § 4.3.8 Hydrogeology
ASS7	We recommend that PEG habits for each pathway, and associated	The habits of members of potential representative persons are documented in	Assessment of Long-term Radiological Impacts § 2.8

	uncertainties, are more transparently documented in future ESCs.	reference [61]. This is a single consistent dataset used by all our assessments. Our overall approach is documented in reference [62].	Environmental Safety During the Period of Authorisation § 3.3
ASS8	Future versions of the ESC should assess the sensitivity of assessment calculations to significant assumptions and parameters in the biosphere.	We suggest that the exposed groups and representative persons are 'measuring instruments' and uncertainties in habits need not be addressed in the same way as other data in the assessments. Our overall approach is documented in reference [62]. Other biosphere uncertainties are treated in the same way as other uncertainties in the assessment − if there are key uncertainties in biosphere parameters or there are uncertain assumptions, then we might undertake sensitivity calculations. We note that in assessment models, equations are often linear and calculations may not be required to understand the impact of parameter changes on calculated radiological impact.	Environmental Safety During the Period of Authorisation Assessment of Long-term Radiological Impacts Reference [37]
ASS9	LLW Repository Ltd should build confidence in its future ESCs by	If there are alternative models of the system, then we would either make cautious	Environmental Safety During the Period of Authorisation

	assessing the effects on calculated results of the choices made when developing and configuring models.	assumptions or consider whether calculations need to be undertaken for different cases. For example, we have undertaken calculations for two different near-field models, and we have considered a number of alternative hydrogeological models and derived probability density functions covering the associated uncertainties.	Assessment of Long-term Radiological Impacts Hydrogeology Hydrogeological Risk Assessment § 4
ASS10	LLW Repository Ltd should present risks together with a clearer indication of the likelihood associated with the potential exposure to enable its context to be more readily understood in future ESCs.	Where we present risks, we also present information on dose and probability of occurrence where appropriate. Probability of occurrence is relevant to the gas assessment [49] and the well pathway in the groundwater assessment [63].	Assessment of Long-term Radiological Impacts § 5 and 6
ASS11	LLW Repository Ltd should consider a consistent set of variant calculations to take account of conceptual model and parameter uncertainty in both detailed process-scale models and assessment models, or explains why this has not been done, in future assessments.	Where appropriate we have defined consistent variant cases e.g. linked to emission scenarios timelines and coastal erosion. However, a completely consistent set of variants is in our view not required, for example because different models represent different processes and the key uncertainties	Assessment of Long-term Radiological Impacts Environmental Safety During the Period of Authorisation § 3.5, 5, 6, 7 and 8 Hydrogeological Risk Assessment § 4

		are different from assessment to assessment.	
ASS12	LLW Repository Ltd should provide a better explanation of how uncertainties are identified and prioritised for consideration in the probabilistic assessment in future ESCs. The company should also clarify the relationships between parameter ranges in probabilistic calculations and data used in variant deterministic calculations to build confidence in the overall robustness of the ESC.	We have only undertaken probabilistic calculations for the groundwater pathway. When developing our groundwater assessment model, we have identified, based upon system understanding, those parametric uncertainties which are most significant in terms of effects on system performance. These uncertainties have been treated probabilistically in the probabilistic calculations [64]. Our deterministic and probabilistic calculations use a common data set. In probabilistic calculations we sample over our probability density functions, whereas in deterministic calculations we take point values extracted from our probability density functions for parameter values. These are typically best estimate values for reference cases. For variant cases which explore the sensitivity of system performance to parametric uncertainty we take parameter values to be some given percentile value of the probability density function. For example,	Assessment of Long-term Radiological Impacts § 5

		in cases considering worse than expected cap performance, we have taken infiltration through the cap to be 95th percentile value. Particular variants are chosen in order to provide insight. We do not think it would be helpful to try to formalise the choice of variants if this is an implication of the recommendation.	
ASS13	LLW Repository Ltd should undertake a structured analysis of uncertainty as part of a future ESC. This should prioritise uncertainties for assessment and consider the use of probabilistic assessment as the main way of comparing against the risk guidance level, where viable.	Our approach to uncertainty laid out in our Assessments Manual [37] recognises the different sources of uncertainty which need to be addressed in our radiological assessments. It further requires that each assessment develops a plan for the identification and treatment of uncertainties. An important part of our treatment of uncertainty is the use of bias and uncertainty audits. We have carried out an audit for each assessment [64, 63]. These provide a systematic means of identifying and assessing the effect of uncertainties on system performance. The audit outputs have been used to refine our assessment approaches.	Environmental Safety During the Period of Authorisation Assessment of Long-term Radiological Impacts Hydrogeological Risk Assessment § 4

		Our approach in general is to use deterministic calculations when comparing assessed impacts against the risk guidance level. For the groundwater pathway, we have used probabilistic calculations to assess the robustness of system performance with respect to parametric uncertainty and to derive radiological capacities. The relationship between parametric uncertainty and assessed impacts is generally simpler for other assessments and therefore a probabilistic treatment would provide less insight.	
ASS14	We recommend that LLW Repository Ltd assesses the sensitivity of estimated impacts arising from a well to the location of the coastline and the effects of saline intrusion.	We have undertaken work to consider the potential for saline intrusion into the B3 lithofacies unit [60] and the effect on flows in the B3 unit. Our assessment model has no representation of saline intrusion. However, the pathlines used to provide input to the assessment calculations are based on an understanding of the distribution of saline water. Our assessment model considers the changing location of the coastline as coastal	Assessment of Long-term Radiological Impacts § 5 Hydrogeology

		erosion occurs. Our assessment approach accounts for uncertainty in the potential location of the well between the site and the coastline when calculating the radiological risks.	
ASS15	We recommend that future groundwater pathway assessments would benefit from a more detailed consideration of spatial heterogeneity.	We have undertaken work to investigate the effects of spatial heterogeneity on groundwater flows [65]. We have used this information to parameterise and understand uncertainties in the water flows in the B3 unit in our probabilistic groundwater assessment calculations and in certain deterministic variant calculations.	Hydrogeology Assessment of Long-term Radiological Impacts § 5 Hydrogeological Risk Assessment § 4
ASS16	We recommend that LLW Repository Ltd develops the groundwater flow model so that projections of spatial variability of contaminant concentrations in the groundwater are more readily able to be compared directly with the assessment calculations.	We do not think that it is appropriate to compare the results of flow calculations for heterogeneous porous medium models directly with the results of assessment calculations which are based on the simplifying assumptions that each hydrogeological unit has homogeneous properties. Our overall approach is to undertake assessment calculations based on homogeneous hydrogeological units and then to understand the potential effects of heterogeneity. The effects of heterogeneity	Hydrogeology Assessment of Long-term Radiological Impacts § 5 Hydrogeological Risk Assessment § 4

		have been investigated in hydrogeological modelling and potential effects on flow through B3 have been accounted for by use of an appropriate probability density function [59].	
ASS17	We recommend that LLW Repository Ltd undertakes further investigation into the nature and significance of uncertainties associated with the well pathway assessment, such as the potential for future groundwater use.	We have undertaken work to review parameters relevant to the well pathway. This includes the frequency of wells along the Cumbrian coast, well abstraction rates and borehole depths [66].	Hydrogeology Assessment of Long-term Radiological Impacts § 5
ASS18	LLW Repository Ltd should improve the clarity of its presentation of complex assessment areas such as the effect of spatial heterogeneity in the hydrogeological properties of the geological units on the migration of contaminated groundwater and future groundwater use in future assessments.	We have undertaken studies to investigate specifically the effect of spatial heterogeneity on groundwater flows. The studies have informed the parameterisation of groundwater flows in the B3 unit and associated uncertainties, which we use in our groundwater assessment models.	Hydrogeology Assessment of Long-term Radiological Impacts § 5 Hydrogeological Risk Assessment § 4

ASS19	We recommend that present-day and historical patterns of human behaviour should be considered when developing analogues for potential future human behaviour.	We have developed a habits handbook [61] that provides a consistent dataset of intake rates and occupancy data for use in our assessments. These data are based on a combination of local habits surveys specific to the LLWR site and expert knowledge of local occupancy patterns.	Environmental Safety During the Period of Authorisation § 3.3 Assessment of Long-term Radiological Impacts § 2.8
ASS20	We recommend that LLW Repository Ltd reviews the ESC to make sure that the assumptions and conclusions are still applicable when the final decision on whether the gas vent in the final cap will be left open or closed is made. If not, this issue should be addressed in future updates of the ESC.	We have undertaken extensive work on gas evolution modelling and pressurisation [63]. The position of the final cap gas vent for the 2026 ESC is the same as for the 2011 ESC; in the reference case we assume a gas vent that is open during the operational phase and closed at the end of the PoA, but the potential for the vent to remain open is also assessed [63]. The final decision will be made at the end of the PoA on the basis of time-series data of gas evolution of the wastes into successive strips of the final cap, and associated modelling and analysis work. This approach is part of our Site Development Plan.	Optimisation and Site Development Plan § 5.4 Engineering Design § 3.2
ASS21	We recommend that future ESCs should have a greater consistency between the models for different	We agree that, as far as is appropriate, there should be reasonable consistency between the representation of the biosphere and	Environmental Safety During the Period of Authorisation

	pathways, including both physical representations of the biosphere and PEG habits, and that significant differences should be justified and implications on impacts identified.	habits data in different assessments. However, when PEGs or processes are different, such consistency may not be appropriate. We have a single source of habits data and a data management system across the assessments, which should aid such consistency.	Assessment of Long-term Radiological Impacts
ASS22	We recommend that a future coastal erosion assessment includes a thorough review of the implications of dilution of waste material in the cliff, beach and foreshore, covering both loose trench waste and vault wastes with higher integrity.	We have undertaken work to better understand coastal erosion processes [67] and have used this to inform the Coastal Erosion Assessment, in particular the parameterisation of the coastal compartmental model.	Site Evolution § 4.3.8 Assessment of Long-term Radiological Impacts § 7
ASS23	LLW Repository Ltd has not carried out quantitative assessments of higher activity particles from other waste materials such as MOX fuels, irradiated highly enriched uranium, weapons-grade enriched uranium and plutonium. Whilst particles of these waste types are not expected to be disposed of in	We have carried out quantitative assessments of the radiological impacts of particles.	Assessment of Long-term Radiological Impacts § 10.2

	large quantities at the LLWR, we recommend that LLW Repository Ltd includes these waste types in future ESC assessments for completeness.		
ASS24	We recommend that LLW Repository Ltd demonstrates that the stacking of currently stored radium-bearing waste will be optimised when they are emplaced for disposal in the BAT assessment that the company intends to undertake on waste stored in Vault 8.	The ESC emplacement strategy states that consignments containing relatively large quantities of key radionuclides, including Ra-226, will be excluded from stack positions within 5 m of the cap surface. In response to Permit IC 5 we undertook an assessment of the stored wastes in Vaults 8 and 9 and undertook a BAT assessment to identify the preferred management option, see reference [51]. The assessment considered both the acceptability of wastes against the revised WAC and also the emplacement strategy. A separate assessment specifically considering Discrete items and Active Particles was also undertaken with the outcome used to inform the stored wastes assessment, see reference [52].	
ASS25	We recommend that LLW Repository Ltd further assesses	This is addressed in reference [68] and reference [42].	

	the likelihood and radiological consequences of a shallow waste fire occurring in the trench waste during the erosion sequence.		
ASS26	We recommend that LLW Repository Ltd audits future assessment calculations for all pathways against the FEP list to make sure that all relevant FEPs are considered.	FEPs audits have been conducted as part of each assessment supporting the 2026 ESC as set out in our Assessments Manual [37].	Assessment of Long-term Radiological Impacts Hydrogeological Risk Assessment § 4 Environmental Safety During the Period of Authorisation
ASS27	We recommend that, in order to clarify the modelling approach, LLW Repository Ltd should pay greater attention to documenting linkages between assessment models in future ESCs.	For complex assessments, in particular the groundwater pathway [64], we have put effort into explaining the links between the different models used. We have used a visual presentation as part of this.	Assessment of Long-term Radiological Impacts § 5 Hydrogeological Risk Assessment § 4
ASS28	We recommend that more discussion is provided about model design and model selection in future ESC updates.	Our approach to model design and selection is set out in our Assessments Manual [37]. Our overall approach is also set out in the '*Main Report*' and the '*Management and Dialogue*' report. Our Assessments Manual provides guidance on 'Assessment Model Design'. Specific software is discussed in the assessment	Main Report Management and Dialogue § 4.5.1 and 7.2 Environmental Safety During the Period of Authorisation Assessment of Long-term Radiological Impacts § 2, 5.4, 6.4, 7.4 and 8.4 Hydrogeological Risk Assessment § 4.6

		reports, including the '*Hydrogeological Risk Assessment*, and the '*Near Field*' and '*Hydrogeology*' reports.	Assessment of Radiological Impacts on Non-human Biota Near Field § 6, 7 and 8 Hydrogeology § 5.1
ASS29	We recommend that at the next major ESC update the non-human biota assessment uses the latest (radionuclide specific where possible) discharge and monitoring data.	Consistent with this recommendation, available site-specific discharge and monitoring data are used in the non-human biota assessment. The approach taken is consistent with the approach taken for the assessment of radiological impacts to people during the Period of Authorisation.	Assessment of Radiological Impacts on Non-human Biota § 4.3.1 Reference [69]
ASS30	We recommend that future non-human biota assessments should include all relevant radionuclides, using surrogate data as required, or substantiate the reasons for, and significance of, their omission	All relevant radionuclides have been considered in the non-human biota assessment. All radionuclides and associated parameters (e.g. concentration ratios), including methods for filling data gaps, are set out in the '*Assessment of Radiological Impacts on Non-human Biota*' report.	Assessment of Radiological Impacts on Non-human Biota § 4.2 Reference [69]
ASS31	We recommend that LLW Repository Ltd fully documents all input data to the non-human biota assessment, including peak modelled environmental	This recommendation is addressed in full in the non-human biota assessment [69] including reporting the timings of the peak calculated radionuclide concentrations in	Reference [69]

	concentrations and times for each peak.	environmental media for each contaminant pathway.	
ASS32	We recommend that LLW Repository Ltd explores the effect of uncertainties in projections of future radionuclide environmental concentrations in future non-human biota assessments.	The non-human biota assessment explores the assumptions and uncertainties within the assessment, including future radionuclide environmental concentrations. A bias audit was included within the phased non-human biota assessment to explore uncertainties.	Assessment of Radiological Impacts on Non-human Biota § 4.6 Reference [69]
ASS33	We recommend that future non-human biota assessments concentrate on those species that are observed today and assume that similar populations will exist in the future.	The representative organisms considered in the non-human biota assessment do not represent a single species but rather groups of species with similar characteristics found in and around the vicinity of the LLWR site in the present day. Whilst individual species may change it is likely, within the range of climate scenarios considered in the ESC, that other similar species will be present and that any changed patterns of behaviour of the original species will still be within the bounds represented by the representative organisms. The representative organisms selected for assessment are therefore considered appropriate to future conditions at the LLWR site in a long-term assessment.	Assessment of Radiological Impacts on Non-human Biota § 3.2 Reference [69]

ASS34	We recommend that the potential for harm to non-human biota coming into contact with high activity particles is considered further in future assessments.	The potential for harm to non-human biota coming into contact with high-activity particles has been considered within the non-human biota assessment. We find that exposure to particles would not have significant impact on the overall health of organisms.	Assessment of Radiological Impacts on Non-human Biota § 4.3.2.7 and 6.5 Reference [69]
ASS35	We recommend that LLW Repository Ltd further considers how it makes better use of trench and vault leachate monitoring data to support the development of the trench, and potentially the vault, source terms and ensure that leachate is appropriately characterised to support this need.	We have considered the use of trench leachate data to characterise the trench source term (including to define the solubility of uranium in the trenches). There are only leachate data for a small number of contaminants, and these only provide a view of contaminant concentrations over a limited time period and at particular locations. They provide little information about spatial variation of contaminant concentrations in the trenches and no information about their evolution with time. Our view, therefore, is that it is more appropriate to base our treatment of the trench source term on inventory information. Monitoring data indicate that activity levels in vault leachate are low. This is because the mild steel ISO-freight containers, in which	Hydrogeological Risk Assessment § 4.1.1 Environmental Safety During the Period of Authorisation Assessment of Long-term Radiological Impacts

		the majority of vault wastes have been disposed, limit contact between incident water and the wastes. Vault leachate monitoring data do not, therefore, provide an appropriate basis on which to characterise the vault source term. It is difficult to use data on tritium to understand the source term from the trenches since it is not possible to characterise an important release process (crushing of glass vials).	
ASS36	We recommend that LLW Repository Ltd carries out further work to confirm the non-radioactive contaminant leachability data used in the assessment of leaching from grout and that it should include grout in the source term for future non-radiological assessments of the vaults.	This was specifically studied in reference [70]. We have used the information in this report to include grout as a source term in our HRA.	Hydrogeological Risk Assessment § 4
ASS37	We recommend that LLW Repository Ltd should pursue any opportunity to improve its understanding of the non-	We have successfully lobbied for better data to be included in the national inventory and we seek the best available information from waste producers.	Disposal Facility Inventory § 5

	radiological component of the inventory.		
ASS38	We recommend that LLW Repository Ltd improves the quality of the inventory records of past and future asbestos disposals to the LLWR.	We do not believe it is possible to improve the quality of the past disposal inventory records for asbestos as details other than those recorded in the tracking system were not required for consignment paperwork. In response to this recommendation, we conducted an in-depth analysis of the asbestos in the 2010 UKRWI potentially heading to the LLWR and is reported in reference [71]. In particular, we considered what fibre types (chrysotile, amosite, crocidolite) and material types (i.e. how friable) they might be and what consequences this might have for hazard. Although the forward inventory has changed since the 2010 UKRWI, the breakdown of materials by friability and fibres will likely have some transferability. Since the introduction of WAC Version 5 in 2016, we have collected data on the type and form of asbestos in a consignment, so we now have more granularity in the disposed inventory.	

ASS39	We recommend that LLW Repository Ltd improves the integration of the period of authorisation and post-closure non-radioactive contaminant assessments. This integration is especially important for reporting on compliance with non-radiological performance requirements. (Also see Recommendation ASS2.)	We have developed an integrated assessment model that considers the PoA and the post-closure period. The model includes the progressive construction, filling and closure of trenches and vaults. The model is used as the basis of our HRA and is also used to assess radiological impacts via the groundwater pathway.	Hydrogeological Risk Assessment § 4 Assessment of Long-term Radiological Impacts
ASS40	We recommend that LLW Repository Ltd improves future hydrogeological risk assessments by: • ensuring that the environmental monitoring and sampling programme can achieve necessary baseline and operational non-radiological monitoring capability in line with landfill guidance (Environment Agency 2011);	We have addressed this recommendation as follows: • Our environmental monitoring programme has been developed to collect non-radiological data. Baseline data are not available as disposal operations predate the environmental monitoring programme but background data is collected from up-gradient monitoring points to allow the impact of the site to be determined. • Our requirements for inventory information on non-radiological	Hydrogeological Risk Assessment Monitoring § 3.6.3

	• working to improve estimates of the hazardous and non-hazardous components of trench and vault leachate, taking into account future disposals and utilising any opportunity to gain better information; • fully integrating the period of authorisation and post-closure assessments; • presenting a more comprehensive assessment of uncertainties and their effects, including the use of probabilistic models as appropriate; • taking better account of the requirements for landfill risk assessment (Environment Agency 2011) wherever possible;	contaminants have been fed into exercises to develop future iterations of the UKRWI. • As discussed in our response to ASS39, we have developed an assessment model that fully integrates treatment of the PoA and the post-closure period. • We have developed an approach to uncertainties in accordance with the requirements of our Assessments Manual [37]. We have undertaken a bias and uncertainty audit to identify and assess the effects of uncertainties and biases on assessed impacts. Our judgement is that a probabilistic calculation is not warranted for the groundwater pathway. • We have agreed compliance points with the Environment Agency. • We have documented the HRA in a separate report [72]. We have made this as stand-alone as is practicable. It is inevitable, given the complexity of	

	• taking into account the latest Environment Agency guidance on setting compliance points and standards for assessing inputs of hazardous substances to groundwater; • documenting the assessment in a stand-alone report containing all relevant monitoring, conceptualisation and assessment information and avoiding the need to refer to numerous supporting documents; • taking into account changes in the designation of hazardous substances by JAGDAG.	the engineered system and the assessment, that references to supporting documents will be required. • We have taken JAGDAG designations into account when assessing the impacts of non-radiological contaminants.	
ASS41	We recommend that LLW Repository Ltd assesses the impact of non-radioactive soil contamination using the latest models and data and derives site-	'Soil' is a potential receptor only for non-radiological contaminant impacts from the coastal erosion and human intrusion pathways. Our understanding from the Environment Agency review [73] is that	

	specific screening criteria where appropriate.	assessment is not required of non-radiological contaminant impacts from these pathways.	
ASS42	We recommend that ingestion of seafood is considered in any non-radioactive contaminant assessment for the coastal erosion pathway.	We had understood that no specific assessment was required for coastal erosion for non-radiological contaminants.	
ASS43	We recommend that LLW Repository Ltd takes into account heterogeneity in the distribution of non-radiological contamination in any future assessments of coastal erosion.	Our understanding from the Environment Agency review [73] is that assessment is not required of non-radiological contaminant impacts from the coastal erosion and human intrusion pathways.	
ASS44	We recommend that LLW Repository Ltd carries out a more detailed review of the probable biodegradation of organic contaminants, taking into account the expected biogeochemical evolution of the vaults and trenches, within any coastal erosion assessment.	We do not consider that such data are relevant to the coastal erosion assessment. As noted above, our understanding is that the Environment Agency does not require an assessment of the chemotoxic impact of such contaminants following coastal erosion.	

ASS45	LLW Repository Ltd should use an approach more closely in line with current UK practice for the assessment of human intrusion impacts associated with exposure to non-radiological contaminants in soil. We would also expect any future non-radiological assessment of human intrusion to include consideration of heterogeneity and uncertainty, including the potential for exposure to organic contaminants.	Our understanding from the Environment Agency review [73] is that assessment is not required of non-radiological contaminant impacts from the coastal erosion and human intrusion pathways.	
ASS46	We recommend that the non-radiological capacity assessment is subject to a comprehensive review at the next major ESC update so as to take account of the most recent non-radiological HRA.	We have re-calculated non-radiological capacities using our revised groundwater assessment model.	Hydrogeological Risk Assessment § 4.7 Implementation § 7
INF1	LLW Repository Ltd should make sure that knowledge on the process for deriving the trench inventory is maintained in the future, for example by bringing it 'in-house'.	Knowledge of the process for deriving the trench inventory has already been brought in house. We now have ownership of the trench inventory, and the methodology used to derive it.	Disposal Facility Inventory § 3

INF2	LLW Repository Ltd should consider assessing the application of the updated radionuclide fingerprints to the trench inventory as part of any wider review of the trench inventory where it may lead to potential improvements	We do not consider this would be appropriate. We believe that fingerprints are likely to become less relevant to the wastes disposed in the trenches over time.	
INF3	LLW Repository Ltd should continue to carry out audits to make sure that the physical locations of containers in the vaults are in agreement with information in its waste tracking system.	The disposed vault data used in the 2011 ESC covered disposals up to 31st March 2008. Since 2008, the quality and quantity of waste consignment information have improved. We have therefore been able to use the more recent consignment data to improve the estimates of inventory associated with the older consignments. These improved techniques have been used for the derivation of inventory data for wastes disposed of up to 1st April 2018, when the eMWaste tracking system was introduced to replace the previous tracking system.	Disposal Facility Inventory § 4.1.1
INF4	LLW Repository should address query 10 within ESC-TQ-INF-004 which relates to consideration of the combination of effects, for key	A review of the RECALL work has been completed and addresses this recommendation: [74].	

	radionuclides, from multiple issues arising from the RECALL work.		
INF5	We expect future updates of the ESC to identify and assess the nature and extent of non-standard disposals in Vault 8 and future vaults, to appropriately inform cap settlement assessments.	Successive cap resilience assessments have considered the relative contributions to voidage and settlements in the vaults, and in particular Vault 8. Stacks of older containers of standard design have been identified as being associated with the most significant potential settlements. The cap has been assessed to be resilient to the full range of plausible settlements. All containers, including non-standard disposals, will be surcharged during the Vault 8 closure process to express available settlements.	Engineering Performance Assessment § 5, 6 and 7 Optimisation and Site Development Plan § 5 Engineering Design § 2.7, 3 and 5 Reference [75]
INF6	In future updates of the ESC, LLW Repository Ltd should consider whether future radionuclide fingerprints are suitably representative of the Vault 8 waste streams currently without a matched radionuclide fingerprint (in an analogous fashion to our recommendation for the trench inventory in Section 2.2.1).	The disposed vault data used in the 2011 ESC covered disposals up to 31st March 2008. Since 2008, the quality and quantity of waste consignment information have improved. We have therefore been able to use the more recent consignment data to improve the estimates of inventory associated with the older consignments. These improved techniques have been used for the derivation of inventory data for wastes disposed of up to 1st April 2018, when the	Disposal Facility Inventory § 4.1.1

		eMWaste tracking system was introduced to replace the previous tracking system.	
INF7	LLW Repository Ltd should continue to engage with consigners and the NDA to reduce the uncertainty associated with the future waste inventory (radiological and non-radiological components).	For the 2011 ESC, we presented a reference inventory based on our understanding of wastes in the 2007 UKRWI. The inventory produced proposed the need to fill up to Vault 20. From the 2016 UKRWI, waste producers were asked to provide routing data for their waste streams. What we have witnessed since is that whilst the total raw LLW volume has remained consistent at between 1.4 and 1.5 million m^3, the calculated volume routed to the LLWR has decreased. For the 2016 UKRWI, 53% of the LLW volume was reported to require LLWR disposal capacity. By 2019, this had further decreased to 14%. This last change was the result of targeted work we undertook in collaboration with waste producers during 2017 to 2018. The 2022 UKRWI, for which the 2026 ESC inventory is based upon, now sees the total LLW raw waste volume needing LLWR disposal capacity down to 11%. The significant reduction in volume also leads to	Disposal Facility Inventory § 5

		a reduction in the total radionuclide activity that will require disposal at the LLWR. We have also made progress on the capturing of data for hazardous and non-hazardous pollutants. We now manage the UKRWI Programme, having transferred the scope from the NDA. This will allow us to work more closely with waste producers and target specific data gaps and uncertainties that have the largest impact on the inventories.	
INF8	LLW Repository Ltd should engage with consigners and the NDA to minimise the implications of unknown alpha and beta/gamma in the forward inventory.	Unknown alpha and beta/gamma, reported as 'Other Alpha' and 'other Beta/gamma' in the 2022 UKRWI, accounts for 1.8% of the total radionuclide activity for the reference forward inventory. We will continue to work with waste producers through a targeted approach to improve the UKRWI data, with a focus on the significant uncertainties that impact the LLWR ESC.	Disposal Facility Inventory § 5
INF9	LLW Repository Ltd should maintain an awareness of any developments nationally and internationally that can help reduce	We are supporting initiatives to address uncertainties, with progress contingent on their integration into UKRWI declarations.	

	the uncertainty associated with the Cl-36 inventory.	The iGraMP (Irradiated Graphite Management Programme) technical working group has been considering the Cl-36 inventory across the NDA estate, covering more than just graphite materials. The group aims to clarify knowledge gaps, define essential data needs, and consider further research requirements. NRS have sponsored a PhD proposal via the NDA bursary to study Cl-36 distribution in waste streams from reactor dismantling, utilising access to the Trawsfynydd site for comprehensive coverage. We commenced graphite C-14 leaching studies several years ago to expand data beyond Magnox graphite, where Oldbury data was previously predominant. Following identification of Cl-36 data gaps, analyses were incorporated into these studies. Although results are pending, detecting Cl-36 at low concentrations remains challenging.	
INF10	LLW Repository Ltd should give further consideration to options for improving the non-radioactive inventory, for example through the	For the disposed vault inventory, there are limited data available on the presence of hazardous substances and non-hazardous pollutants. The level of detail we ask for	Disposal Facility Inventory § 4

	use of appropriate waste fingerprints.	today has only been requested since 2016. With annual waste receipts to the LLWR declining over the past ~10 years, the data we do have on these substances represent a small proportion of the total vault disposed waste volume. Therefore, it is not appropriate to use the limited dataset to make assumptions on the potential quantities of these substances in the remaining vault disposed inventory.	
INF11	A small proportion of the Vault 8 non-radiological inventory has been derived using a back-fitting process similar to that used for the trenches. We expect LLW Repository Ltd to review the back fitted Vault 8 inventory component against future waste stream compositions and to refine it where possible.	In addition to the response given for INF10, it has been deemed not appropriate to use UKRWI data to provide a basis for hazardous substances and non-hazardous pollutants that may be present in the wastes received to date for disposal at the LLWR. The 'as reported' data generally suggest that we have used tiny percentages of the non-radiological capacities. The same is true if they are extrapolated over a greater time period than that over which we have been collecting the data. A more cautious approach is used in the HRA for the older disposals with poor non-radiological contaminant inventory information. For these wastes, bulk materials such as organic ion	Disposal Facility Inventory § 4 Hydrogeological Risk Assessment § 3.1

		exchange resins or halogenated polymers are assumed to degrade to produce mobile contaminants (e.g. benzene, vinyl chloride etc.) even though there is often poor evidence that such degradation would occur. However, the result is to bound the potential impacts. For more recent disposals and future disposal with better information, a less cautious approach may be possible. However, where we do not have full confidence in the consignor-declared quantities of non-radiological contaminants, we may still take a similar position to that for EDTA [76], with a method to estimate the quantities that is cautious enough to bound all likely disposals, such as described above for organic materials.	
INF12	LLW Repository Ltd should engage with the NDA to ensure that future updates of the UKRWI better address the non-radiological components, in order to support future non-radiological assessments within the ESC.	We now manage the UKRWI Programme, having transferred the scope from the NDA. This will allow us to work more closely with waste producers and target specific data gaps and uncertainties that have the largest impact on the inventories for both the LLWR and the GDF. We have updated the UKRWI data requirements to include the known hazardous substances and non-hazardous	

		pollutants that important to the ESC and have made it the top priority for data improvement for waste producers.	
INF13	LLW Repository Ltd should consider a more systematic treatment of uncertainty in the non-radiological component of the inventory. This may potentially be achieved using variant cases.	Our approach to inventory uncertainty is laid out in our '*Disposal Facility Inventory*' report. Our view is that the definition of variant cases to explore uncertainty in the non-radiological inventory would not offer insights into the level of safety provided by the facility. We have calculated non-radiological capacities and will use these to ensure that non-radiological impacts from the wastes comply with relevant regulatory standards. We have treated uncertainties in inventory within the probability density functions used for probabilistic calculations for the groundwater pathway.	Disposal Facility Inventory Assessment of Long-term Radiological Impacts
INF14	LLW Repository Ltd should use a systematic approach when defining 'other' components in the LLWTS and the development of future LLW tracking systems.	In the LLWTS, the material group 'Other' represented one of the six, and then one of eight, and then one of twelve material groups. The WCI form was introduced and began to capture specific material masses in consignments; however, the LLWTS could not be configured to accept the improved material mass data. The LLWTS was	

		replaced with the current waste tracking system eMWaste in 2018. Data are uploaded into the system directly from the WCI form. The 'Other' group will continue to be used when describing the material composition of the disposed inventory, however the WCI form and the link with eMWaste ensures that we have a clear understanding of the material fingerprint of future waste receipts.	
INF15	Should the GRM model be used to support future ESC updates, LLW Repository Ltd should consider implementing the recommendations in Small et al. (2009) to make sure that the time steps applied in GRM are optimised. If a different model is used in future ESC updates then LLW Repository Ltd should ensure that applicable findings of Small et al (2009) are reviewed.	GRM has been replaced for the chemical modelling of the near field by a suite of models at different length scales in the PFLOTRAN software. Part of the rationale for different scale models (e.g. single container, container stack, vault and site) was to ensure discretisation in both time and space was appropriate for the modelling cases being considered. Other advantages of using PFLOTRAN include the treatment of unsaturated media and multi-phase flow of gases and water, including water vapour which mean the chemical processes in the variably saturated near field can be properly represented.	Near Field § 6

INF16	LLW Repository Ltd should assess the leachability of Sikament-700 from both fresh and aged samples of grout, this work could be carried out as part of wider investigations into the leachability of the LLWR grout formulation.	Work has been carried out recently for the UK GDF programme examining whether the presence of superplasticisers used in the production of grouted wasteforms can enhance mobility of radionuclides and other contaminants from the grout [ref]. A range of grout formulations, which covered the LLWR PFA/OPC formulation, were considered in the extensive experimental study. Leaching was carried out on intact samples and using flow-through tests, as well as leaching of crushed samples, which are considered to give unrepresentative results because of the enhanced surface area of the sample. The results indicated that polycarboxylate ether superplasticisers do not enhance contaminant mobility from the set grout, either at early or later ages. These results are consistent with a larger body of work from both UK and overseas organisations and provide a robust basis for discounting this process as a significant contribution to contaminant release in the repository environment. As a result, LLWR has not initiated any additional work in this area. However, grout leaching studies have been	Near Field § 4.5.4

		carried out recently to examine the behaviour of non-radiological contaminants in the PFA/OPC grout. This work is on-going. The work is unlikely to be repeated in the near future as there are no more available samples of aged LLWR grout across the nuclear estate. That said, for future grouting campaigns (especially for new grout formulations if adopted), a sample library will be generated and stored on the LLWR site so that the work on aged grout samples could be undertaken at some point in the future. Note: The Sikament 700 superplasticiser currently used on the DGF has been replaced by the manufacturers (Sika UK) Visco-Crete 150-PF, which is identical to Sikament 700 in that the polymer component is the same (polycarboxylate ether) but the antifoaming agent has been changed. We believe that Visco-Crete 150-PF is likely to behave in the same way as Sikament 700, and do not intend to undertake leaching trials with the new superplasticiser until such time as sufficient samples can be taken as indicated above.	

INF17	If bulk quantities of complexants are disposed of to the LLWR, LLW Repository Ltd should assess the possible effects of heterogeneity in the vaults. This could assess, in particular, whether the placement of bulk quantities of complexant next to disposals containing high quantities of strongly complexed pollutants (for example lead), could affect the results of the 2011 ESC assessments.	Current understanding of the evolution of saturation in the vaults following capping indicates that the vaults will be largely unsaturated for most or even all of the period before the site is disrupted by coastal erosion. Under these unsaturated conditions, there will be very little interaction between adjacent container stacks, or even containers in the same stack. As a result, once there is sufficient infiltration to exceed water consumption by corrosion reactions, radionuclides and complexants will leach out of individual perforated containers into water flowing in the gaps between stacks. Heterogeneity in disposals of complexants and potentially affected contaminants will be unimportant in determining mobility of contaminants from the waste as they can only mix once released from the containers. It may be possible that mixing of complexants and contaminants, once there is a saturated zone at the base of the vaults, enhances mobility from the near field into the geosphere by reducing sorption onto steel corrosion products or the concrete bases and walls of the vaults, but these processes	Near Field

		are not included in the assessment models which already consider a cautious representation of the role of complexants.	
INF18	LLW Repository Ltd should consider periodic sampling and analysis for DTPA in trench leachate.	A method for analysis of DTPA in trench leachate was developed as part of a PhD project we commissioned in 2016. We are currently in consultation with a commercial laboratory to have this method validated for application to the samples of leachate from trench probe holes that we analyse annually for EDTA, as per our complexants monitoring strategy [47].	Monitoring § 4.6
INF19	LLW Repository Ltd should provide further supporting evidence for its choice of K_d and solubility parameters for non-radiological contaminants.	As part of work to develop the 2026 ESC, we have undertaken an extensive programme of data review. This has included reviewing sorption and solubility parameters. We have documented the outcomes of these reviews in references [77, 78, 79, 80].	
INF20	We expect future updates of the ESC to include an increased understanding of the impact on near field performance of low grout to waste ratio containers that were	We have used the new PFLOTRAN container-scale models to examine the impact of contaminant release from the grouted wastes. The models use a range of grout to waste ratios to examine the differences in pH evolution, contaminant sorption and flux from the container for the	Near Field § 6 and 6.5

	identified during the container condition investigations.	evolving infiltration conditions. These results are reported in detail in the Level 3 PFLOTRAN report [81] and summarised in the '*Near Field*' report.	
INF21	We recommend that future modelling of container settlement incorporates a more realistic degree of discretisation and greater consideration of the geotechnical response of containers to the loss of waste volume resulting from cellulose degradation.	The approach used to evaluate cap settlement is cautious and we believe it does not require discretisation at a sub-container scale.	Engineering Performance Assessment § 5, 6 and 7 Optimisation and Site Development Plan § 5 Engineering Design § 2.7, 3 and 5
INF22	LLW Repository Ltd should consider further experimental and/or near field monitoring work, similar to the GRE work carried out at Olkiluoto, to support the future near field modelling, particularly in relation to the partitioning of C-14 and the behaviour of C-14 in unsaturated vault conditions.	We submitted a response to ESC-FI-018 that outlines our plans for a near-field experimental programme [55]. The scope of the experimental programme has since changed due to technical and practical reasons, but we have undertaken a programme of small-scale trials, and we are in the process of refining the design of an experimental system that will run for approximately two years. The focus of the small-scale trials that have already been conducted and the main stage	

		of the experimental programme is on better understanding the saturation state of the grouted waste. It was not possible to include investigation of C-14 partitioning within the scope of the experiment due to technical and practical constraints. The near-field processes that will be simulated by the experiment will be incomplete, such that it would not be possible to draw meaningful conclusions regarding the fate of C-14 in the vaults. However, the conceptual model for the processes affecting C-14 in the current assessments results in all the C-14 that is not released immediately from waste as methane to the biosphere or retained in the form of carbonate minerals in the grout being released in the form of small dissolved organic species into infiltration in the gaps between the waste containers. In the gas assessment, it is assumed that all this aqueous C-14 is subject to microbial degradation in the low pH environment outside the containers and released as gas. In contrast, the groundwater assessment assumes all aqueous C-14 is released to groundwater with no microbial degradation to gas. It is not possible to justify partitioning	

		the aqueous C-14 into gas and groundwater components because the environment in the gaps is too uncertain, and in all likelihood too heterogeneous, in the unsaturated system, thus a cautious approach is adopted. It is also unlikely that experimental evidence would be sufficiently robust to justify such a split.	
INF23	LLW Repository Ltd should consider an appropriate gas sampling campaign from Vault 8 after the vault has been capped. LLW Repository Ltd should consider use of any data obtained from this monitoring programme to support the modelling carried out in the 2011 ESC.	New monitoring points are being established in Vault 8 as part of the capping programme. These will include gas sampling infrastructure, and this data will be used to support future modelling.	Monitoring § 7 and 7.1
INF24	LLW Repository Ltd should make sure that extremes of waste to grout ratios within containers are considered and as necessary assessed, in particular in relation to C-14 behaviour.	See INF20, above. It is worth noting that the role of the grout in capturing C-14 carbon dioxide is much less affected by the presence of cellulosic wastes in the near field. In the 2011 ESC it was assumed that these wastes were degraded in the presence of microbes which generated large volumes of CO_2 that could carbonate the grout and, in	Near Field § 6 and 6.5

		extreme cases, reduce the efficiency of C-14 CO_2 retention in the grout. However, the more recent understanding of grout pH indicates that microbial degradation of cellulosic wastes will be much more restricted as a result of pH >12.5 in the grout porewater. Microbial activity may still occur in restricted niches but large-scale carbonation of the grout will not occur and cellulose degradation products such as isosaccharinic acid will dominate gaseous products.	
INF25	LLW Repository Ltd should consider the potential use of vault and laboratory based investigations into the nature and extent of microbiological processes in the grouted waste form.	The current understanding of the grout chemistry indicates that the pH will be around pH 13 (at 11 °C). A literature review [82] considered recent research into the activity of microbes under extreme pH conditions. The work indicates that at such elevated pH conditions microbial activity will effectively be prevented except in localised niches that are isolated from the grout porewater. Our near-field experiment (see INF22) will investigate such.	Near Field § 4.3
INF26	LLW Repository Ltd should maintain a watching brief of developments to understand what	A report for RWM (now NWS) considered the fate of graphite in the cementitious near field of a GDF [5] in support of the proposed	

	other materials, for example graphite, may act as sources of nutrients for microbial processes.	disposal of highly enriched but very low burn-up research reactor fuel containing graphite. The study concluded that there was no evidence that graphite could be utilised by microbes on a 1 My timescale, and that any reactions of the graphite at repository temperatures (ca. 35 to 40 °C) would only involve the surface attached functional groups that constitute an insignificant portion of the material. In view of the changed understanding of the conditions in the LLWR near field, we see no reason to revisit this topic for graphite or other materials in the waste.	
INF27	LLW Repository Ltd should investigate the effect of human intrusion on the evolution of the near field and the consequences for the risks associated with the gas and groundwater pathways. Any additional assumptions needed for this investigation should be simple and plausible, building on the human intrusion scenarios already assumed to have occurred. Variant scenarios	Only events that would penetrate the low permeability layers in the cap are assessed as other shallower events would not significantly impact the performance of the cap. Although some events would lead to localised deviations in repository evolution and performance, none of the events would damage substantial proportion of the cap. The largest area of damage is associated with an aircraft impact, and this area is only 0.5% of the total cap area.	Assessment of Long-term Radiological Impacts § 8.7

	need not be explored unless small changes in assumptions could make the longer term outcome radically worse.	Our assessment indicates that damage from human intrusion events should not lead to groundwater pathway risks above the risk guidance level. The potential doses and risks from damage to the cap providing a conduit for gas release are analogous to the doses and risks from an open vent, with peak risks from the open vent case demonstrated as below the risk guidance level.	
INF28	LLW Repository Ltd should continue to monitor the leachate from the vaults for all applicable Cr species. If spikes in Cr concentrations are detected, it should consider further analysis for Cr(VI).	A wider suite of analyses is undertaken on bulk trench and vault leachates on a triennial basis to understand if the composition of non-radioactive chemical contaminants is changing through degradation of the waste. We analyse for total chromium as the limit of detection for Cr(VI) is an order of magnitude higher than for total chromium and would not allow sufficient resolution.	Monitoring § 4.1
INF29	LLW Repository Ltd should maintain an awareness of the volume and form of likely future waste consignments to the LLWR and the effect that this may have on the EDA near field.	The EDA is no longer a design feature. However, we have conducted annual reviews of the ESC since 2016. As part of the annual review, we compare the volume and form of actual disposed waste with that assumed in the ESC to assure ourselves that the	Implementation § 3.4

		material content of the waste being disposed of is consistent with the projections used to support the ESC.	
INF30	LLW Repository Ltd should consider incorporating the flow charts describing the development of the trench inventory, similar to those presented in Wareing et al. (2008), into future ESC updates.	Our understanding of the trench inventory has not advanced significantly since 2011, and so the derivation process has less prominence in the 2026 ESC. No action is proposed.	
INF31	LLW Repository Ltd should consider providing worked examples of how it calculates the activity of a sub-bay in the trenches in future updates to the ESC. Examples could cover both a sub-bay where the total activity is dominated by a specific waste consignment and also one where a number of routine consignments each make a significant contribution to the total activity.	Our understanding of the trench inventory has not advanced significantly since 2011, and so the derivation process has less prominence in the 2026 ESC. No action is proposed.	
INF32	LLW Repository Ltd should provide as full a forward work programme	Our Near Field report identifies potential further work that could be developed into a work programme.	Main Report Near Field § 9.2

	on near field issues as possible within future updates to the ESC.	We have developed our plans for further near field experiments based on an initial stage of work.	
INF33	LLW Repository Ltd's use of elicitation to gain an understanding of near field processes should be proportionate and should be combined with experimental and modelling work to reduce the uncertainties in the near field.	The updated understanding of the LLWR near field and, in particular, the higher pH than considered in 2011, has allowed us to draw on more work for the GDF programme. The cementitious backfill (e.g. NRVB) planned for use in the ILW vaults means that pH conditions are similar to those now expected in the LLWR grouted waste. This has meant that parameters describing processes such as solubility, sorption, complexation (e.g. ISA) and metal corrosion can draw on GDF literature. As a result, we have been able to avoid elicitation exercises to a significant extent in favour of expert reviews (see INF9). Improved understanding of, and models for, the PFA/OPC grout has also allowed us to represent this component of the near field more accurately and confidently than was the case in 2011. The Grout Development Programme (GDP) has been instrumental in this as a result of the use of the current PFA/OPC grout as a benchmark for new formulations. We have	Near Field

		also initiated a large-scale, long-term experimental study to consider the unsaturated conditions in the near field. The initial small-scale tests have already confirmed our assumption about the initial saturation state of the grout (in fact, the results are also consistent with older, academic experimental work) [83].	
O&E1	Links between the developing engineering design and the ESC should be clearly documented in formal procedures.	We have developed a Requirements Management System (RMS) that clearly defines all of the many requirements on the disposal system and its components and shows how these are interlinked and affect each other. The RMS aims to define how requirements flow down from regulatory requirements, through ESC requirements and into detailed engineering specifications. The system will place decisions within a structured framework that clearly defines all of the requirements on the disposal system and its components and shows how these are interlinked and affect each other. The baseline configuration of the RMS is set out in reference [84]. Reference [85] explains how the RMS is to be administered and	Engineering Design § 2 Optimisation and Site Development Plan § 3 Implementation

		defines how changes to the RMS are to be managed.	
O&E2	At future opportunities (for example periodic reviews of the ESC) LLW Repository Ltd should revisit the optimisation decisions presented in the 2011 ESC to make sure they remain valid.	Key optimisation decisions will be reviewed in each ESC. Periodic reviews will also identify any requirements to revise optimisation studies. Optimisation and any required updates to previous studies will also be considered as part of the Engineering Plan. We have recently revised our design for the cap. We have considered steps required to dispose of ILW, should this be considered appropriate, and we are giving further consideration to the cap vent.	Optimisation and Site Development Plan Engineering Design
O&E3	Future updates of the ESC should provide greater clarity on how operational safety issues and decisions are factored in to the optimised design.	Operational safety is considered as an attribute in our optimisation assessments. Examples include external irradiation as a significant factor in some of the design choices that we have made. Ongoing container optimisation work has considered container stacks and vault bases as an integrated system to ensure stability and operational safety. Operational construction safety was a core consideration	Optimisation and Site Development Plan § 3 and 5

		throughout the Vault 8 closure optimisation work.	
O&E4	Future iterations of the ESC might benefit from a narrative describing past optimisation decisions, including those that took place between the 2002 ESC and the 2011 ESC.	The overall narrative on optimisation presented in the 2026 ESC includes some additional information on history to provide context for ongoing analysis and decisions. This is not a full history but focuses on key developments relevant to present designs and choices.	Optimisation and Site Development Plan
O&E5	LLW Repository Ltd should make the weight attributed to all factors considered in future optimisation studies more explicit (whether qualitatively or quantitatively), allowing greater clarity on how decisions about option choices have been reached.	The discussions on process and outcomes of optimisation in the 2026 ESC aim to make the rationale for final choices clearer. On the specific topic of weighting, in our process we make clear that differentiators associated with human or environmental safety are always the priority concerns in our assessments, with other factors then being considered. More broadly, in our qualitative assessment process, weighting is intrinsically tied into logical arguments that reflect both differentiators and the overall importance of criteria or factors. These are therefore specific to the nature of the study, the role of options in ensuring safety, and the differentiating criteria involved. These details	Optimisation and Site Development Plan

		are typically provided by the reports supporting the '*Optimisation and Site Development Plan*'.	
O&E6	LLW Repository Ltd should reassess the cost model for retrieval and re-disposal of certain trench waste if the English policy for disposal of higher activity waste changes.	Key optimisation decisions will be reviewed in each ESC. Periodic reviews will also identify any requirements to revise optimisation studies. Optimisation and any required updates to previous studies will also be considered as part of the Site Development Plan and associated Engineering Plans. For the 2026 ESC, we have undertaken a specific optimisation study to review arguments relating to retrieval of waste from the trenches [86].	Optimisation and Site Development Plan § 6
O&E7	Because of the predicted likelihood of coastal erosion of the site, LLW Repository Ltd should make sure that future operational and design decisions do not unnecessarily foreclose options for the retrieval of waste in existing and future vaults.	We produced a response to a very similar query subsequent to the 2011 ESC and this is recorded in reference [87]. We concluded then, and retain the view, that the approach to long-term waste isolation and containment does not rule out the potential future recovery of disposed wastes, were this to be desired.	
O&E8	We recommend that the company reviews the viability of selective	We have undertaken a specific optimisation study to review arguments relating to	Optimisation and Site Development Plan § 6 and 6.3

	retrievals and the associated environmental safety arguments in future updates of the ESC.	retrieval of waste from the trenches [86]. The review concluded that the arguments in the 2011 ESC against selective retrieval remained valid, that the doses associated with trench disposals are as low as reasonably achievable and that the effort required for either selective retrieval or in situ remediation would be grossly disproportionate to the benefit that would be gained	
O&E9	Future updates of the ESC and SDP should consider how the design accommodates (or does not foreclose) understanding around future likely uses of the site and builds in sufficient flexibility to address uncertainties around this.	The 2026 ESC and Site Development Plan have been updated to ensure the Engineering Design remains flexible and does not unnecessarily constrain potential future uses of the site. The Engineering Design work maintains a modular and adaptable approach, allowing future changes in waste arisings, technology developments, and national strategy to be accommodated without foreclosing options. The ESC also considers potential future land use scenarios not as a commitment, but to ensure the design is robust under a range of plausible future conditions. The Site Development Plan and Site Strategy are maintained as living documents, revised in response to	Engineering Design Optimisation and Site Development Plan § 7

		monitoring data, regulatory feedback, stakeholder views, and evolving understanding of site evolution. Together, these measures ensure that flexibility is retained and uncertainties around future site use are appropriately managed.	
O&E10	The company should continue to develop strategies for the period of institutional control and to incorporate them into future updates of the ESC.	Building on work developed for the 2011 ESC [88], we have reviewed our approach to the institutional control period. We conducted a BAT assessment on the duration of the period of active institutional control and have confirmed 100 years as our reference approach [89].	Optimisation and Site Development Plan § 7
O&E11	LLW Repository should consider the potential for the provision of passive engineered features to mitigate and slow disruptive processes, thus also serving to reduce individual annual risks.	We do not consider that any practicable steps can be taken to protect the site in the long term from the expected effects of coastal erosion. We further consider that we could not rely upon passive engineered features to mitigate and slow disruptive processes. We do not take credit for such features within the ESC.	Optimisation and Site Development Plan § 5.2.2
O&E12	LLW Repository Ltd should investigate the implications of diffusive flow through the engineered barriers or substantiate	Diffusive fluxes are of most significance for the grout and the vault bases.	Assessment of Long-term Radiological Impacts Near Field

	why these flows are insignificant compared with advective fluxes.	We have explicitly considered diffusive transport of contaminants through the grouted wasteform in our near-field studies and our groundwater and C-14 gas assessments. In our near-field studies we have considered flows through cracks in the concrete of the vault base. At early times, while there is a negative water balance, the cracks will be dry and have a low permeability and hence diffusive transport through the slab would be the more significant process. However, under these conditions, there will be minimal contaminant release from the wastes. Furthermore, the drainage blanket and upper B2 beneath the vault may also be unsaturated so that contaminants diffusing through the vault base are not released to advecting groundwater. The result for contaminant release from the repository will be minimal. As the cracks saturate, the permeability of the cracks will become relatively high, water will drain into the underlying drainage blanket and B2. Under these conditions, advective flows of contaminants through the vault base	Hydrogeological Risk Assessment § 4

		and into the underlying groundwater will dominate.	
O&E13	In future optimisation decision making, we expect to see a more effective linkage between hydraulic performance and design objectives.	Our overall approach is to optimise the design to get the best practical barriers, then to assess the performance of the design, taking account of the evolution of key engineered components. Our optimised concept and outcomes for components are based on evaluations of confidence that the barriers and wider functions of the engineering will be provided into the longer-term. These are then translated into requirements captured into the RMS and therefore inform detailed design requirements. We do not attempt to define a requirement or performance target for hydraulic properties of components without first understanding the performance of the optimised concept. The evolution of the components is captured in detail in the Engineering Performance Assessment and the understanding gained supports our assessments and is also fed back into optimisation and design iterations.	Optimisation and Site Development Plan Engineering Performance Assessment Engineering Design

		The links are therefore contained within our iterative optimisation process informed by the Engineering Performance Assessment, then translated into Requirements.	
O&E14	Future updates of the ESC would benefit from clear documentation of the process LLW Repository Ltd has used to determine the engineering design, which provide details of baseline assumptions, inputs to the decision making process and substantiation of chosen components.	This has been enhanced by the use of our Requirements Management System. The relationship of the Requirements Management System with optimisation, design and Engineering Performance Assessment is described in the 2026 ESC.	Engineering Design § 2 Implementation § 3.2
O&E15	LLW Repository Ltd should investigate the feasibility of reducing the angle of the steepest cap slopes or consider measures to mitigate long-term erosion.	The optimal cap edge slope angle has been determined by balancing a range of factors. A gradient of 1:10 will be typical for edge gradients across the cap, with 1:5 locally where required, though some outer sections will be steepened to 1:3 during the PoA in order to maintain access arrangements and for the cap height to remain consistent with the planning permission. The angle remains within that recommended in best practice guidance to minimise erosion.	Engineering Design § 3.2

O&E16	To optimise the basal drainage system for each vault, we recommend that the functional requirements of this system (drainage capacity) are defined on a vault-by-vault basis.	We have set out requirements for the basal drainage system in the Requirements Management System. The RMS specifies that the design of the Vault Basal Drainage System shall account for the heterogeneity of the underlying geological formations (e.g. the system might be locally absent if the formations are very permeable, but good function will be required where underlying clays are present). In addition, the blankets for each vault will be laterally disconnected from one another by ensuring low permeability materials between blankets. This ensures the blankets operate independently and is consistent with allowing flexibility in future detailed design processes.	Engineering Design § 5 Optimisation and Site Development Plan § 5.4 Implementation § 3.2
O&E17	We recommend that future updates of the ESC provide an effective linkage between the environmental safety objectives and the detailed engineering performance specifications.	We have developed a Requirements Management System (RMS) that clearly defines all of the many requirements on the disposal system and its components and shows how these are interlinked and affect each other. The RMS aims to define how requirements flow down from regulatory requirements, through ESC requirements and into detailed engineering specifications. The system will place decisions within a	Engineering Design § 2 Implementation § 3.2

		structured framework that clearly defines all of the requirements on the disposal system and its components and shows how these are interlinked and affect each other. The baseline configuration of the RMS is set out in reference [84]. Reference [85] explains how the RMS is to be administered and defines how changes to the RMS are to be managed.	
O&E18	Where engineering systems or barriers provide multiple safety functions we recommend that LLW Repository Ltd differentiates between the primary environmental safety functions and the secondary environmental safety functions.	We have done this in our '*Safety Functions*' report.	Safety Functions
O&E19	LLW Repository Ltd should consider carrying out destructive container investigations similar to those carried out by Wood (2002).	We do not believe this is justified given the cost of undertaking such studies and the limited additional insights they are likely to provide, and given that simulated rather than real waste packages would be used.	
O&E20	We consider it important that LLW Repository Ltd continues to review the use of non-destructive	As part of the Waste Mis-consignment Risk Mitigation Project we have undertaken	

	container inspection methods to meet its operational waste packaging information needs.	studies and trials looking at container x-ray technology and gas detection methods. A full-scale ISO trial of x-ray detection was carried out in 2025. The ISO was packed with representative materials to demonstrate the effectiveness of the technique in distinguishing materials and identifying deliberately placed WAC non-compliances. A 'blind trial' workshop using the x-ray images and mock consignment paperwork determined that in terms of the current process for routine consignments to the LLWR, the use of x-ray technology would likely not provide significant benefits at the HHISO scale compared to the potential issues and difficulties that may arise from trying to assess the images for the mixed nature of wastes loaded by consignors at this scale. However, we found that there is still potential to investigate further use of this technology for the following situations: • smaller package types than a HHISO; • one-off opportunity wastes where this could provide useful assurance and understanding;	

		• legacy wastes where the level of information required by current standards is not available, such as a lack of loading photos etc.; • potential useful opportunities for Near Surface Disposal/ Geological Disposal Facility disposal. Moving forwards, we propose to keep a watching brief on this technology to stay up to date with the latest developments and how these could be applied. Collaboration with others investigating the technology for similar applications, such as Sellafield Limited on both x-ray imaging and muon emission tomography, is to be maintained. The use of gas detection as part of mis-consignment prevention was considered by a technologies review and data quality objectives process. Detection of hydrogen gas, in relation to WAC clause L2.5 Reactive Metals and Materials, was taken forward to trials in collaboration with our Nuclear Safety Case team.	
O&E21	LLW Repository Ltd should make sure that elicited data are	We have undertaken elicitation exercises as part of the development of the Engineering	Engineering Performance Assessment

	consistent with, and where possible use outputs from, future engineering performance assessments.	Performance Assessment. The elicited data are therefore necessarily consistent with the Engineering Performance Assessment.	
O&E22	LLW Repository Ltd should undertake further investigations into the timing, mechanisms and uncertainty associated with the failure and degradation of performance of the engineered systems during and after the period of authorisation.	We have developed a methodology for, and carried out, an Engineering Performance Assessment. The Engineering Performance Assessment considers the timing and mechanisms of barrier degradation during and after the PoA. Appropriate evolution cases are defined to explore uncertainties in the timing and nature of degradation.	Engineering Performance Assessment
O&E23	LLW Repository Ltd should bring the engineering performance FEPs identified in Table A1.4 of Lean and Willans (2010) into the FEP and uncertainty tracking system, or suitable future alternative systems.	FEPs related to engineering performance are included in the FEP audits documented in each of our L3 assessment reports.	Main Report Assessment of Long-term Radiological Impacts Environmental Safety During the Period of Authorisation Hydrogeological Risk Assessment
O&E24	We recommend that the uncertainty associated with the performance of the leachate management system and basal drainage system is better reflected	Our EPA accounts for uncertainties in the long-term performance of these engineered features. Our hydrogeological models suggest that the dominant uncertainty with respect to vertical flow beneath the vaults is associated with the properties of the	Engineering Performance Assessment § 4 and 5.8 Hydrogeology

	in any future FEP and uncertainty tracking system.	surrounding geology rather than the capacity of the basal drainage system. Therefore, we do not propose to adopt this recommendation.	
O&E25	LLW Repository Ltd should develop a specific FEP for the uncertainty associated with the magnitude and timing of past and future container settlement.	The nature of container settlement has been extensively considered in our work. Relevant FEPs are documented in each of our L3 assessment reports.	Engineering Performance Assessment
O&E26	In future updates of the FEP and uncertainty tracking system (or future alternative systems) we recommend an increased level of detail in FEPs covering the engineered system and its performance, and the associated uncertainties. These FEPs should be effectively linked to the developing design and uncertainties associated with it.	We have reviewed the engineering FEPs that are included. However, we note that our revised objective is not to provide a comprehensive set of FEPs, but rather to identify key uncertainties and to ensure that appropriate work is being undertaken to reduce them.	Engineering Design § 3.2.9.1 and 5 Engineering Performance Assessment
O&E27	We recommend that prior to construction of the final engineered cap, LLW Repository Ltd ensures, through monitoring, that waste settlement achieved through the	Settlement during profile fill placement and surcharging will be monitored using an observational approach, combining periodic topographic surveys with sub-surface deformation instrumentation to quantify the	Engineering Design § 3.2.9.1, 4, 5 Optimisation and Site Development Plan § 7

	application of surcharging provides evidence that any remaining potential for waste settlement is consistent with assumptions made within the 2011 ESC.	magnitude and rate of movement, confirm expected engineered barrier behaviour, and inform staged construction decisions (including surcharge depth selection and hold durations) based on trend analysis and engineering judgement.	
O&E28	LLW Repository Ltd should give careful consideration to the performance benefits from the profiling materials, including how the profiling material will affect leakage through the cap.	We have set out the requirements for the profile fill layer in the Requirements Management System on the basis of the outcomes of successive optimisation studies. We do not seek a hydraulic barrier function from the profile fill layer, we do not believe this would be proportionate or required given that function is provided by other layers of the final cap. Nevertheless, the profiling is a component of the repository and as such its evolution and functions need to be considered. We have considered the hydraulic performance of the profile fill layer within the Engineering Performance Assessment and in a supporting reference where we calculate water infiltration rates through the engineered cap [90].	Engineering Design § 3.2 Optimisation and Site Development Plan § 5.4 Engineering Performance Assessment § 4 and 5.2

O&E29	LLW Repository Ltd should consider engineering profiling and fill materials as part of the engineered safety systems.	We consider the profile fill to be part of the engineered system and we have considered its performance as part of the Engineering Performance Assessment. We have defined a specification for the profile fill to ensure that it contributes to the provision of environmental safety. We have considered safety functions offered by the profile fill in our safety function analysis.	Engineering Design § 3.2 Optimisation and Site Development Plan § 5.4 Engineering Performance Assessment § 4 and 5.2 Safety Functions
O&E30	LLW Repository Ltd should consider further optimisation of the final design of the cap surface, including cover system and vegetation.	The final cap has been subject to iterations of optimisation and design for many years, including refinement of cap layers during the Repository Development Programme. We have considered the cap surface in our design studies. The cap surface layer and vegetation will: • maximise stability and minimise erosion; • encourage run-off and ensure evapotranspiration; • ensure the final cap is aesthetically appropriate.	Engineering Design § 3.2 Optimisation and Site Development Plan § 5.4

		The final specification for the surface layer and vegetation will be agreed with planners and landscape specialists.	
O&E31	We recommend that future updates of the ESC more clearly describe the role of the cut-off wall, in conjunction with the basal drainage layer and in-situ granular material in reducing the extent and mitigating the consequences of overtopping.	We have set out in the Engineering Design and the Engineering Performance Assessment reports how the repository will be engineered to minimise the potential for overtopping to occur. Our safety function analysis also considers the role of the repository engineering in minimising the potential for near-surface discharges.	Engineering Design § 3.2 Optimisation and Site Development Plan § 5.4 Safety Functions Engineering Performance Assessment § 4, 5.2, 5.6 and 5.8
O&E32	To validate the ongoing performance of the cut-off wall in limiting groundwater ingress into the vaults, LLW Repository Ltd should consider incorporation of monitoring infrastructure between the cut-off wall and the vaults.	The ESC incorporates plans for additional monitoring infrastructure located between the cut-off wall and the vaults	Monitoring § 7.6
O&E33	The design should, as far as possible, ensure that no actions are taken that will preclude long-term maintenance or replacement of infrastructure required	We agree and believe this principle has been embedded throughout our optimised design. As a general point, we seek to avoid reliance on maintenance infrastructure placed beneath the final cap, as any required	Engineering Design Optimisation and Site Development Plan

	throughout the period of institutional control.	maintenance would likely risk compromising wider performance.	
SCM1	LLW Repository Ltd should consider continuation of regular ESC Liaison meetings to support development of future updates to the ESC.	We hold regular ESC liaison meetings and have used these meeting to support the development of the 2026 ESC. In addition to the process by agreement, regular liaison meetings involving the ESC team, the Environment Agency and ONR have been held. At these meetings, each organisation presented a progress update. These meetings also include updates from the LLWR site environmental monitoring team where any results from the programme that could impact the ESC are also discussed.	Management and Dialogue § 2.1.1 and 2.2
SCM2	LLW Repository Ltd should continue to make efforts to maintain engagement with a wide range of potentially interested parties throughout the period of operation of the site.	Liaison meetings are held with the Cumberland Council, on an as-needed basis, to discuss planning matters and provide the Council's planning team with advanced notice and information about potential upcoming planning submissions The WCSSG, plays a key role in the dialogue and transparency surrounding the LLWR ESC.	Management and Dialogue § 3

		We are currently undergoing a major engineering project focused on the final capping of legacy disposal trenches and vaults. The Southern Trench Cap Interim Membrane is the first step, involving the installation of a protective membrane and other foundational materials. Our public engagement strategy emphasises openness about the project's goals, safety measures, and environmental benefits. We have engagement with local communities, including updates, consultations, and possibly site visits or educational outreach.	
SCM3	LLW Repository Ltd should provide support to consignors to understand the background to any changes to its WAC, their meaning and appropriate ways to help ensure compliance and adoption of good practice.	We have a dedicated Waste Services team, which manages our relationship with consignors and a dedicated Waste Acceptance team that are responsible for the waste acceptance processes that govern waste disposal at the LLWR Site. If we plan to implement changes to the WAC that would affect consignors, we consult our customers and give them at least 12 weeks' notice (unless changes need to be introduced more rapidly to ensure our	Management and Dialogue § 3.1.4 Implementation

		compliance with legal or regulatory conditions). We also aim to reduce the impact of WAC changes for the customer, by appointing a dedicated project manager and managing to a detailed implementation plan that considers any implications associated with a WAC revision, such as complementary training and guidance materials or customer software used to produce NWS Waste Acceptance Procedure (WAP) forms.	
SCM4	To ensure transparency, LLW Repository Ltd should make sure that the audit trail of all documentation supporting the current ESC is clearly signposted, dating back to the publication of the 2011 ESC in May 2011.	Our 2011 ESC is available online through the National Archives. This includes the Level 1 and 2 reports, a selection of key Level 3 documents, and the Environment Agency reports documenting its review of the 2011 ESC. Our annual and periodic reviews, including our Enhanced Periodic Review of the ESC in 2021, are submitted to the Environment Agency where they can be shared upon the public register. Our Annual and Periodic reviews provide the audit trail as changes, new information, and developments in understanding arise.	Implementation § 3.4 Management and Dialogue § 2.3.1, 8 and 9.1.1

SCM5	LLW Repository Ltd should aim, as far as possible, to achieve a position in any future ESC submission where all information necessary to 'make the case' is presented within the main tiers of documentation, without the need for us to request further information.	Our '*Main Report*', and suite of Level 2 documents provide the claims, arguments and evidence to demonstrate environmental safety of the LLWR.	Main Report All Level 2 reports
SCM6	Future updates of the ESC should aim to make fuller use of alternative lines of reasoning wherever reasonable to do so.	We seek to identify good independent and complimentary arguments to the extent these are available for our facility. Our key lines of technical argument cover: 1) calculated impacts are consistent with regulatory criteria; 2) our design is optimised; 3) monitoring data provide an independent line of argument for the short term; 4) analogue data for coastal erosion support our general approach and models.	Main Report § 4
SCM7	Over the operational period of the site we expect to see elicited data	We have made extensive use of monitoring data to understand the hydrogeology of the	Management and Dialogue § 7.1

	supplemented and supported by empirical data (site and, where appropriate, experimental data) wherever practical and beneficial to do so.	site and the surrounding region. We have used this understanding when developing our detailed hydrogeological models and the Compartment Flow Model which we use in the groundwater assessment. In general, we do not think it proportionate to undertake programmes of experimental work to determine parameters such as sorption parameters. We have, however, commissioned near-field experiments to understand the evolution of grout saturation. As part of work to optimise the selection of the geomembrane for use in the final cap, we have outlined a programme of in situ testing which would be used to build confidence in the long-term performance of the membrane. We are also undertaking work to develop an optimised grout formulation which will replace the PFA-based grout currently used. As part of this work we are undertaking experimental studies which will inform future ESC assessments. We would always prefer the use of site-specific rather than elicited data when such data are available.	

SCM8	LLW Repository Ltd should continue to review the future scenarios that it considers within the ESC, continuing to focus on ‘important’ areas, but also considering other scenarios such as, for example, delayed coastal erosion, which must be considered proportionately.	We have developed three natural evolution scenarios that are applied consistently across the ESC; a high carbon emissions scenario, a low emissions scenario and a reference emissions scenario. These bound an appropriate range of uncertainty. We have also considered less credible 'what-if' cases relating to accelerated ice-sheet collapse (extreme sea-level rise) and no coastal erosion.	Site Evolution § 3.5, 3.6 and 4 Assessment of Long-term Radiological Impacts § 3.5 Environmental Safety During the Period of Authorisation § 4.11 Hydrogeological Risk Assessment § 4
SCM9	LLW Repository Ltd should continue to regularly review and update the management system with a view to tailoring it to the specific requirements of the site, to rationalise it where possible, to adapt to new processes such as the implementation of the ESC and to continue to make improvements based on learning.	Management and maintenance of our ESC is integrated into our management system, controlled via the process [22]. The management arrangements are subject to a formal annual management review, undertaken to ensure the adequacy, effectiveness and alignment to the direction of the organisation. The output of the review is submitted to the Nuclear Safety Committee. In addition to this, individual Process Owners undertake periodic reviews of their process to ensure they are current, appropriate and adequate.	Management and Dialogue § 4.2.2

SCM10	LLW Repository Ltd should be cautious in its reliance on PBO reachback support.	This is not applicable because NWS no longer operates under a PBO model.	
SCM11	LLW Repository Ltd should pay particular attention to the maintenance of skills and capabilities associated with maintenance and implementation of the ESC, ensuring adequate defence in depth and succession planning is in place.	Document [91] forms part of our guidance on succession planning within the broader Talent, Learning and Development framework. This guidance supports the NWSTM 17.08 Succession Planning Principles [91] and outlines the structured approach NWS takes to ensure organisational resilience and continuity through effective succession planning. Relevant competencies are to be maintained over the lifetime of the facility, including any period of authorisation after closure through the Management of Change procedures [33]. It is the Heads of Professions' responsibility to ensure that a deputy is identified for all key EHSS&Q posts and roles and longer-term succession plans for roles are maintained; these are reviewed during the annual management review meetings. It is the responsibility of the management team, supported by the Human Resources and Training Manager, to ensure that there is	Management and Dialogue § 4.8.3

		adequate training of personnel within an Intelligent Customer capability and that there are arrangements for succession planning [91].	
SCM12	Continuing efforts should be made to ensure access to relevant contractor skills and capabilities which may only be required on a periodic basis.	SQEP ESC contractors are engaged to support the work programme both to provide expertise in specialist disciplines and to address fluctuating resource requirements. Wherever possible, contracted work for ESC development is procured through ESC-specific routes with specialists who have extensive experience of developing and implementing ESC both in the UK and internationally. We intend to continue utilising the supply chain to support ongoing ESC development and are currently going through a procurement exercise to secure access to such specialists. In addition to contractor support, with the formation of NWS, we now have access to Geological Disposal Facility ESC expertise, which provides additional capability and technical depth to support the development, maintenance and review of our ESC and related safety case activities.	Management and Dialogue § 4.8.2 and 4.8.3

SCM13	LLW Repository Ltd should define and use strict definitions of relevant terms used for records management of different record types (for example data, information, knowledge, understanding).	Records management terms and definitions are defined within our Records Management Topic Manual [92] which provides detailed guidance on our approach to records management, specifically focusing on metadata requirements and record handling protocols.	Management and Dialogue § 9.1
SCM14	LLW Repository Ltd should continue to engage with the NDA's Information Management Compliance Programme, but at the same time to make sure an LLWR specific long-term records management strategy is developed, which meets the needs of the LLWR, considering issues such as the need for long-term retention of data local to the LLWR site, how long-term records will be linked to the site and its end-use in the longer-term (post-closure) and how the strategy is made compatible with any wider NDA long-term records storage solution. LLW Repository Ltd will need to engage with NDA to make sure	We have undertaken a review of records management, and applied a revised record retention schedule [26] for the ESC, in particular identifying the key records for indefinite retention, and their associated metadata. We have a records management end user agreement contract in place with the NDA to support long term preservation of our records. If records are deemed as vital the end user agreement states that duplicate copies of records are transferred to the NDA archive (the Nucleus facility) in Wick for long term storage. Nucleus stores records that need to be retained longer than seven years.	Management and Dialogue § 9.1

	any centralised repository of nuclear site information can meet the possible needs for local information to support the site's end-state.		
SCM15	LLW Repository Ltd should maintain a watching brief on improved methods of records management from national and international experience and consider how it can best use these means.	Since merging with RWM, we now have an improved reach in this area. The NWS records capability will be striving to ensure records management practices remain current and fit for purpose and that improvements are applied when feasible to do so. We maintain a watching brief and are constantly seeking improvements through activities such as industry benchmarking and national and international experience. A member of our Safety Case team is currently a member of the Bureau of two NEA groups relating to Information, Data and Knowledge Management (IDKM) and Information Management Strategy.	Management and Dialogue § 9.1
SCM16	LLW Repository Ltd should review records management associated with all ESC records, following completion of the ESC and its initial implementation	We have undertaken a review of records management and applied a revised record retention schedule [26] for the ESC, in particular identifying the key records for indefinite retention.	Management and Dialogue § 9.1.1

SCM17	Within future ESC submissions LLW Repository Ltd should consider inclusion of information on key assessment models and codes used in the ESC, addressing model selection and assurance measures, so as to provide confidence in the quality assurance procedures applied. Also to provide better information on interactions between computer models and the transfer of model output between different models; good practice would include provision of an assessment model flowchart or similar.	Our Assessments Manual [37] provides structured instructions and advice for performing safety assessment calculations. Guidance on model selection and assurance is provided in the 'Assessment Model Design' section and information on interactions between computer models and the transfer of model output between different models given in the 'Assessment Model Design and Integration of Models' section. We have also used model flowcharts where appropriate to illustrate links and data flows between models.	Management and Dialogue § 4.5 and 7.2 Environmental Safety During the Period of Authorisation Assessment of Long-term Radiological Impacts Hydrogeological Risk Assessment
SCM18	Within future iterations of the safety assessment, data management forms should record all data used in the assessment calculations to maintain a transparent audit trail.	We work in accordance with our Data Management Procedure [36]. This sets out that Data Management Forms are used to ensure consistent use of data across multiple calculations or assessments used in the 2026 ESC. Therefore, a transparent audit trail of data is maintained. We apply the procedure to data that are used in more than one assessment or calculation.	Management and Dialogue § 7.2

		The ESC utilises the Project Quality team resource who conduct external audits of contractors engaged on the assessments for the 2026 ESC, specifically focusing on the procedures and approaches applied to check the correct base data are being used, and processes are in place to verify calculations.	
SCM19	The future peer review process should consider provision of the peer review group's response to LLW Repository Ltd's response to their comments. This would ensure transparency of all findings and demonstrate that all findings have been closed to both LLW Repository Ltd's satisfaction, and ideally also the peer review group.	Should the PRG deem it appropriate to issue a further response to our response, we would of course publish it. However, we consider that our approach of publishing the PRG's summary report and our response to it is sufficient and proportionate. The purpose of the PRG process is not to achieve absolute agreement.	Management and Dialogue § 4.9.3.2
SCM20	A peer review tracking system should be an addition to the peer review process, to demonstrate that actions resulting from the peer review process have been carried forward and closed.	We maintain a tracker of submissions to the Independent PRG, their review comments and our resulting actions or response. The PRG also publish a periodic summary report showing an overview of their work.	Management and Dialog § 4.9.3.2
SCM21	The recommendations of the peer review group should be taken into	We systematically consider the PRG review comments and recommendations and	Management and Dialogue § 4.9.3.2

	account in the ESC forward programme.	address them within the ESC forward programme as appropriate. Not all recommendations are taken forward but where they are not, this is recorded and justified in the response. This may be because recommendations become superseded by other developments, or we judge them to be not necessary.	
SCM22	LLW Repository Ltd should consider adoption of a safety function approach within future iterations of the ESC.	The ESC has always fundamentally taken a safety functions approach, but we have made it more explicit in the 2026 ESC, and have added a '*Safety Functions*' report for clarity.	Safety Functions
SCM23	If LLW Repository Ltd considers that conceptual uncertainty is not important to the ESC, then an argument to this effect should be presented.	Uncertainties are discussed and addressed within each assessment, including conceptual uncertainties. The uncertainty and bias audits record for each identified uncertainty or bias, what course of action we judge as being appropriate be that to reduce, address or accept. An example of how we may address or reduce a conceptual uncertainty, is by adding a variant case to the assessment model. Key uncertainties are collated in our '*Register of Significant Uncertainties*' [38].	Management and Dialogue § 5.2.3 and 4.5.1 Assessment of Long-term Radiological Impacts Hydrogeological Risk Assessment Environmental Safety During the Period of Authorisation

SCM24	Consideration should be given to inclusion of a section in the overall register of significant uncertainties devoted to alternative lines of reasoning.	We consider that it is good to have a list of key uncertainties (see the '*Register of Significant Uncertainties*' and the '*Main Report*') and it is good to have a list of complementary arguments (see the *'Main Report*' for our safety arguments). However, these are different things and therefore they should not be in the same list.	Main Report Reference [38]
SCM25	The elicitation process only deals with parameter uncertainty. Parallel exercises would be useful to deal with modelling uncertainties, conceptual uncertainties and scenario uncertainties.	We do, of course, consider modelling, conceptual and scenario uncertainties within our assessments. We sometimes consider some of these uncertainties within elicitation processes or in relevant workshops or project discussions. However, we do not think that a formal process, as for parameter uncertainty, is needed.	Environmental Safety During the Period of Authorisation Assessment of Long-term Radiological Impacts Hydrogeological Risk Assessment
SCM26	LLW Repository Ltd should make sure that areas of good practice from the previous assessments (for example, the 2002 ESCs) are carried through to future ESCs.	We have undertaken a specific study on this topic [57] and incorporated relevant findings into our development programme. We intend to conduct a similar exercise for the 2026 ESC.	
SCM27	LLW Repository Ltd should make sure that future iterations of the ESC are fully representative of the	The Extended Disposal Area is no longer part of our proposed design and the issue of	

	proposals being made and that the ESC assesses the entirety of the proposals in a consistent manner.	an 'add-on' proposal does not arise for the 2026 ESC.	
SCM28	LLW Repository Ltd should continue to develop its asbestos assessment in line with national developments in contaminated land and landfill disruption assessment.	Following the 2011 ESC, we assessed the risk arising from asbestos disposal in the repository in detail [71]. This assessment was issued in 2017 [71]. As noted by the Environment Agency, it was done 'in the absence of any clear national or international assessment framework' [73]. In preparation for the 2026 ESC, we have reviewed national guidance for assessment and control of asbestos risk arising from contaminated land and landfill disruption. Although there have been some changes in the organisation and content of guidance documents for landfill disposal of asbestos, the underlying requirements remain the same as at the time of our previous work [93, 71]. The only new guidance we identified was published by the Society of Brownfield Risk Assessors (SoBRA) [94, 95, 96]. SoBRA compared different asbestos risk models; the quantitative findings of their	

		analysis are consistent with our analysis [71, 97].	
SCM29	LLW Repository Ltd should consider use of the definition of 'explosive' in our guidance on definition and classification of hazardous waste of 'substances and preparations which may explode under the effect of flame or which are more sensitive to shocks or friction than dinitrobenzene'.	This recommendation was addressed and definitions were added to the WAC [98]. A specific workshop was held for the Environment Agency regulators to brief them on the WAC changes and underpinning.	Management and Dialogue § 2.2.2 Implementation
SCM30	Within its organisation, LLW Repository Ltd should ensure clear ownership of the WAC as well as ESC Project Team input to changes driven by non-ESC considerations (for example, transport requirements).	We have implemented formal procedures (NWSSOP 40.07.01 [22]) that govern production and updating of the WAC.	Management and Dialogue § 2.3.1 Implementation § 5.2.4 and 8
SCM31	LLW Repository Ltd should make sure it is satisfied that consignor systems are capable of providing an appropriate level of	We have a dedicated Waste Services team which engages with waste consignors and a dedicated Waste Acceptance team responsible for the waste acceptance processes that govern waste disposal at the LLWR Site. These teams also support	Management and Dialogue § 3 Implementation § 8

	characterisation through provision of instruction, guidance and audit.	various waste assurance activities, such as site-based and desktop audits in addition to the provision of education and training. Consignors are guided additionally by the NDA Solid Radioactive Waste Characterisation Good Practice Guide which has been developed to identify and facilitate consistent application of good practice within the nuclear industry regarding the characterisation of solid radioactive waste. However, we do provide a robust technical challenge as part of our Waste Characterisation process and reinforce any issues or concerns with consignors proposed characterisation approach.	
SCM32	LLW Repository Ltd should initiate work to enable an informed choice to be made between possible future institutional control strategies.	We undertook work in support of the 2011 ESC to consider a range of possible future institutional control strategies [88]. We have used these in our more recent work and have also undertaken a review in light of UK Government Policy development and developments in the LLWR programme [89]. This informed our institutional control plan for the 2026 ESC for the LLWR [99].	Optimisation and Site Development Plan § 7.3 Reference [89]

SCM33	LLW Repository Ltd should clarify and substantiate whether, during the period of active institutional control, it is envisaged that maintenance and remediation will be carried out routinely, or whether remediation will only be carried out in the event that a significant deterioration in performance is detected.	Maintenance activities (e.g. to access or service monitoring infrastructure, or as part of establishing mature vegetation) will be carried out routinely during the period of active institutional control. Remedial action would only be carried out during the period of active institutional control if required, as determined from monitoring or surveillance [99].	Engineering Design § 3.2.9 and 8.6 Optimisation and Site Development Plan § 7.3.5 and 9 Reference [99]
SCM34	LLW Repository Ltd should consider the final land use of the site such that it can be ensured it is compatible with the final cap design, the wider ESC and assessment of habitats.	The whole area of trenches and vaults will be covered by a single, gently-domed, low permeability engineered cap, designed for stability and resistance to erosion and presenting acceptable visual impact. Suitable long-term vegetation cover, consistent with surrounding vegetation, will be established on the cap area and periphery. This is consistent with stakeholders' preferred end use for the site of 'waste management and recreation or nature conservation' [99, 100].	Engineering Design Reference [99]
SCM35	Maintaining detailed knowledge and tools or assessing safety performance, as well as retaining	We have an established process and tools relating to Record Management and Retention. Records required to support the	Management and Dialogue § 9.1 Reference [89]

	appropriate records must be an active feature of the management of the site through to the end of active institutional control and beyond.	2026 ESC are identified in the controlling business process for the activity and transferred to the NWS record retention schedule.	Reference [99]
SCM36	Skills maintenance throughout the period of active institutional control will be required; this is a challenging issue and we would expect to see documentation dealing with this topic as part of a future ESC suite.	The Learning and Development (L&D) section of our NWS Integrated Management System supports compliance with Site Licence Condition 36 (Organisational Capability) to ensure the maintenance of skills throughout the period of active institutional control. Our Heads of Profession, Line Managers, Human Resources Directorate and management team are responsible for ensuring that Suitably Qualified and Experienced Personnel (SQEP) and competent services are available to fulfil our EHSS&Q capability.	Management and Dialogue § 4.8
SCM37	LLW Repository Ltd should continue to look at how its implementation of the ESC can be improved and enhanced. In particular we recommend that, with the implementation of new and revised WAC, LLW Repository Ltd	Following the introduction of the current LLWR Disposal WAC in 2016, we have maintained a register of issues and improvements identified by both customers and NWS personnel involved in the waste acceptance process. Most issues concern minor editorial changes, however, there are	Implementation

	considers the adequacy of the checks it completes on waste transfers to the site to confirm that consignors have adequately interpreted and met the new requirements and have provided all the necessary waste information associated with those transfers.	some notable exceptions, such as the need for further clarification on the WAC Heterogeneity condition (L3.2.3) and Reactive Metals and Materials (L2.5) following recent research in this area. We aim to address all issues and suggested improvements gathered to date as part of the next update to the WAC. Other LfE and operational experience will also be used in the WAC update proposed (see *Implementation*). We have undertaken a Waste Acceptance Procedure (WAP) review in response to an Office for Nuclear Regulation (ONR) requirement. The objectives of the WAP review were to: • understand the root cause(s) for challenges in waste flow from producer to treatment provider or disposal site (e.g. waste being accumulated or delayed at consigning sites); • consider how best to deliver robust, compliant, efficient waste management arrangements to	

		support the UK nuclear mission, including better alignment to decommissioning; • identify areas for improvement within the WAP in the shorter-term, plus define user requirements to feed into longer-term changes and the wider picture. As part of the waste mis-consignment mitigation project we have also undertaken a study looking at container x-ray technology and also gas detection methods (see O&E20).	
SUE1	LLW Repository Ltd should continue to review the quality and appropriateness of past borehole data and make sure it is appropriately used to inform future ESCs.	The 2026 ESC geological update fully addresses this recommendation through a comprehensive review, re-interpretation, and quality assessment of all historical borehole records alongside newly acquired intrusive data. The programme evaluated 1,249 intrusive records using a systematic quality-scoring framework to identify data reliability and suitability for modelling. High-quality records were prioritised in developing the updated stratigraphic framework, while lower-confidence logs were	Hydrogeology § 3.2.2

		reassessed, re-interpreted, or de-weighted where drilling methods (e.g., percussive techniques) had produced disturbed or unrepresentative samples. New 2021 cored boreholes, thin-section analysis, CPT correlations, and detailed geomorphological and geophysical evidence were used to validate or correct earlier interpretations, ensuring past data are applied appropriately and only where consistent with the improved conceptual understanding.	
SUE2	As understanding and technology related to geophysical surveying increases, we expect LLW Repository Ltd to take this into account and to undertake further geophysical surveys or reprocess existing information as appropriate, to further inform site geological understanding.	Since the 2011 ESC, we have incorporated major advances in geophysical methods through the acquisition of new high-resolution datasets exceeding 2,700 km of geophysical coverage. Existing legacy datasets were reprocessed or re-interpreted using improved velocity modelling and modern seismic processing techniques. These updated and reprocessed datasets were integrated with intrusive and geomorphological evidence to refine the bedrock surface, identify new features such as the Madeline Channel, better resolve tunnel valleys, detect faulting beneath the	Hydrogeology § 3.2.2

		site, and constrain Quaternary unit geometries.	
SUE3	LLW Repository Ltd should seek to undertake further opportunistic investigations of the area between the LLWR and the coast, taking into account access constraints and without compromising the integrity of the protected environment. This might, for example, include re-assessment of existing information and the construction of boreholes immediately adjacent to, but not within, the protected sites.	We have carried out a review of existing datasets as part of the continued development of the geological model for the site (L2 Hydrogeology) New monitoring boreholes will be constructed adjacent to the protected areas as part of the construction of the cut-off wall and capping of Vault 8. Several new deep boreholes were drilled around the site in 2021 as part of a study into the depth and properties of the bedrock in support of an investigation into the potential for enhanced disposal facilities (silos) to be constructed at the LLWR site. Data yielded from these new boreholes have been fed into our geological and hydrogeological models.	Hydrogeology § 2.2 and 3.2.2
SUE4	In future updates of the ESC, we expect to see clear identification of models being used and demonstration that they have clear audit trails.	As required by our Assessments Manual [37], models used in our assessments are clearly documented.	Environmental Safety During the Period of Authorisation Assessment of Long-term Radiological Impacts Hydrogeological Risk Assessment
SUE5	We recommend that any observed or predicted changes in the nature	The dunes are recognised as being relatively stable but the effects of coastal erosion on	Site Evolution § 4

	and extent of the dunes is considered in future reviews of the ESC hydrogeological models.	the dunes is recorded as part of regular surveys. Understanding has been incorporated into the assessment of coastal erosion.	Hydrogeology § 4.2.3
SUE6	As the shoreline is eroded, we recommend that geological information derived from the exposed cliffs is considered in the repository geological model where appropriate.	Studies of the cliff sections have been used to inform the development of the geological model and we will continue to collect data as it becomes available.	Site Evolution § 4 Hydrogeology § 4.2.3
SUE7	LLW Repository Ltd should include where possible the reduction of the remaining uncertainties in the repository conceptualisation as a site investigation objective.	It is recognised that there will always be a degree of uncertainty in the geological conceptualisation due to the heterogeneous nature of the Quaternary deposits and extrapolation of limited data sets in geological modelling in general. The effects of geological uncertainty and interpretation have been assessed as part of the hydrogeological modelling [101]. The report concluded that uncertainty in the bulk permeabilities, particularly of the B3 aquifer, is confirmed to be the dominant control on modelled bulk flow rate variability. Other sources of uncertainty are found to have only a small effect in comparison. A first-order	Hydrogeology § 2.2

		variance summation method has been used to combine the different uncertainty sources into final flow rate distributions for use in risk assessment. These distributions are well approximated by log-normal forms with bounding flow rates approximately 10 times faster or slower than the mean, which is consistent with variations in flow rates considered in previous groundwater assessment models. As such, while additional site investigation data will continue to be collected where it is required to support site development work and the geological model updated, it is not expected to significantly affect the overall uncertainty.	
SUE8	LLW Repository Ltd should further investigate the potential effect of incised infilled channels acting as fast groundwater pathways.	The hydrogeological model takes into account the different properties of the geological units. The channels in the B2 unit have been infilled with lower permeability material and are not expected to act as fast pathways.	Hydrogeology § 4.2
SUE9	LLW Repository Ltd should continue to review the importance of contaminant migration in the	Contaminant transport in the upper sandstone has been considered as part of the development of the hydrogeological	Hydrogeology § 4.2

	upper sandstone. This should include consideration of the relative importance of fracture flow versus matrix flow in the upper sandstone, as well as the potential effect of faults on flow within the upper sandstone.	model, The site investigation carried out in 2021 provided additional data on the properties of the sandstone and nature of the faulting. This has been incorporated into the hydrogeological conceptual model.	
SUE10	We recommend that applicable outcomes from the groundwater mound investigations should be considered in future updates of the ESC. If the groundwater mound is found to be the result of measurement errors, then we would expect the site hydrogeological understanding to be updated accordingly.	The groundwater mound has been considered further as part of the development of the hydrogeological conceptual model [102] and as part of the uncertainty studies [65]. The results indicate that although there is some uncertainty around the groundwater mound it does not materially affect the conclusions that uncertainty in the bulk permeabilities, particularly of the B3 aquifer, is confirmed to be the dominant control on modelled bulk flow rate variability. It is expected that new monitoring boreholes will be constructed in the vicinity of the mound as part of the construction of the cut-off wall and capping of Vault 8. This will be used to assess whether the mound is real or	Hydrogeology § 4.1.4

		is an artifact of the well construction technique.	
SUE11	LLW Repository Ltd should monitor the effects of the construction of future vaults on contaminant migration and the behaviour of the existing trench contamination plume throughout the construction and restoration sequence.	The objectives of the monitoring programme include the following: To define baseline conditions before specific engineering developments or activities, such as the construction of a new repository component (for example, a vault) or the disposal of wastes at a particular location. To confirm that construction activities are not giving rise to unacceptable environmental hazards by direct measurement of their impacts.	Monitoring § 3.4
SUE12	LLW Repository Ltd should consider potential improvements to its modelling of small and medium scale behaviour of leachate within the waste mass and continue to align groundwater flow and contaminant transport models with the engineering design.	We have developed an Engineering Performance Assessment which provides us with a conceptual description of the evolution of the engineered barriers and also provides a parameterisation of barrier performance. The EPA is based upon our engineering design. The conceptualisation and parameterisation of barrier evolution defined in the EPA is used in our site-scale hydrogeological models and in the Compartment Flow Model	Near Field Engineering Performance Assessment Hydrogeology Assessment of Long-term Radiological Impacts Hydrogeological Risk Assessment

		which is an integrated part of our groundwater assessment model. In the near-field modelling, we have considered the infiltration through the cap at a variety of scales to understand the 'average' behaviour in a vault compared with e.g. localised behaviour of a single container (as it is perforated), or a stack of containers both with 'average' (i.e. uniform) infiltration, and localised enhanced infiltration such as may occur under a defect before geomembrane failure. In this respect, we are tying the modelling very closely to the understanding of performance of the cap (and also the vault bases). Near-field modelling at various length scales has been used to inform our understanding of contaminant release in, and transport through, the grouted waste mass. We have used this in the groundwater assessment model through the development of the dual porosity model. The engineering evolution cases defined in the EPA have been used to help define	

		appropriate assessment cases in the groundwater assessment model.	
SUE13	We will expect future updates of the ESC to improve presentation of models used for site understanding, to improve the clarity of documentation.	We have considered how best to present all the available data and substantial body of work that underpins the geological and hydrogeological models.	Hydrogeology
SUE14	To better inform the conceptualisation of the overtopping sequence we recommend that the hydrogeological characteristics of the area of land between the vault and cut-off wall are considered for further investigation.	Further site investigation work is planned as part of cut-off wall construction. This will provide additional data on the hydrological properties. The existing data sets have been reviewed as part of the development of the hydrogeological model. The cap is expected to greatly reduce infiltration into the waste combined with a design that incorporates passive drainage that reduces the risk of overtopping.	Hydrogeology § 2.2 Engineering Design Engineering Performance Assessment
SUE 15	For future updates of the ESC we recommend that a longer period of monitoring data is used to calibrate and build confidence in numerical models developed to support safety assessments.	The updated hydrogeological model has been calibrated using data from 1989 to 2018.	Hydrogeology § 5.2.2

SUE16	We recommend that future model calibration recognises and uses quantitative tests as part of the calibration process and summarises them appropriately.	The approach to model calibration and parameter selection is captured in the hydrogeological modelling report [101]. For the current hydrogeological model, a semi-automatic calibration methodology, using inverse modelling concepts inspired by [103], is used to augment the process. This seeks to make the most effective use of the available system information and observations to obtain estimates of the parameter values. The approach also helps to understand how uncertainty is propagated through the modelling process.	Hydrogeology § 2.5
SUE17	LLW Repository Ltd should consider use of quantitative analysis to support the qualitative interpretation of groundwater models and build further confidence.	We have always employed and will continue to employ quantitative analysis and qualitative interpretation.	Hydrogeology § 5.1
SUE18	LLW Repository Ltd should clearly substantiate its choice of parameters and data ranges used in the calibration of future hydrogeological models.	We believe that we did this in the 2011 ESC although the presentation may not have been accessible and some information was in underlying reports. We have sought to improve the presentation in the 2026 ESC.	Hydrogeology § 5.2

SUE19	LLW Repository Ltd should make sure that an objective of the routine site environmental monitoring programme is the systematic collection of hydrological and hydrogeological data to support future refinements of the ESC hydrogeological models.	The objectives of the monitoring programme include the following: To develop and build confidence in the models of the repository system by collecting data that may be used to refine conceptual models or in model parameterisation, calibration or validation These objectives guide our approach.	Monitoring § 3.4
SUE20	LLW Repository Ltd should provide a way of building confidence that there are no other equally valid model parameterisations that would significantly impact the ESC.	The approach to model development is captured in the hydrogeological modelling report [101] along with the approach to model uncertainty [65].	Hydrogeology § 2.5
SUE21	In future updates of the ESC, we expect this representation in the hydrogeological flow model to be better underpinned, taking into account the variability of the geological media in the unsaturated zone and changes brought about by the trench and vault development and restoration sequence.	The approach to model development is captured in the hydrogeological modelling report [101] and takes into account future changes.	Hydrogeology § 2.5

SUE22	Future ESC updates should seek to provide a clear linkage between the variant scenario models undertaken and the assessment scenarios utilised in the main ESC assessment. Where appropriate full descriptions of the nature and implication of the variant scenario models should be presented.	We have provided such cross referencing where appropriate.	
SUE23	We expect future updates of the ESC to further explore conceptual model uncertainty as well as realistic alternative conceptualisations.	We have devoted considerable effort to investigating geological and hydrogeological uncertainties and capturing their implications in assessments [65].	Hydrogeology § 5.3 Assessment of Long-term Radiological Impacts Hydrogeological Risk Assessment
SUE24	LLW Repository Ltd should seek to better understand the nature and significance of geomorphology and the resulting depositional environment on spatial variability of hydraulic conductivity. Where appropriate the output of these investigations should inform the nature and number of groundwater flow model realisations.	This is covered as part of the hydrogeological model uncertainty studies [65].	Hydrogeology § 5.3

SUE25	We recommend that in future updates of the hydrogeological modelling used to inform the ESC, LLW Repository Ltd should provide a more transparent and structured approach to the treatment of uncertainty in hydrogeological understanding.	This is covered as part of the hydrogeological model uncertainty studies [65]	Hydrogeology § 5.3 Assessment of Long-term Radiological Impacts Hydrogeological Risk Assessment
SUE26	Before the construction of future vaults we recommend that LLW Repository Ltd aims to better understand uncertainties associated with the variability in the height of groundwater, connectivity and hydraulic head. As future vaults are developed, we expect site-derived information to be used to inform hydrogeological modelling and the engineering design.	The monitoring programme is designed to collect groundwater data to inform future vault development and support model development.	Hydrogeology § 4.2.3 Monitoring § 7
SUE27	As the repository is developed, future updates of the ESC should seek to incorporate, where appropriate, further site-derived information together with further	The monitoring programme is designed to support future site and build confidence in the models of the repository system by collecting data that may be used to refine	Monitoring § 7

	improvements in the functionality of the groundwater models. This might include, for example, changes in groundwater height associated with increased sea levels or changes in hydraulically effective rainfall	conceptual models or in model parameterisation, calibration or validation.	
SUE28	We would like to see the continued collection of hydrogeological information and material properties of the geologies adjacent to and below the future vaults. In particular, we would like to see ongoing characterisation and monitoring of the area covered by the final cap.	We will continue to collect site investigation and monitoring data as part of future vault development to inform model parameterisation.	Monitoring § 7 Hydrogeology § 2.2
SUE29	We recommend that LLW Repository Ltd further reviews its water budget and calculations of HER to assess uncertainties and changes over time and further substantiate the chosen parameter values.	HER has been considered as part of the EPA work with specific interest in cap infiltration under future climate conditions. We will continue to collect data from monitoring cap run-off as part of evaluation of the cap performance.	Monitoring § 7.6 Engineering Performance Assessment § 4 and 5.2

SUE30	LLW Repository Ltd's forward programme should include updates to the site geochemical understanding.	We have carried out further work to update the hydrogeochemical interpretation of the LLWR site [104].	Hydrogeology § 4.1.5
SUE31	LLW Repository Ltd should substantiate that the selected Kd data are consistent with site conditions and review any future developments in the modelling of retardation.	We consider that the K_d data are appropriate to site conditions although mostly we do not have site-specific measurements. We note that there is limited sensitivity to the parameter as most of the impacts arise from radionuclides that do not sorb strongly.	
SUE32	The need to develop and maintain an understanding of the tritium source term should be included in any consideration of future trench monitoring infrastructure requirements.	Tritium monitoring is used to provide qualitative confidence that observed behaviour remains consistent with the site conceptual model and engineered barrier performance, rather than to quantitatively reconstruct inventory. Given the significant and irreducible uncertainty in the historical trench tritium inventory, existing monitoring, assessment and change-management arrangements are considered proportionate and demonstrate that tritium is being managed to the extent that is reasonably practicable within the ESC.	Monitoring

SUE33	To further reduce uncertainty associated with the extent of the unsaturated zone under the EDA and to support the hydrogeological assessment of the EDA, we recommend that LLW Repository Ltd consider an increased level of site characterisation in this area.	The EDA is no longer a design feature.	
SUE34	For completeness, we recommend that in future, LLW Repository Ltd improves the ESC further by consideration of more extreme, but physically plausible sea level rise scenarios out to 2100, such as the H++ scenario.	We have adopted a range of scenarios which bound the plausible uncertainty for use across the ESC. The H++ scenario is of less relevance as it only applies to 2100, whereas our timescales of interest are much greater. Instead, we have developed an accelerated ice-sheet collapse for consideration as a 'what-if' case in our coastal erosion assessment, and a high emissions scenario for the PoA assessment.	Site Evolution § 4 Assessment of Long-term Radiological Impacts § 3.5 Environmental Safety During the Period of Authorisation § 4.5.5
SUE35	In between major ESC updates, we recommend that LLW Repository Ltd maintains a good understanding of the latest developments in climate change science, for example the results of	Our projections are based on the latest understanding set out by the IPCC in its sixth assessment report, supplemented by more recent and regional understanding. We have also applied bespoke methods to extend the	Site Evolution § 3

	the fifth assessment of the IPCC (IPCC 2013), and its potential impact on the ESC projections.	projections over the extended timescales of interest.	
SUE36	As part of the forward programme, we recommend that LLW Repository Ltd keeps up to date with research on short-term and long-term climate change projections.	We maintain a watching brief and ensure the ESC is aligned with the latest science. We have used the latest scientific understanding from the sixth assessment report of the IPCC in our current projections.	Site Evolution § 3
SUE37	We recommend that LLW Repository Ltd should re-visit technologies and benefits of onsite measurement of isostatic uplift as part of future ESC reviews.	We have not identified any additional work as the rate of isostatic uplift is not the most significant contributor to the uncertainty in relative sea level.	
SUE38	The company should maintain a watching brief on the development of understanding long-term changes in storminess associated with climate change, as well as the frequency and magnitude of storm surge events.	Our projections have taken account of the current scientific consensus on these matters.	Site Evolution § 3
SUE39	Due to their importance in determining the rate of erosion and the potential benefits from the use	Geological data will continue to be collected from the cliff sections as it becomes available	Monitoring § 7 Hydrogeology § 2.2

	of more site-specific coastal recession models, we recommend that local shallow geological information continues to be collected from ongoing site development activities, cliff exposures and, if required, dedicated investigation programmes.	and has been used to inform the geological model development.	
SUE40	We recommend that future updates of the ESC consider the potential for increased use of information on local shallow geological sequences in the development of site-specific coastal recession models.	Knowledge of the bedrock and Quaternary geology in the vicinity of the repository has increased significantly since 2011 and this understanding is reflected in the coastal evolution projections for the 2026 ESC. The conceptual model for coastal evolution recognises that coastal geomorphology and erosion rates will be dictated by the geology. At the broadest scale, bedrock cropping out above sea-level will form resistant cliffs while glacial sediments will be more rapidly eroded. Understanding of the elevation of bedrock in the vicinity of the repository has been improved since 2011 following an extensive programme of intrusive and non-	Site Evolution § 4.2

		intrusive ground investigation and 3D geological modelling. The geological model provides an update to the stratigraphy and origin of Quaternary deposits, which has a bearing on future sediment budgets. The cliff recession model, which is one of the tools used to assess future coastal erosion for the 2026 ESC, uses sediment inputs from cliff recession to determine beach volume and the associated level or natural cliff protection. Despite these improvements to the geological model, the implications to erosion modelling are limited. This is because the cliff recession model only considers the proportion of eroded material which is beach-building sand and gravel, and the refined stratigraphy of the new model does not change this information.	
SUE41	We recommend that LLW Repository Ltd considers how differences in localised erosion rates resulting from geological heterogeneity and complex coastal geomorphological processes could	This is described in the relevant report. The conceptual model for the coastline shows that the regional scale coastal geomorphology is in balance with the angle of incoming waves. A ‘swash aligned’ coast has developed that is perpendicular to the	Site Evolution § 4.2

	be better communicated and presented within future updates to the ESC.	angle of incoming waves. This means that net alongshore sediment transport is minimised. At the local scale, the coast shows a series of subtle headlands and bays that reflect variations in local geology. Headlands form where boulder lags (e.g. Barn Scar) or bedrock (e.g. Nethertown) crop out on the foreshore providing some degree of cliff protection or resistance of the cliff; bays form between headlands. The swash aligned coast is expected to persist as the coastline erodes, meaning the alignment of the shoreline will persist. The location of subtle headlands will change over time. Existing headlands will be lost as the protection afforded by foreshore boulder deposits diminishes with sea-level rise and new headlands may appear if boulder deposits are eroded from the cliffs. This will persist until all glacial sediment is eroded and bedrock crops out at the coast, which is not expected to occur before the repository is completely eroded. There is no evidence from the site or hinterland geological investigations for boulder or	

		cobble-rich strata that could form lag deposits similar to Barn Scar. Variation in erosion rates along the shore are considered in the latest work by modelling three transects with the cliff recession model. Each transect has unique parameters for sediment inputs from cliff recession, beach volume and cliff height. Models generate only slightly different results, because local variations in sediments are small and because the models are more greatly influenced by uniformly-applied sediment budget outputs and sea-level rise parameters. These transects will assist in communicating and presenting complex coastal geomorphological processes including those resulting from geological heterogeneity.	
SUE42	Although we accept that over the long term storm events will not have a significant impact on the overall predicted coastal erosion rate, such events could become more important as the coast approaches and encounters the LLWR in the future. We	Our coastal monitoring programme has emphasised the importance of storm events for coastal erosion and this has been incorporated into the coastal erosion conceptual model. We have explored the sensitivity of our coastal evolution models to the nature and frequency of storms. We have reviewed the latest scientific understanding	Site Evolution § 3.5.5, 4.2.5 and 4.3.4

	recommend that LLW Repository Ltd considers investigating these phenomena further or identifying any national or international studies that support further understanding.	on potential changes to the frequency and magnitude of storm events, and found that there is no consensus that they would become more frequent or severe; sea level rise is the most significant driving factor for changes to erosion rates.	
SUE43	We recommend that future updates to the cliff recession models consider the outputs of the geophysical surveys of the site frontage and Drigg barrier carried out in autumn 2009 and the derived clast size distribution sections.	An updated geological model supports the coastal evolution assessment. This model includes the results of the 2009 geophysical survey of the Drigg barrier. The 2009 survey concluded the barrier is a composite landform comprising a northern section of glacial sediment and a southern spit formed of prograding gravel beach ridges. The whole landform is mantled by dunes. No evidence was found to support a theory that the River Irt formerly took a direct route to the coastline through the barrier. With the Eskmeals spit, the Drigg barrier impounds the Ravenglass estuary complex. The impacts of sea-level rise and changes in sediment budget on estuary evolution and the Drigg barrier were addressed in the 2011 ESC and have been reassessed for the 2026 ESC. The barrier is expected to be lost to coastal erosion, meaning the rivers Irt and	Site Evolution § 4

		Mite will develop into tidal inlets. Coastal erosion and cliff recession will always affect the repository before estuary processes could impact the repository.	
SUE44	We recommend that LLW Repository Ltd maintains ongoing links with wider investigations into the characterisation, assessment and remediation of eroding historical landfills, and incorporates relevant learning into the ESC.	Subsequent to the 2011 ESC, risks arising from eroding landfill sites around the UK coast have been reviewed. We have used understanding from eroding landfills to inform our projections, particularly surrounding the fate of eroded waste materials and presented a dedicated appendix in the Level 3 report on the matter. We have also supported CIRIA in production of their 2013 book ‘Guidance on The Management of Landfill Sites and Land Contamination on Eroding or Low-Lying Coastlines (C718)’. Since publication, this guidance has been updated (CIRIA 2018) following experience from interventions at three coastal landfill sites. More recently, we have supported preparation of a report for the Environment Agency titled ‘Regulatory Considerations of Climate Change Impacts and Adaptation for Waste Deposit, Landfill and Land Contamination’. Where relevant, guidance in these documents has been	Site Evolution § 4.3.8

		adopted in coastal evolution projections for the 2026 ESC.	
SUE45	We recommend that LLW Repository Ltd considers investigation of the significance of interactions between different erosion processes, including significant thresholds, during coastal erosion processes.	Subsequent to the 2011 ESC and in response to an EA technical query, we undertook an assessment of the eroding waste cliff using slope stability modelling and natural analogues from the west Cumbrian coast. This work illustrated the morphology of an eroding cliff formed in wastes at various stages of degradation and the likely mechanisms of failure. More recent work undertaken discusses the different modes of site disruption under different sea-level projections. These comprise undercutting of the vaults in projections of relatively low sea-level rise to direct wave attack in higher sea-level projections. In both cases, analogue sites are provided to help visualise the failure mechanisms and the behaviour of ISOs that are substantially intact when exposed to coastal process.	Site Evolution § 4.3.6 and 4.3.8
SUE46	LLW Repository Ltd should identify any significant changes to sea defences on the coastline to the	There have been no changes to the sea defences north and south of Drigg Beach.	

	north and south of Drigg and assess the implications in future updates of the ESC. This should include changes to the current SMP that could impact on the LLWR.	The SMP has not changed and states 'No active intervention'.	
SUE47	Because of the differences in waste age between the RDA and EDA, we recommend that LLW Repository Ltd should consider the implications of differences in degradation state on erosion between the newer EDA vault waste and the older RDA vault waste.	We will no longer be distinguishing between the RDA and the EDA. However, we agree that consideration of waste ageing is relevant. Degradation of the waste in the repository when exposed to coastal processes has been considered in our coastal evolution projections. The process of degradation determines the degree to which the wastes will contribute to the beach sediment budget. This assessment does not distinguish between wastes stored in different areas of the repository, but the assessment suggests that these variations will not be significant. This is because even if waste is relatively intact when first exposed to coastal processes, the impact of saline and oxic conditions will result in rapid degradation. However, consideration is given to differences between the first vault wastes to	Site Evolution § 4.3.8

		be exposed and the last vault wastes to be exposed. The time difference is expected to be >1,000 years, which is far longer than differences in the ages of the vault wastes at the end of operations. However, since these items will be limited in number and distributed across the site, they are not expected to have a significant impact on coastal evolution. Analogues are used to help describe the possible impact of large waste items on coastal evolution.	
SUE48	We consider that the monitoring capability adjacent to and within the trench disposals would benefit from increased functionality both before and after the placement of the final capping system.	Changes to the monitoring infrastructure have been considered as part of the capping works and we will continue to monitor leachate levels in the trenches. The existing probe holes into the trenches were never designed for monitoring but for venting gas. Some of these will be retained and extended as part of capping. The option for drilling new points is retained but the risks to workers and the uncertainty in creating effective monitoring points is considered to be unacceptable at present.	Monitoring § 7 Engineering Design § 3.2.9
SUE49	We recommend that the company takes background groundwater	The monitoring programme includes sampling of surface water and groundwater	Monitoring § 3.6

	concentrations of contaminants into account within the LLWR non-radiological groundwater monitoring programme.	up-gradient of the site. Screening criteria have been identified in order to assess the impact of LLWR site operations, including disposals, on river water, surface water and groundwater taking into account background concentrations. Monitoring Assessment Levels (MALs) are used to assess the non-radiological impact of the LLWR site operations, including disposals, on groundwater. In general, MALs are set at the LLWRAS or the level discernible above the background, whichever is higher. The discernible level has been calculated at the 95th percentile of the background dataset. The use of MALs will result in a reduction in the number of false positives.	Hydrogeological Risk Assessment § 5 and 2.1.2
SUE50	Because the elevated background groundwater concentrations of some non-radiological contaminants could be the result of activities external to the LLWR, such as agriculture, we recommend that LLW Repository Ltd considers whether further sampling of up gradient	The monitoring programme includes sampling of surface water and groundwater up-gradient of the site. Screening criteria have been identified in order to assess the impact of LLWR site operations, including disposals, on river water, surface water and groundwater taking into account background concentrations.	Monitoring § 3.6 Hydrogeological Risk Assessment § 5 and 2.1.2

	groundwater is necessary to ensure the timely and effective identification and quantification of offsite sources.	Monitoring Assessment Levels (MALs) are used to assess the non-radiological impact of the LLWR site operations, including disposals, on groundwater. In general, MALs are set at the LLWRAS or the level discernible above the background, whichever is higher. The discernible level has been calculated at the 95th percentile of the background dataset. The use of MALs will result in a reduction in the number of false positives.	
SUE51	We recommend that LLW Repository Ltd makes further efforts to improve understanding of background levels of radioactivity in and around the site in the future ESC.	The monitoring programme includes sampling of surface water and groundwater up-gradient of the site. Screening criteria have been identified in order to assess the impact of LLWR site operations, including disposals, on river water, surface water and groundwater taking into account background concentrations. Monitoring Assessment Levels (MALs) are used to assess the non-radiological impact of the LLWR site operations, including disposals, on groundwater. In general, MALs are set at the LLWRAS or the level discernible above the background, whichever is higher. The discernible level has been	Monitoring § 3.6

		calculated at the 95th percentile of the background dataset. The use of MALs will result in a reduction in the number of false positives.	
SUE52	We recommend that the company reviews its tritium monitoring capability before the placement of surcharge material onto the trench disposals.	Monitoring in and around the trenches for tritium during capping has been incorporated into the monitoring programme.	Monitoring
SUE53	We expect the company to take into account the extended operational period of the site in the design of monitoring infrastructure and strategies.	The long-term monitoring requirements and changes to the programme due to future developments and site closure have been considered as part of the development of the monitoring strategy.	Monitoring § 7
SUE54	In future updates of the ESC, we would like to see use of site-derived monitoring information wherever practicable and beneficial in the development and calibration of conceptual and assessment models and to inform site understanding.	We use site monitoring data as input to and to inform both the assessment models for development of the marine leachate discharge pathway, tritium bearing gas pathway and Drigg stream pathway in the hydrogeological conceptual model and the assessment of impacts during the PoA.	Hydrogeology § 5.2.2 Environmental Safety During the Period of Authorisation
SUE55	We recommend that LLW Repository Ltd considers how	The long-term monitoring requirements and changes to the programme due to future	Monitoring § 7 and 7.2.5

	monitoring requirements and priorities will change during the period of authorisation, ensuring that no actions are taken (for example, relating to site engineering) that would unnecessarily jeopardise future monitoring opportunities.	developments and site closure have been considered as part of the development of the monitoring strategy.	
SUE56	We recommend that LLW Repository Ltd reviews the strategy presented in Hayes et al. (2011) to make sure that its recommendations have been appropriately considered.	The long-term monitoring strategy has been reviewed as part of the 2026 ESC and will continue to be developed in response to learning from monitoring and to adapt to future site developments	Monitoring § 7

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