Radiological Impact Assessment in the LLWR's 2011 Environmental Safety Case

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Abstract

The Low Level Waste Repository (LLWR) is the United Kingdom's principal facility for the disposal of low-level waste (LLW). The LLWR recently submitted an Environmental Safety Case (ESC), which will support applications to regulatory and government authorities to dispose of LLW and to start to install final closure engineering. The ESC is a major submission, with important implications for the future of the LLWR and the United Kingdom's management of LLW. This paper provides information on the LLWR, national strategy and regulatory context, and regulatory guidance and review of the 2011 ESC. The supporting radiological assessment is described, and its use is discussed in supporting optimisation, demonstrating consistency with regulatory guidance levels, deriving waste acceptance arrangements and providing support to key safety arguments.

Key Words: LLW, repository, environmental safety case

1 Introduction

The Low Level Waste Repository (LLWR) is the United Kingdom's principal facility for the disposal of low-level waste (LLW). The LLWR submitted an Environmental Safety Case (ESC) to the Environment Agency on the 1st May 2011 [1]. The ESC will support applications, to the environmental regulator and the local government authority, to dispose of LLW and to start to install final closure engineering. The ESC is a major submission that will decide the future use of the LLWR and has important implications for the success of the UK's LLW strategy and the progress of operational and decommissioning programmes in the nuclear industry.

The 2011 ESC addresses a wide range of aspects relating to environmental safety. After brief descriptions of the LLWR, the context of the ESC, relevant regulatory guidance and the presentation of key safety arguments, this paper focuses on a number of new or innovative aspects of the ESC in the areas of optimisation, radiological impact assessment and waste acceptance.

2 Description of the LLWR

The LLWR is owned by the Nuclear Decommissioning Authority (NDA), which is a non-departmental public body created under the Energy Act 2004 and owns a number of civil nuclear sites and associated nuclear liabilities and assets in the United Kingdom. The LLWR is operated on behalf of the NDA by a Site Licence Company, the LLW Repository Ltd.

The LLWR is located in the Northwest of England on the West Cumbrian coastal plain, close to the village of Drigg and approximately five kilometres south-east of the Sellafield site. Apart from Sellafield, the area is predominantly rural. The area along the coast adjacent to the site is designated as a Site of Special Scientific Interest (SSSI). Along the north-eastern boundary is the Carlisle to Barrow-in-Furness railway line, a siding from which enters the site for the delivery of waste containers and other materials. A river estuary lies to the south. The Cumbrian mountains rise further to the east. The LLWR lies outside the Lake District National Park.

The LLWR site is about two kilometres long and half a kilometre wide and lies on a northwest-southeast axis. The northern half of the site is used for waste disposal. This area is about 400 m away from the coast (high-water mark) at its closest point. The natural topography of the site slopes gently from about 20m above mean sea level at its northern end to 5m at its southern end.

The site of the LLWR was first developed in 1940 as a Royal Ordnance Factory (ROF). LLW has been disposed at the site since 1959. For the first 36 years, drummed, bagged or loose waste was tumble-tipped into seven consecutively constructed trenches. The trenches are currently covered by an interim cap of soil, containing a plastic membrane to minimise the infiltration of water into the wastes. The trenches contain about 500,000 m^3 of waste.

From the late 1980s onwards, disposal operations were upgraded to be consistent with modern standards. A concrete disposal vault was constructed, Vault 8, allowing the disposal of wastes in containers. Waste was first put into Vault 8 in 1988. The first seven years of the operation of Vault 8 overlapped with completion of disposals to Trench 7. Construction of a second vault, Vault 9, was completed in December 2010. Waste started to be placed in Vault 9, in a prepared area, in 2009.

Most wastes are received within steel ISO containers, mainly half-height, which are cement grouted at the site and then stacked within one of the vaults. Currently, larger items are placed or grouted directly within specific areas of Vault 8. Vault 8 contains about 200,000 m^3 of waste containers.

It was originally planned that waste containers would be stacked to a height equivalent to four half-height ISO containers in Vault 8. Waste containers in Vault 8 up to this height are authorised disposals – see below. The vault is now almost full to this original design capacity. However, some waste containers are also stored in Vault 8 in higher stack positions above the disposed waste. Waste is also stored, rather than disposed, in Vault 9 – again, see below.

Water infiltrating into the trenches and rain water entering Vaults 8 and 9 is collected and sampled prior to discharge to the sea via a marine pipeline in accordance with our discharge consent.

A recent aerial photograph of the facility is provided as Figure 1

3 National Strategy and Regulatory Context

LLW is defined in the United Kingdom as radioactive waste having a radioactive content not exceeding 4 GBq t^{-1} of alpha or 12 GBq t^{-1} of beta/gamma activity. LLW can contain long-lived radionuclides.

The NDA has published a '*UK Strategy for the Management of Solid Low Level Radioactive Waste from the Nuclear Industry*' [2]. The Strategy has been prepared by the NDA for the UK Government and devolved administrations in response to their '*Policy for the Long Term Management of Solid Low Level Radioactive Waste in the United Kingdom*' [3], published in 2007. The United Kingdom's Strategy is to make '*best use of existing LLW management assets*' for the management of LLW. This approach is based on a Strategic Environmental Assessment (SEA), conducted to support the development of the Strategy. '*Best use of existing LLW management assets*' means continuing to use the LLWR to dispose of LLW, but only LLW that requires the protection provided by disposal in vaults. It also means minimising the volume of LLW that needs to be disposed at the LLWR, while maximising the capacity of the facility to safely take waste. An important part of the United Kingdom's Strategy is the implementation of the waste hierarchy to minimise the volume of LLW that needs vault disposal. The Strategy recognises that the LLWR can only continue to be used to dispose of LLW if an environmental safety case is produced demonstrating that the facility is safe.

The disposal of radioactive waste in England and Wales is regulated by the Environment Agency under the Environmental Permitting (England and Wales) Regulations 2010 [4]. The Environment Agency issues permits that set out the conditions under which radioactive wastes may be disposed. The LLWR's current Permit is based on the Environment Agency's review of safety cases prepared by the previous site operator and submitted in 2002. The Environment Agency considered that these safety cases, and especially the safety case addressing the safety of the facility in the long term after it closes (the Post-closure Safety Case or PCSC [5]), had failed to make '*an adequate or robust argument for continued disposals of LLW*' [6]. The Environment Agency decided, therefore, that continued disposal of LLW would be authorised only until Vault 8 was filled to its originally planned capacity, and that any further waste received by the facility could only be stored and not disposed. The Environment Agency placed a requirement on the site operator to present a revised environmental safety case by the 1st May 2011. The objective has been to develop and present an ESC that demonstrates to the Environment Agency that it is safe to continue to dispose of LLW at the LLWR. In achieving this objective, the ESC will also provide a sound basis for future management of the site by LLW Repository Ltd and regulation of the site by the Environment Agency.

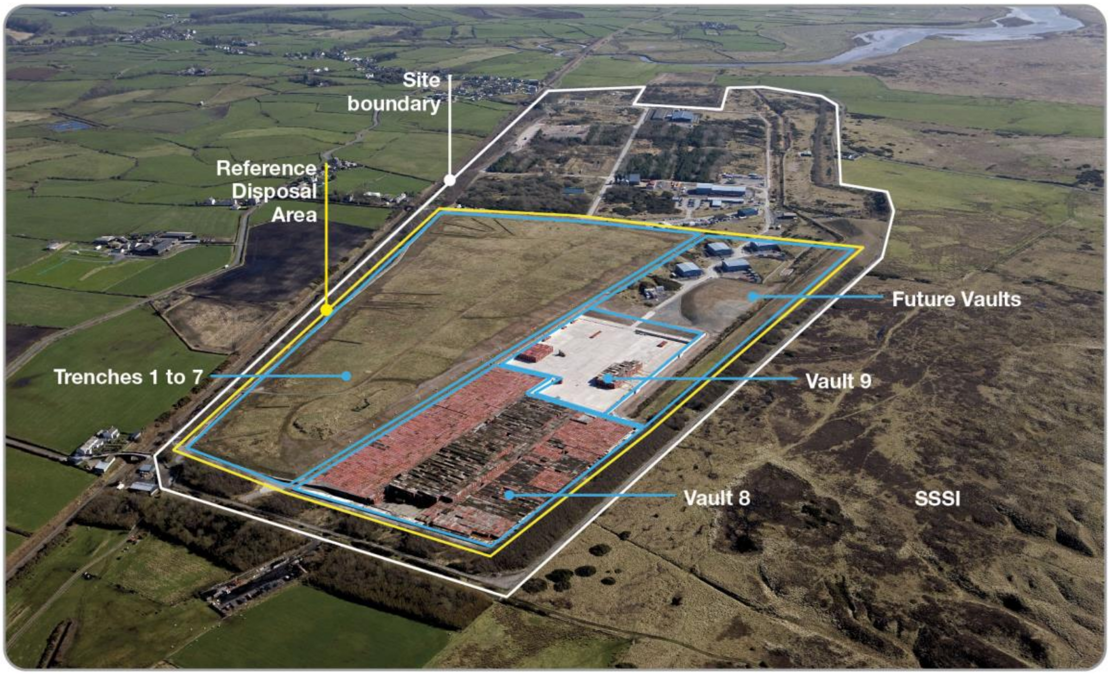

Figure 1. The LLWR viewed from the north

4 Regulatory Guidance and Review

The United Kingdom's environment agencies, including the Environment Agency, have provided guidance on the requirements that a near-surface disposal facility must fulfil. These requirements are set out in the '*Guidance on Requirements for Authorisation*' (the GRA) [7]. The GRA sets out the principles that must be followed, and formal requirements that must be met, in developing an ESC. The principles and requirements cover environmental safety both during operations at a facility and during and after closure, for however long the wastes will remain a potential hazard. The guidance is generally non-prescriptive on the methods and evidence by which an ESC should demonstrate that the principles are adhered to and requirements met. A proportionate approach is advised, applying sound science and good engineering practice, and taking account of uncertainties.

The fourteen main requirements are listed in Figure 2. The requirements cover a wide range of aspects relating to environmental safety, including environmental management; safety culture and regulatory and stakeholder engagement; system characterisation and understanding; optimisation and site plans; and impact assessment and waste acceptance. A modern 'safety case' is required, not just an assessment of radiological impact for a given facility design. However, an ESC in the UK is not concerned with conventional or radiological safety of workers, or security, which are regulated separately by the Office for Nuclear Regulation. An ESC is also not concerned with some conventional environmental impacts, for example, traffic, noise, and visual amenity, which are dealt with under local planning procedures.

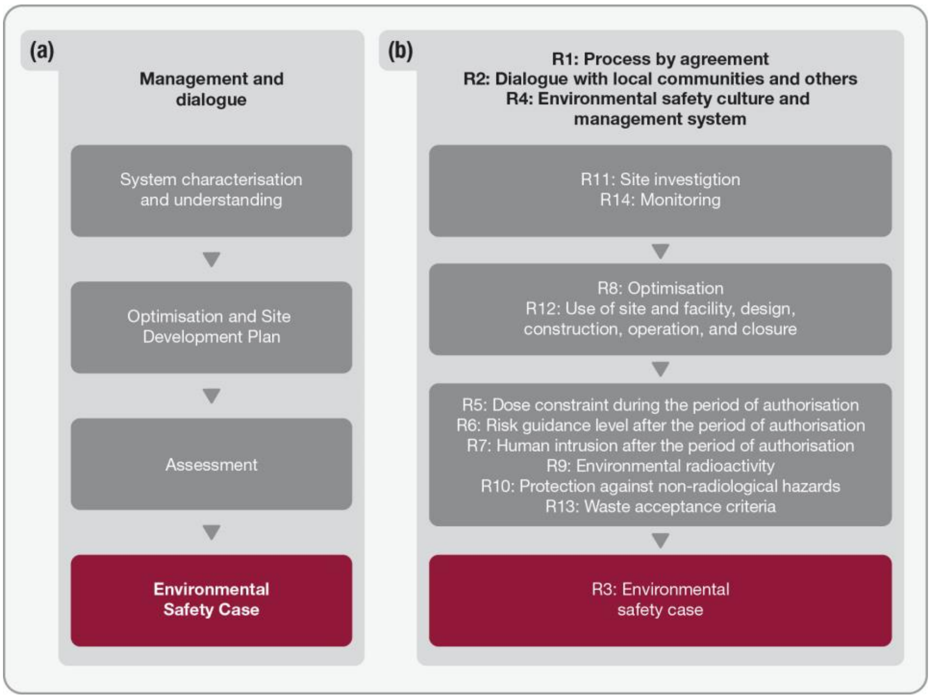

Figure 2. Grouping of key safety arguments (a) and links to regulatory requirements (b) [1]

The GRA sets out dose constraints for the period during which a permit is in force, termed the period of authorisation, and risk and dose guidance levels for the period after the release of the site from regulatory control. 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 of 0.3 mSv per year. As part of the implementation of the 2006 Groundwater Directive, a dose constraint of 20 microSv per year is expected to be applied to the groundwater pathway during the period of authorisation. After the period of authorisation, the assessed radiological risk from a disposal facility to a person representative of those at greatest risk should be consistent with a risk guidance level of 10^{-6} per year. The potential consequences of human intrusion should be assessed on the basis that it is likely to occur, and 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 per year to around 20 mSv per year. Values towards the lower end of the range apply to assessed exposures continuing over a period of years, while the values towards the upper end of the range apply to assessed exposures that are only short term.

The Environment Agency is currently reviewing our ESC. During 2012, we plan to submit an application for a new permit to allow disposal of wastes in Vault 9 and future vaults and those higher stacked in Vault 8, and to start installation of the closure engineering, including a proposed cut-off wall and final capping of Vault 8 and the adjacent strip of trenches. A planning application to the local planning authority has already been submitted and will be considered in parallel with the Agency review of the ESC. We hope to receive a new permit during 2013.

5 Presentation and Key Safety Arguments of the 2011 ESC

The GRA defines an environmental safety case as:

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

Following this definition, the LLWR's 2011 ESC is presented as a set of twenty-six key safety arguments. The arguments are structured into four sets around a high-level statement of our safety case:

- We have worked within a sound management framework and firm safety culture, while engaging in dialogue with stakeholders.
- We have characterised and established a sufficient understanding of the LLWR site and facility, and their evolution, relevant to its environmental safety.
- On which basis, we have carried out a comprehensive evaluation of options to arrive at an optimised Site Development Plan (SDP) for the LLWR.
- We have assessed the environmental safety of the SDP, showing that impacts are appropriately low and consistent with regulatory guidance. Using our assessments, we have determined the radiological capacity of the facility and conditions under which waste may be safely accepted and disposed.

The four sets of arguments are:

- Management and dialogue;
- System characterisation and understanding;
- Optimisation and SDP;
- Assessment and conditions for waste acceptance.

The main ESC documentation is structured in two levels. At 'Level 1', the '*Main Report*' contains a statement of the twenty-six key safety arguments. The Level 1 report also describes the context of the ESC, in summary the site, its history and environmental context, our approach to developing the ESC and our Environmental Safety Strategy and SDP, our future work programme, and progress since the previous safety cases. There are sixteen 'Level 2' reports containing the analyses and evidence supporting the key safety arguments. The structure of the ESC allows clear links between the key safety arguments and the supporting evidence. It is also shown within the ESC how the key safety arguments meet the fourteen main requirements set out in the GRA. The grouping of arguments and their links to the fourteen requirements are shown in Figure 2.

The rest of this paper focuses on analyses undertaken to support key safety arguments on radiological optimisation and assessment. The use of the radiological assessments in deriving waste acceptance arrangements is also discussed.

6 Optimisation and Site Development

6.1 Importance of Optimisation

The 2007 Recommendations of the ICRP [8] re-enforce the principle of optimisation as applicable to all exposure situations. The principle is adopted as one the principles for solid radioactive waste disposal within the GRA, which also sets an explicit requirement that:

> *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 the radiological risks to members of the public, both during the period of authorisation and afterwards, are as low as reasonably achievable (ALARA), taking into account economic and social factors.*

Lack of demonstration of optimisation was one of the main criticisms of the 2002 safety cases [6]. As part of the development of the 2011 ESC, we have carried out a wide-ranging evaluation of options for the future development of the facility up to closure and beyond [9]. A variety of approaches have been used to optimise different aspects, with emphasis on detailed technical analysis of options, rather than subjective comparison or multi-attribute analysis. The radiological and other assessments have been used, as they developed, to evaluate the environmental safety of alternative options. Remediation of past waste disposals, future waste disposals, site engineering, waste emplacement strategies, management of run-off and leachate, and management during closure have all been considered. Here we concentrate on only two of the studies, on remediation of past disposals and on site engineering.

6.2 Remediation of Past Disposals

In the 2002 PCSC, calculated doses and risks from the existing disposals in the trenches significantly exceeded regulatory guidance levels. Also, no justification was provided for the position that the trenches should not be remediated. As a result of improved assessment methods and models developed for the 2011 ESC (see Section 7), calculated doses and risks from the trench disposals are now consistent with regulatory guidance levels. Nevertheless, we have undertaken work to consider the ways that we could further reduce the environmental impact associated with past disposals [9]. These options, such as removing selected wastes or remediating wastes in-situ, have been assessed in terms of the potential reductions in risk they would provide. Consideration has also been given to the other detriments that might arise, e.g. doses to workers and local environmental impacts. The analysis of selective removal of wastes was based on a detailed review of disposal records. The review was used to understand whether key radionuclides making a significant contribution to calculated doses and risks were sufficiently concentrated in particular areas of the trenches to allow selective retrieval and hence reduction in potential impacts. It was found that only a small number of key radionuclides, including thorium and radium isotopes, were sufficiently concentrated.

Our options assessments demonstrate that while selective retrievals are practicable and could be managed safely, and reductions to doses and risks would be achievable, the benefit (reduction in future doses and risks that are already small and consistent with the guidance levels) is small. On the other hand, the detriments would be large especially in terms of (1) time taken to accomplish the retrievals, which would be of order of decades, during which existing disposals would be disturbed and final capping delayed, (2) cost of conditioning, interim storage and deep underground disposal of target wastes, and (3) use of LLWR engineered vault capacity to accommodate excavated wastes that while not requiring deep disposal might not be replaced in the trenches. The final impact assessments undertaken for the 2011 ESC are based on the assumptions that the past disposals will be left in situ.

6.3 Vault Design and Closure Engineering

The baseline design for the closure engineering at the start of the development of the 2011 ESC included a 'gull-wing' final cap with a gulley between the vaults and trenches, and a deep bentonite cut-off wall round the disposal area designed mainly to limit water inflows. The vault design utilised bentonite layers underneath and in the vault walls intended to contain infiltrating water for as long as possible. To mitigate the eventual filling of the vaults, and the vulnerability of the cap to erosion in the gulley that might lead to infiltration there, the design included deep drains between the trenches and vaults to act as a soak-away.

The outcome of optimisation studies undertaken as part of the development of the 2011 ESC led to adaptations to this baseline design [9]. A key input to the process was the use of a new and better calibrated 3D hydrogeological model developed for the ESC [10]. This model allowed the effects of the engineering features on water flows and saturation levels to be understood, and hence judgments made about the effects on radiological and other impacts of different design philosophies and options. The model results gave confidence that a change in design philosophy for the vaults was the optimal approach. In the revised design, the vaults have low side walls. The design allows run-off and leachate to be collected during operations and for a period after final capping, but once active leachate management ceases prevents 'bath-tubbing' in the facility. The cap will provide sufficient reduction in infiltration to keep most of the waste unsaturated for hundreds of years, reducing it is believed contaminant release rates from the facility. The design also limits the likelihood of the release of leachate to surface pathways for a long period. Thus, the design balances the different requirements of reducing impacts during operations and for a period after and in the long term when reliance cannot be placed on active leachate management continuing. The hydrogeological modelling also showed that the proposed depth of the cut-off wall can be reduced because only a certain depth is required to provide the necessary levels of unsaturation and limit the potential for near-surface release of contaminants. The optimisation studies also concluded that a single-dome final cap design would be less likely to suffer erosion. The changed cap and vault designs remove the need for deep drains.

6.4 Continuing Optimisation and Implementation of the ESC

A SDP [1,9] was developed for the 2011 ESC based on the outcomes of the different optimisation studies that presented an appropriate combination of implementable options for the development of the site. The assessments performed for the 2011 ESC were based on this SDP.

Our current Permit requires us to manage the LLWR in accordance with our most up-to-date ESC. In accordance with this requirement, we are starting to implement the ESC to the extent possible while remaining consistent with the requirements in our current Permit. Our intention is to implement the ESC as a ‘live’ safety case using the well-developed processes and procedures used to maintain and implement our operational nuclear safety cases, adapted as necessary. The ESC will be used as a basis for assessing proposed modifications to the operation and closure of the facility, to ensure that they are consistent with the requirements of the ESC. The process will ensure that the SDP continues to remain optimised. Further optimisation studies are underway on waste container design and the management of the interim cap over the trenches.

7 Radiological Assessments

A range of assessments of the radiological impacts from the facility on humans have been undertaken for the 2011 ESC addressing the release of radionuclides from the facility both during operations and afterwards. Pathways considered include releases into groundwater and in dust or gas, and through exposure and dispersal of the wastes after coastal erosion and inadvertent human intrusion into the facility. The impact of direct irradiation from the uncapped waste packages during operations has also been addressed. All the methodologies used are either new or significantly improved since the assessments undertaken for the 2002 safety cases. The radiological assessments are summarised in references [11,12]. We have also undertaken a radiological impact assessment for non-human biota [13], using the Environment Agencies ERICA methodology [14], and an assessment of non-radiological impacts arising from the release of chemotoxic substances in the wastes [15].

In the rest of this section, we discuss the assessments of radiological impact to humans through the groundwater, gas, coastal erosion and human intrusion pathways in the long term. That is, after final closure of the repository following a period of institutional control, which is envisaged after the last wastes are emplaced and the final cap over the disposal facility is completed. The descriptions below are of the methodologies used. Doses and risks were assessed taking account of the key uncertainties within each pathway, the potential for interaction between pathways, and the spatial distribution of radionuclides within the repository. All of the assessed impacts are consistent with the regulatory guidance described in Section 4. The 2011 ESC thus addresses two key criticisms of the 2002 PCSC that some of the assessed doses and risks greatly exceeded regulatory guidance levels and there was an inadequate treatment of uncertainty.

7.1 Groundwater Pathway

A new assessment model has been developed using the Gold*Sim* software [16]. The main model assumes the natural evolution scenario for the system, i.e. including coastal erosion (see Subsection 7.3). Key features of the model include:

- a near-field model in which radionuclides in saturated regions of the trenches and vaults are assumed to be immediately available for dissolution, except for C-14, which is given a more realistic treatment;
- models of contaminant release and sorption in both the saturated and unsaturated components of the trenches and vaults;
- a representation of solubility limitation;
- a representation of the partitioning of C-14 between gaseous, aqueous and solid phases;
- a compartment flow model to provide a detailed representation of the water flows through the near field;
- a treatment of geosphere transport within a flow and transport network model;
- potentially exposed groups receiving external exposure, inhaling and ingesting dust, and consuming contaminated products consistent with the biosphere path, for example, drinking water, garden produce, animal products, marine foodstuffs etc.

The treatment of the near field, including the behaviour of C-14, is based on the results of an experimental and modelling programme undertaken to support the original 2002 safety cases and the 2011 ESC [17]. The compartment flow model and treatment of geosphere transport are based on results from the new and better calibrated 3D hydrogeological model [10]. A variety of deterministic and probabilistic calculations have been undertaken based on a reference case and further variant calculations have been undertaken to explore the implications of uncertainties. The key pathway is a water abstraction well between the site and the coast drilled in the future. The annual probability of such a well has been assessed based on a survey of land use along the West Cumbrian coast and frequency of licensed and unlicensed boreholes in the region.

7.2 Gas Pathway

Impacts from the gas pathway potentially result from the release of C-14 bearing gas after the end of active institutional control. Gases, principally hydrogen, methane and carbon dioxide, are produced from waste and package degradation processes in the vaults and trenches. The release of C-14 bearing gases (methane and carbon dioxide) is estimated using a model of biogeochemical processes that takes account of evolving biogeochemical conditions and inventories of C-14 bearing and other waste forms as distributed in the repository. Gas released from the wastes is assumed to migrate to the environment without attenuation, methane is converted to carbon dioxide in the soil zone, and the C-14 is then taken up by photosynthesis in plants thus entering food pathways. Calculated impacts to a smallholder assumed to be farming on the cap fall to around the regulatory risk guidance level after about 300 years after final waste emplacement; however, we believe the analysis contains several significant pessimisms relating to the release of C-14 and on gas migration in the plant canopy, and that we will be able to demonstrate consistency with the guidance level after 100 years with further work, which is underway. 100 years after final waste emplacement is the assumed end of active institutional control in the 2011 ESC. Even if we cannot demonstrate consistency after 100 years, assuming up to a 300-year period of active control is consistent with international practice. Alternatively, it may be possible to rely on passive controls, such as knowledge retention, beneficial land use by the local community, and legal land covenants to restrict land use.

7.3 Coastal Erosion Pathway

The proximity of the LLWR to the sea was described in Section 2. There is, therefore, a need to consider the implications of sea-level rise and coastal erosion. We have undertaken extensive studies over the last decade to characterise the coastal environment and understand how the coast will evolve in the future [18]. A range of studies has also been undertaken that focuses on historical and present coastal processes in the vicinity of the LLWR, plus interpretation of paleo-evidence placing bounds on how the coast has developed over the last ten thousand years. The local coastal processes are now considered to be well characterised through analysis of historical maps and photographs, contemporary observations, interpretation and computer modelling. It has been concluded that the disposal area will start to erode on a timescale of hundreds to thousands of years and the repository will be eroded on a timescale of one to a few thousand years. There is uncertainty over the timing of the erosion of the facility, mainly resulting from uncertainty over the rate and magnitude of sea-level rise, but the evidence indicates the final outcome will be complete erosion of the site, commencing by undercutting of the vaults and continuing by undercutting or direct erosion of the trenches.

Environmental safety cases for surface or shallow repositories often address impacts resulting from natural erosion processes, but we believe the 2011 ESC is unique in needing to consider coastal erosion. Since we believe erosion will occur, coastal erosion of the facility is part of the expected natural evolution scenario for the repository system. An appropriate depth of analysis is therefore required, beyond that provided in the 2011 PCSC [5]. Based on the understanding gained of coastal erosion, a Gold*Sim* assessment model has been developed. An important feature of the model is that it includes a spatial representation of the site and location of wastes, so as to estimate the variation in impacts as different wastes are eroded. The model calculates the uncovering and dispersal of the wastes into the shore and marine environments and the doses to different potentially exposed groups as a function of time. Potentially exposed groups include recreational beach users, for example dog walkers or beachcombers, inshore fisherman, and high-rate consumers of marine foodstuffs from local coastal waters. Despite the wastes being exposed, dilution and radioactive decay is sufficient to lead to estimates of doses and risks consistent with regulatory guidance levels. Again, uncertainty is addressed by undertaking variant calculations.

7.4 Human Intrusion Pathway

The 2011 ESC assesses the potential radiological impacts from inadvertent human intrusion as a function of spatial locations of intrusion and time. A number of different types of intrusion have been analysed, based on a consideration of present day activities and land uses that might lead to intrusion, such as site geotechnical investigations using trial pits and boreholes and consequent site uses for housing, agriculture or other uses. Calculations have been undertaken using a model implemented in Gold*Sim*, taking account of location in terms of the cover thickness and waste disposed, and the conventional exposure pathways. Calculated doses are dominated by those arising from exposure to radon accumulating in a dwelling constructed on excavated spoil including Ra-226 bearing wastes. A new model used to calculate the release of radon into a dwelling has been developed based on empirical data linking radium concentrations in analogous soils to radon concentrations in dwellings. This model replaces a process-based model with uncertain parameters used in the 2002 PCSC.

8 Waste Acceptance

An important outcome of the ESC is a fully underpinned set of proposed waste acceptance arrangements that will allow the repository to be operated consistently with the assumptions and assessed impacts of the ESC [19]. A set of waste acceptance criteria have been rigorously derived from the ESC.

We are also proposing to introduce a small number of waste emplacement strategies, to control where in the waste stacks specific waste packages are emplaced. These strategies will increase the amounts of wastes that can be disposed safety and can be viewed as part of the optimisation of the repository. Two of these strategies have been derived from the radiological assessments. We are intending to limit local concentrations of activity near the tops of the stacks, to reduce the potential impacts from human intrusion. This strategy will have the effect of limiting the amount of radium high in the stacks and hence the potential impact of the release of radon if the cap is damaged. We are also intending to limit the local concentrations of activity throughout the stacks to limit potential impacts from coastal erosion. Based on a review of waste packages already received, it is believed that few packages will need to be managed under the radiological emplacement strategies.

The radiological assessments have also allowed us to calculate the total radiological capacity of the repository. Currently, capacity is controlled by annual limits on the acceptance on specific radionuclides or groups of radionuclides stated in our current Permit. We intend to seek a permit in which the annual limits are replaced with controls on total radiological capacity for the site.

The approaches to radiological emplacement strategies and controlling the total radiological inventory within the repository are based on the 'sum-of-fractions' methodology [19].

9 Conclusions

The LLWR's 2011 ESC is a major submission, with important implications for the future of the LLWR and the United Kingdom's management of LLW. Consistent with regulatory guidance, our ESC is a modern safety case developed as a range of safety arguments concerning our management, scientific and technical understanding, optimisation of the facility, as well as assessment calculations.

A number of key advances have been made since the previous submission. In particular, the 2011 ESC addresses the criticisms made by the regulator on the previous submission in 2002 [6], including those relating to the lack of demonstration of optimisation, high calculated doses and risks compared with guidance levels, treatment of coastal erosion, and treatment of uncertainty.

The ESC is being reviewed by the Environment Agency and it is hoped that a new permit for disposal of LLW and installation of closure engineering, along with the appropriate planning permission, will be obtained during 2013. The ESC, including its proposed waste acceptance arrangements, is already being implemented by the LLWR where consistent with our current Permit.

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