

The LLWR Environmental Safety Case

Application to Vary LLWR's Permit

LLWR/ESC/R(13)10057 Issue 1

October 2013

	Name	Signature	Date
ESC Project Manager	Richard Cummings		25.10.13
Head of Safety, Regulatory Liaison and Governance	Nigel Lister		25.10.13

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Preface

The Low Level Waste Repository (LLWR) is the United Kingdom's principal facility for the disposal of solid low-level radioactive waste (LLW). The LLWR is owned by the Nuclear Decommissioning Authority (NDA) and operated on behalf of the NDA by a Site Licence Company (SLC) – LLW Repository Ltd. The LLWR is operated under the terms of a Permit issued by the Environment Agency.

We, LLW Repository Ltd, submitted our revised Environmental Safety Case to the Environment Agency on 1st May 2011 (2011 ESC). This satisfied a requirement in the LLWR's current Permit. Since its submission, the Agency has been undertaking a review of the 2011 ESC, which will inform the granting, conditions and requirements of a future permit.

Further technical work has been undertaken since the delivery of the 2011 ESC, including in response to a number of queries and requests for information set out by the Environment Agency during their review.

In parallel with the Agency's review, the LLWR is implementing the ESC, as required by our current Permit.

The LLWR has considered the feedback provided by the Environment Agency so far during the review process. Having consulted with the Environment Agency about progress with the review of the 2011 ESC, we are now making an application to vary our existing Permit. This application is based on the 2011 ESC, the subsequent work, and the feedback from the Agency.

This document supports, and is intended as a high-level explanation of, our application. It provides a 'route map' to supporting information, briefly summarises technical developments and changes since the 2011 ESC, and sets out and explains the changes requested to the Permit. There is also a second supporting document, which describes in more detail the technical developments and changes since the submission of the 2011 ESC. There are also further supporting references to these two documents.

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Executive Summary

The disposal of radioactive waste at or from the Low Level Waste Repository (LLWR) is regulated by the Environment Agency. The LLWR currently holds a Permit under the Environmental Permitting Regulations allowing it to dispose of and transfer radioactive wastes. This document is the top-level supporting document to an application by the LLWR to vary its existing Permit. The application concerns the disposal of solid low-level radioactive waste (LLW) to the LLWR. The application is based on a revised Environmental Safety Case (ESC) for the Repository.

The LLWR submitted a fully revised ESC to the Environment Agency in May 2011, referred to as the 2011 ESC. This was in response to a condition in the LLWR's current Permit. Since its submission, the Environment Agency has been undertaking a review of the 2011 ESC. In support of the review, we have engaged with the Environment Agency to answer questions and provide further information and clarification where required. Other technical work has also been undertaken since the delivery of the 2011 ESC.

We are required by our Permit to manage the site in accordance with the assumptions of the most recent ESC. To this end, we are implementing the 2011 ESC, which will be treated as a 'live' safety case within the LLWR's formal change control processes. The revised waste acceptance arrangements proposed in the 2011 ESC, and further developed during the Environment Agency's review, are being implemented where these comply with the current Permit. The implementation will ensure that the repository is operated in a safe and optimised way, consistent with the assumptions and results of the ESC.

Taking account of feedback and discussions with the Environment Agency, the LLWR is now submitting an application for a variation to its Permit.

This document is intended as a high-level explanation of our application. It provides a 'route map' to the information required for the application, briefly summarises technical developments and changes since the 2011 ESC, and explains the changes requested to the Permit and how we propose to control the wastes accepted for disposal at the site and their emplacement in the repository vaults under any revised permit.

The LLWR is currently prevented by the Environment Agency from disposing of LLW other than in Vault 8 (where only a small capacity remains unused). The 2011 ESC demonstrates that it is safe for the Agency to remove this restriction. Work since the 2011 ESC confirms that position.

We request that the Permit is varied to remove a number of specific restrictions:

- the annual limits on the activities disposed, which have no basis in the 2011 ESC;
- on the disposal of a small number of materials or items that might have implications for operational safety, which are best addressed through the LLWR's Waste Acceptance Criteria (WAC);
- on the disposal of chemical complexing or chelating agents, because it has been shown that the blanket restriction is not necessary and that some

complexants can be safely disposed, and sufficient control on the others can be exercised within the waste acceptance process.

The requirement in the Permit to manage the site in accordance with the assumptions of the most recent ESC will ensure that the following controls on waste acceptance are in place, consistent with the assumptions and results of the 2011 ESC and subsequent developments:

- disposal of LLW meeting our WAC or that otherwise have been assessed as meeting the requirements of the ESC;
- disposal of different radionuclides within specified limits (set out in this document), applied through a sum-of-fractions approach, such that the total radiological capacity of the site is not exceeded;
- the disposal of LLW with non-radiological toxic properties is limited to ensure that the capacity of the site to safely accept such wastes is not exceeded;
- wastes are emplaced according to our Waste Emplacement Strategy, which contributes to ensuring that environmental performance is optimised.

The LLWR's procedures will ensure that the Environment Agency is informed of any significant changes to the above controls.

Since the Environment Agency imposed its restriction on the further disposal of waste, the LLWR has been allowed to continue to accept LLW for storage, pending the outcome of the 2011 ESC, the Agency's review of the ESC, and the permitting process. We propose that a revised permit allows conversion of the stored waste to disposed waste if it can be demonstrated that disposal is consistent with the 2011 ESC and disposal is the Best Available Technique (BAT) for managing the waste.

We also propose that the revised permit allows waste to continue to be accepted for storage, or implementation of the revised permit is delayed, for at least three months, to allow time for the LLWR and waste consignors to make the necessary changes to their systems and procedures to meet the requirements of the revised permit once its contents are known.

In accordance with the 2011 ESC, we wish to begin the progressive installation of engineered barriers necessary to eventually close the site, starting with the extension of the existing cut-off wall in the ground and final capping of Vault 8 and the adjacent strip of the trenches.

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1 Introduction

The Low Level Waste Repository (LLWR) is the United Kingdom's principal facility for the disposal of solid low-level radioactive waste (LLW). LLW has been disposed at the LLWR since 1959, initially tipped into trenches and, since the late-1980s, packed in containers and placed in engineered vaults.

The LLWR is owned by the Nuclear Decommissioning Authority (NDA), which is a non-departmental public body created under the Energy Act 2004. The NDA is a strategic authority that owns the 19 civil nuclear sites, and associated nuclear liabilities and assets, previously under the control of the United Kingdom Atomic Energy Agency and British Nuclear Fuels Ltd.

LLW Repository Ltd is the Site Licence Company that operates the LLWR on behalf of the NDA.

The disposal of radioactive waste at or from the LLWR is regulated by the Environment Agency. The LLWR currently holds a Permit [1] under the Environmental Permitting Regulations allowing it to dispose of and transfer radioactive wastes. The LLWR submitted a fully revised Environmental Safety Case (ESC) to the Environment Agency in May 2011, referred to as the 2011 ESC [2]. This was in response to a condition in the LLWR's Permit. Since its submission, the Environment Agency has been undertaking a review of the 2011 ESC. In support of the review, we have engaged with the Environment Agency to answer questions and provide further information and clarification where required.

We are required by our Permit to manage the site in accordance with the assumptions of the most recent ESC. To this end, we are implementing the 2011 ESC. The 2011 ESC is being implemented as a 'live' safety case within the LLWR's formal change control processes. The revised waste acceptance arrangements proposed in the 2011 ESC, and further developed during the Environment Agency's review, are being implemented where these comply with the current Permit. The implementation will ensure that the repository is operated in a safe and optimised way, consistent with the assumptions and results of the ESC.

Taking account of feedback and discussions with the Environment Agency, the LLWR is now submitting an application for a variation to our Permit. The formal application for a variation is made using Environment Agency RSR Forms A, C3 and F [3, 4, 5]. The objective of this document is to provide supporting information in relation to that application. This includes details and an explanation of what the LLWR is asking for in any revised permit.

The application is also supported by a more technical document, the 'Developments' report:

- *Developments Since the 2011 ESC*, LLWR/ESC/R(13)10058 [6].

The *Developments* report provides a summary of the technical and management changes since the 2011 ESC, including work undertaken in response to various Environment Agency queries and requests for information. It is not intended as a 'standalone' document but rather it is assumed that the reader is familiar with the 2011 ESC. It is supported by a number of references that provide more detailed information and which also support our permit application.

The application for a variation is concerned with the disposal of solid LLW on the site. It is not concerned with the contaminated land that is present on the site, arising in part from the original use of the site as a Royal Ordnance Factory for the manufacture of explosives.

We note that an Article 37 submission will be made to the European Commission, covering changes in proposed disposals to the LLWR.

The rest of this document is structured as follows:

- in Section 2 we indicate where various information required as part of the application is provided;
- in Section 3 we set out what we are asking for in any permit variation and how we propose to control what wastes are accepted for disposal at the site and their emplacement in the repository vaults under any revised permit.

As noted above, we recognise that this application needs to be read in conjunction with the 2011 ESC. Some readers may find it helpful to refer to the Non-technical Summary of the 2011 ESC [7]. This provides a context for the requests set out in this document. More detailed information can be found in the 2011 ESC suite of documentation that is referenced in the next section.

2 Information Requirements

A range of information supports the application for a variation to the LLWR's existing Permit. A simple 'route map' to this information is provided in this section.

2.1 Information Requested in the Application Form

The application requires details of the LLWR's proposed changes, addressing how a range of applicable items is affected by the changes (see Table 2 of reference [3]). The relevant changes to this application for a variation relate to:

- a technical description of the activities;
- operating techniques to protect the environment and optimise the protection of people;
- the quantity of aqueous radioactive waste that might be discharged;
- monitoring;
- impact on people of discharges and on-site disposals;
- impact on non-human species of discharges and on-site disposals;
- receipt of radioactive waste and its subsequent management.

The 2011 ESC, including all the supporting documents, sets out a position on all of these issues and is the primary source of information on our proposals. The Level 1 and Level 2 documents comprising the 2011 ESC are as follows:

Level 1	
The 2011 Environmental Safety Case – Main Report [2]	
Level 2	
Management and dialogue	Management and Dialogue [8]
System characterisation and understanding	Site History and Description [9] Inventory [10] Engineering Design [11] Near Field [12] Hydrogeology [13] Site Evolution [14] Monitoring [15]
Optimisation and Site Development Plan	Optimisation and Development Plan [16]
Assessments	Environmental Safety During the Period of Authorisation [17] Assessment of Long-term Radiological Impacts [18] Assessment of Non-radiological Impacts [19] Assessment of Impacts on Non-human Biota [20] Waste Acceptance [21] Assessment of an Extended Disposal Area [22]
Audit	Addressing the GRA [23]

Below, we reference the key reports that address each of the information requirements in the bullet point list above.

Technical Description of the Activities

The proposed activities are described in the 2011 ESC documents, in particular the Level 2 reports *Engineering Design* [11], *Management and Dialogue* [8], *Optimisation and Site Development* [16] and *Assessment of an Extended Disposal Area* [22].

Operating Techniques to Protect the Environment and Optimise the Protection of People

Much of the 2011 ESC is concerned with the period after the end of management control when operational actions are not relevant. In the period before the end of management control, the following are relevant considerations:

- the approach to installing closure engineering (see reference [11]);

- the approach to managing the site during the period of authorisation (see reference [16]);
- the approach to the emplacement of waste (see Subsection 8.3 of reference [21]);
- the approach to managing discharges from the site (see reference [24]).

Overall, the Level 2 report *Optimisation and Site Development* [16] shows that we have done the best we reasonably can to minimise radiological impacts to people, taking account of facility development and design and how the facility is operated and managed during the Period of Authorisation (PoA).

The Quantity of Aqueous Waste that Might be Discharged

The LLWR is not seeking any changes to the Permit requirements related to the discharge of aqueous waste. However, the installation of closure engineering (e.g. the final cap) will result in a reduction in the quantity of aqueous radioactive waste that needs to be discharged, compared with the present. The disposal of additional wastes to the repository will have a minimal impact on aqueous discharges since the wastes are disposed in containers and any significant water present in the vaults after capping will be removed by pumping. The radiological impacts resulting from the discharge of aqueous wastes from the repository to the marine pipeline are addressed in the 2011 ESC Level 2 report *Environmental Safety During the Period of Authorisation* [17] (see Subsection 5.2 of that report).

Monitoring

The LLWR's position on monitoring has been presented in the 2011 ESC Level 2 *Monitoring* report [15]. Recent developments are covered in Subsection 2.3 of the *Developments* report.

Impact on People of Discharges and On-site Disposals

The impacts are addressed in the 2011 ESC Level 2 reports *Environmental Safety During the Period of Authorisation* [17] and *Assessment of Long-term Radiological Impacts* [18].

Impact on Non-human Species of Discharges and On-site Disposals

The impacts are addressed in the Level 2 report *Assessment of Impacts on Non-human Biota* [20].

Receipt of Radioactive Waste and its Subsequent Management

If the Environment Agency decides to issue a revised permit, further waste will be accepted at the site for disposal. Quantities of waste that might be received are set out in the 2011 ESC Level 2 report *Inventory* [10] and our approach to managing the wastes is covered in the Level 2 report *Optimisation and Development Plan* [16]. All wastes received on site are subject to various waste acceptance controls, which are set out in the Level 2 report *Waste Acceptance* [21].

2.2 Information on Developments and Changes since the 2011 ESC

It was noted above that the 2011 ESC was submitted in May 2011. Since that time there have been a number of technical developments. These include:

- the Environment Agency have raised a number of Issue Resolution Forms (IRFs) against which information, clarifications or updated assessments or arguments have been provided by the LLWR;
- other technical work programmes have been pursued, either at the request of the Environment Agency or work that the LLWR considered necessary;
- a small number of corrections and refinements to the existing calculations have been required;
- investigations of the waste in Vault 8 related to the condition of the containers and their content of cement grout;
- implementation of the ESC;
- radiological capacities have been recalculated taking account of slightly revised models and changed assumptions;
- developments to our forward plan;
- information has been collated relevant to the assessment of the site under the Habitats Directive.

These are considered in turn in the following subsections.

Issue Resolution Forms

At an early stage during their review of the 2011 ESC, the Environment Agency established an 'issues resolution' process whereby any questions, queries or further information requests could be formally raised with the LLWR. Issues were documented in IRFs, to which the LLWR responded. The issues were in three categories:

- **Regulatory Issue:** The most significant issues, which if not adequately addressed could lead to the Environment Agency being unable to permit further disposals or to severely limit or condition disposals.
- **Regulatory Observation:** Significant issues, which if not adequately addressed, could lead to significant limitation of disposals or permit conditions.
- **Technical Query:** Simple questions, unlikely on their own to affect any regulatory decision.

The LLWR has received and responded to 72 IRFs since the submission of the ESC.

For most of the IRFs, we believe that we have provided information or arguments that substantiate the position set out in the 2011 ESC. In a small number of cases,

we have modified the position set out in the 2011 ESC as a result of the Environment Agency's comments and requests. All of the IRFs are listed and summarised in the Appendix to the *Developments* report that supports this application [6]. Where there have been any significant changes in position that affect the ESC, we have provided further information and discussion in Section 2 of that report.

Technical Developments

Some key technical developments have taken place in a number of areas and these are discussed in Section 2 of the *Developments* report [6].

- We consider that the performance of the interim cap on the trenches is less good than was assumed in the 2011 ESC. This is on the basis of review of water balance data following the installation of new monitoring equipment. We have undertaken an optimisation study to consider how the interim cap could be improved to produce better performance. We have also recalculated estimates of radiological impact from releases to groundwater during the PoA. These developments are described in Subsection 2.2 of the *Developments* report.
- We have undertaken a review of the monitoring programme in the light of the ESC and have modified certain aspects of the monitoring programme. These developments are described in Subsection 2.3 of the *Developments* report.
- Work has been undertaken to develop the hydrogeological understanding of the site and in particular to better link hydrogeological and geological data in developing the hydrogeological conceptual model of the site. This work is described in Subsection 2.4 of the *Developments* report.
- As noted in the 2011 ESC, our treatment of the radiological impact of C-14 bearing gas was very cautious. We have undertaken a substantial programme of work to develop less cautious models of the near field and biosphere to better account for the impact of such radioactive gas. Our programme of work is described in Subsection 2.6 of the *Developments* report.
- A programme of work has been undertaken to determine the potential impacts arising from exposure to radioactive particles, sources and discrete items. The assessments have been used to derive appropriate waste acceptance criteria. The assessments are described in Subsection 2.11 of the *Developments* report and WAC are discussed in Section 3 of this report.
- Since the 2011 ESC, we have undertaken a review of the different organic complexants that might affect the release of radionuclides or toxic non-radioactive substances. In most cases, we have developed improved understanding to confirm that the complexants will have very limited impact. However, in the case of aminopolycarboxylic acids, we have identified a potential impact and have undertaken assessments and derived waste acceptance controls to take account of this impact. Relevant work and WAC are covered respectively in Subsection 2.5 and Section 3 of the *Developments* report.
- Our approach to specifying the capacities for certain toxic non-radioactive substances has been developed. Relevant work and WAC are covered

respectively in Subsection 2.9 and Section 3 of the *Developments* report.

Corrections and Refinements

Since the delivery of the 2011 ESC, a small number of corrections and refinements have been required (see Subsection 2.7 in the *Developments* report). These address the fact that:

- decay corrections were not correctly performed when calculating external dose to the public during the PoA;
- radionuclides with daughters were not correctly treated when setting WAC;
- the assessment model for the groundwater pathway was revised to remove inconsistencies between the separate calculations for the Extended Disposal Area (EDA) and Reference Disposal Area (RDA) repositories.

These revised calculations do not result in a significantly different position from that presented in the 2011 ESC.

Vault 8 Investigations

Investigations of the waste in Vault 8 have been undertaken focused on the condition of the containers and the quantity of grout and voidage in the containers. The results and conclusions of this work are discussed in Subsection 2.10 of the *Developments* report.

Implementation

A programme of work has been planned to implement the ESC and the implementation is underway. Further staff have been recruited to the ESC Team to support the application and further development of the ESC. These changes are discussed in Section 4 of the *Developments* report.

Radiological Capacities

Radiological capacities have been recalculated taking account of slightly revised models and changed assumptions. These are reported in Section 3 of the *Developments* report.

Forward Plans

Refinements to our forward work plans are discussed in Section 5 of the *Developments* report.

Information Relevant to the Assessment of the Site under the Habitats Directive

The Environment Agency has required information from the LLWR to support an assessment of the impact of changes at the LLWR on the Site of Special Scientific Interest (SSSI) that lies between the facility and the coast. This information is reported in reference [25].

3 Changes Requested to the Permit

In this section, we set out the changes that we are requesting in any revised permit, and how we propose to control the wastes accepted for disposal at the site and their emplacement in the repository vaults under any revised permit based on the ESC.

3.1 Disposal

The LLWR is currently prevented by the Environment Agency from disposing of LLW other than in Vault 8 (where only a small capacity remains unused). The 2011 ESC demonstrates that disposal would meet the Environment Agency's criteria and guidance and that it is safe for the Agency to remove this restriction. Work since the 2011 ESC confirms that position.

The LLWR would like permission to dispose of LLW within the area referred to in the 2011 ESC as the EDA, according to the approach and Site Development Plan described in the 2011 ESC. A revised permit that allows the site to be designed, operated and closed according to the 2011 ESC, which assesses disposal to the EDA and shows it is safe, will provide reassurance that a disposal option is available for all the UK's LLW in the United Kingdom Radioactive Waste Inventory that requires disposal in engineered vaults. This will be helpful in waste management planning, particularly for strategic planning for final decommissioning and restoration of the UK's reactor and other major nuclear sites.

In accordance with the 2011 ESC, we wish to begin the progressive installation of engineered barriers necessary to eventually close the site, starting with the extension of the existing cut-off wall in the ground and final capping of Vault 8 and the adjacent strip of the trenches.

3.2 Removal of Specific Restrictions

We request that the Permit is varied to remove a number of specific restrictions:

- The current Permit places annual limits on the activities disposed of a set of radionuclides or groups of radionuclides. The limits are set out in Schedule 8 of the Permit. These annual limits are not dictated by any safety or environmental performance requirement and have no basis in the 2011 ESC. The limits can reduce the flexibility of waste producers to consign waste and hence unnecessarily adversely affect operational or decommissioning activities. We are implementing an approach to radiological capacity management proposed in the 2011 ESC. The approach is described below in Subsection 3.5. This approach will ensure that wastes are not disposed at the LLWR that exceed the safe radiological capacity of the Repository.
- Schedule 8 of the current Permit prevents (unless agreed in writing by the Environment Agency) the disposal of a small number of materials and items that might have implications for operational safety. The materials and items are listed in paragraph 2 of Schedule 8, numbered (b)(i) to (b)(vi). Such restrictions are best derived from the LLWR's operational nuclear safety cases and implemented through the WAC.

- Paragraph 2 of Schedule 8 of the current Permit also prevents the disposal of chemical complexing (or chelating) agents (unless agreed in writing by the Environment Agency). Work during the development of the 2011 ESC and subsequently has shown that the blanket restriction is not necessary. Some complexants can be safely disposed, while sufficient control on the others can be exercised within the waste acceptance process. Our proposals are set out in Subsection 2.5 and Section 3 of the *Developments* report.

3.3 Management According to the ESC

We would like permission to continue to manage the LLWR in accordance with the ESC. This requirement in the revised permit will in itself ensure that adequate controls are put in place to safely design, operate and close the facility. These controls will include controls on waste acceptance.

The current Permit states a date, the 1st May 2011, by which an updated ESC had to be submitted to the Environment Agency. The ESC will be updated according to a formal procedure that has been implemented. The Environment Agency will be informed of the process for updating the ESC and of significant updates. We suggest that major updates of the ESC should take place approximately every 10 years if a review shows this to be necessary. If the Environment Agency wish to require major updates in any revised permit, we suggest that there should be flexibility to allow such updates to be aligned appropriately with construction works.

3.4 Status of Stored Wastes in Vaults 8 and 9

Since the Environment Agency imposed its restriction on the further disposal of waste, the LLWR has been allowed to continue to accept LLW for storage, pending the outcome of the 2011 ESC, the Agency's review of the ESC, and the permitting process. The stored wastes are located stacked above the disposed wastes in Vault 8 and in Vault 9. The stored wastes include some previously disposed in Vault 8 that have been moved to Vault 9 for operational reasons and are now stored.

The LLWR would like permission to convert the wastes currently stored in Vaults 8 and 9 into disposals. These wastes have been accepted against the WAC that were applicable at the time of receipt. We recognise that it must be demonstrated that disposal of these wastes is consistent with the 2011 ESC and that disposal at the LLWR is demonstrated to be an option that is consistent with BAT, i.e. it is the optimal management approach. If the Environment Agency wish to place a limit on the time allowed to make a case for conversion of stored to disposed waste, we request that at least a twelve-month period, from when the requirements in the revised permit are known, is allowed to deal with the backlog of wastes.

It may take both the LLWR and consignors some time to implement any new conditions or requirements in the revised permit and the resulting new WAC or other controls. It is therefore likely that consignors will wish to send wastes some months after the issue of a new permit that are not compliant with the conditions set out in the revised permit. It is assumed that the waste consignments would have been assembled in good faith against the existing permit and WAC. We propose that a similar process (to that described in the previous paragraph) should apply to such wastes if they are not compliant with the revised permit. Such wastes would be stored pending completion of the necessary disposal process. Alternatively, the

implementation of the revised permit could be delayed. Whichever approach is used, we propose a period of at least three months is allowed.

Any such wastes consignors wish to dispose after this period would be treated as a request for a variation of the WAC and assessed under our normal process for dealing with such requests.

Some details of our proposed approach are set out in Subsection 5.2 of the *Developments* report [6].

3.5 Waste Acceptance

We are currently implementing the 2011 ESC, as required by our current Permit. The main new controls on waste acceptance and how wastes are emplaced in the Repository are briefly summarised in this subsection. Further details are given in Section 3 of the *Developments* report. The requirement in the current Permit to operate the LLWR in accordance with the assumptions made in the most recent ESC ensures that adequate controls will be in place.

3.5.1 Overall Approach

The main control we will use to ensure that only wastes consistent with the ESC are accepted for disposal is to derive and apply WAC based on the assumptions and results of the ESC. The waste acceptance process is described in the 2011 ESC Level 2 *Waste Acceptance* report [21]. Our current WAC are given in reference [26]. New WAC, derived from the 2011 ESC and subsequent work, have been drafted and will be implemented.

Our WAC include a broad range of criteria covering limits on the quantities of radionuclides, material characteristics, and packaging of the wastes. They are derived not only from the ESC but also from our operational safety cases and transport regulations, and from our Permit. We propose that, as far as possible, WAC and other controls on waste acceptance should not be included in any revised permit. We believe this is an appropriate and flexible approach since criteria can be refined and focused to provide more effective environmental performance or better guidance to consignors or changed in the light of new data without needing to apply for a permit variation. The WAC are available to the Environment Agency and they will be informed of any significant changes. This will facilitate any regulatory requirement that might arise to change or modify the WAC in order to meet a regulatory objective.

We are introducing new controls to ensure that we only accept wastes within the overall safe radiological capacity of the site. Our approach to radiological capacity management is summarised below in Subsection 3.5.2. We are also introducing a new approach to controlling the disposal of LLW with non-radiological toxic properties to ensure that the capacity of the Repository to accept such wastes is not exceeded. Our approach is summarised in Subsection 3.5.3. We are also introducing a Waste Emplacement Strategy, which contributes to ensuring environmental performance is optimised, and is summarised in Subsection 3.5.4.

3.5.2 Radiological Capacity Management

An approach to setting limits on the total quantities and specific activity of radionuclides that can be safely disposed to a repository is set out by the IAEA [27], often referred to as the 'sum-of-fractions' methodology. The approach is based on derivation of values of radiological capacity for each assessment case¹ and for each radionuclide. As discussed in Section 6 of reference [21], the radiological capacity for radionuclide (n) is the activity or activity concentration (as appropriate for the assessment being considered) at which the peak impact from that radionuclide alone would be equal to the appropriate regulatory criterion. In order to limit the total impact from all radionuclides such that it does not exceed the regulatory criterion, the following summation is required:

$$\sum_n \frac{I_n}{L_n} \leq 1$$

where I_n is the disposed activity or activity concentration of each radionuclide and L_n is the radiological capacity.

To ensure regulatory criteria are met:

- total disposals to a facility must be such that the sum-of-fractions values for each assessment case, based on total inventory, are less than one;
- activity concentration levels, for example in each consignment, must be such that the sum-of-fractions values for each assessment case based on activity concentration are less than one.

Such an approach can be used for both the operational and post-closure periods of a disposal facility, with sets of radiological capacity values derived for each assessment case. The IAEA notes that this approach is cautious as no account is taken of the likelihood that the dose contributions from different radionuclides will arise at different times. (The approach ensures that disposals do not exceed a value of one even based on the total time-independent sum of individual peak doses or risks. The full time-dependent assessment for the same disposals might show that, as individual radionuclide peak doses arise at different times, the peak combined dose or risk with time never exceeds the regulatory criterion.)

The derived radiological capacity values for different assessment cases then need to be considered in order to establish a set of radiological limits. These limits can be calculated by a conservative approach, based upon taking the most restrictive capacity values for each radionuclide from all the assessment cases, or by selecting a sub-set of cases that represent the most limiting cases. An example of the sum-of-fractions approach, for a single assessment case, is given in Subsection 3.3 of the Level 2 report *Waste Acceptance* [21].

In Section 3 of the *Developments* report, we have derived total radiological capacities according to this methodology, in order to provide controls in accordance with regulatory criteria. The required limits are those in Table 1 and Table 2 to be applied

¹ An assessment case is defined in the ESC as a specified combination of events, circumstances, conditions or their evolution, including specification of model boundary conditions and data, which represents a particular realisation of the disposal system, its evolutions and radionuclide or contaminant release, migration and exposures.

using the sum-of-fractions methodology. There are also limits of 130 TBq for C-14 and 18,000 TBq for H-3 derived from consideration of potential impacts arising from the release of radioactive gases. Sum-of-fractions calculations are not required for these capacity limits because only a single radionuclide is calculated to cause a potentially significant impact in the assessment cases from which they are derived. Each of the three sum-of-fractions and individual radionuclide limits apply independently. The justifications for these values are set out in detail in the *Developments* report.

Table 1 Radiological capacity values for groundwater

Radionuclide	Radiological Capacity Values for EDA (TBq)
C-14	190
Cl-36	35
Ca-41	3500
Mo-93	130
Tc-99	250,000
I-129	1.5
Ra-226	1500
Pa-231	7100
Th-230	5600
U-233	220,000
U-234	250,000
U-235	240,000
U-236	250,000
U-238	350,000
Np-237	49,000
Am-241	340,000
Am-243	140,000
Cm-245	35,000
Cm-246	72,000
Cm-248	23,000
Others*	1,000,000

*Others exclude radionuclides of less than three months half-life.

Table 2 Radiological capacity values for coastal erosion

Radionuclide	Radiological Capacity Values (TBq)	
	Recreational Beach User	Marine Foodstuffs Case
C-14	530,000	180
Cl-36	16,000	-
Se-79	100,000	400
Zr-93	140,000	70,000
Nb-94	5.3	53,000
Mo-93	64,000	79,000
Tc-99	210,000	9,000
Ag-108m	34	2,500
I-129	1,800	780
Cs-135	130,000	170,000
Ra-226	6.4	3.8
Th-229	26	48
Th-230	8.2	4.6
Th-232	3.0	59
Pa-231	16	130
U-233	160	340
U-234	820	620
U-235	58	2,900
U-236	2,100	7,100
U-238	330	6,900
Np-237	41	1,400
Pu-238	750,000	-
Pu-239	200	420
Pu-240	210	460
Pu-241	38,000	130,000
Pu-242	180	420
Am-241	1,300	4,500
Am-242m	13,000	89,000
Am-243	49	540
Cm-243	150,000	350,000
Cm-244	75,000	170,000
Cm-245	65	280
Cm-246	240	600
Cm-248	2.9	130
Others*	1,000,000	1,000,000

*Others exclude radionuclides of less than three months half-life.

3.5.3 Waste with Non-radiological Toxic Properties

Our approach to limiting the environmental impacts of LLW with non-radiological toxic properties has generally been to ensure wastes are sufficiently conditioned to meet leaching test standards from the landfill industry. Such tests are not directly relevant to the LLWR design concept, where wastes are put in steel containers, which are grouted before emplacement in engineered concrete vaults. Based on the 2011 ESC and subsequent work, we are implementing alternative controls based on defining safe repository capacities for individual materials. The approach is consistent with and similar to the approach to be used for controlling radiological capacity, although the sum-of-fractions approach (described in Subsection 3.5.2) is not necessary for these materials. The approach is described in more detail and the numerical limits provided in Section 3 of the *Developments* report.

3.5.4 Waste Emplacement Strategy

We are introducing a Waste Emplacement Strategy, i.e. we will control where certain waste packages are emplaced in the waste stacks in the Repository vaults. The overall Waste Emplacement Strategy includes a number of controls designed to contribute to ensuring that environmental performance is optimised.

Some waste packages with relatively high concentrations of certain radionuclides will not be placed at the top of the waste stacks or they will be distributed between stacks of individual packages. A sum-of-fractions approach (see Subsection 3.5.2) will be used to identify which waste packages need to be emplaced in these ways. The voidage in individual stacks of packages will be controlled to minimise settlement in the waste stacks and hence final cap as the waste packages degrade. Other controls will also apply.

The Waste Emplacement Strategy is discussed in Subsection 4.2 of the *Developments* report and in the ESC Level 2 *Waste Acceptance* report [21].

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