LLW Repository Ltd

LLWR Environmental Safety Case

Assessment of Environmental Safety during the Period of Authorisation for the LLWR 2011 ESC (Extended Disposal Area)

A report prepared by Quintessa for and on behalf of the Low Level Waste Repository Site Licence Company.

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Summary

LLW Repository Limited (LLWR Ltd) is undertaking a programme of work that will result in the publication of a new Environmental Safety Case by May 2011 (the 2011 ESC). The 2011 ESC will be submitted to the Environment Agency in support of a formal application to permit continued disposal operations.

The 2011 ESC is based on a reference design that assumes five additional vaults will be created in the future (i.e. vaults 10 to 14) and that the facility will reach volumetric capacity at c. 2080.

LLWR Ltd is also considering whether it could be possible – from an ESC perspective, whether it would be safe – to dispose a greater volume of LLW to the facility than is presently in the baseline plan. The aim is to examine whether, under defined assumptions regarding future waste treatment and diversion of very low-level wastes (VLLW), the complete UK inventory of LLW suitable for near-surface disposal, including predicted arisings from the UK nuclear decommissioning programme, could be accommodated at the LLWR. The additional vaults that would be required to dispose of LLW arisings beyond those associated with the baseline plan are referred to in the current study as the Extended Disposal Area.

An exploration of the potential design, capacity, and inventory that might be associated with implementation of the Extended Disposal Area is to be provided as a variant case within the 2011 ESC. An associated safety assessment will also be presented. The purpose of the variant case is to support planning for future LLW management in the UK. In particular, should such an extension to the lifetime and capacity of the LLWR be shown to be feasible, this could eliminate the need for another repository to accommodate anticipated future decommissioning wastes.

This document has been developed in support of this aim. It presents the outcomes of assessments of environmental safety during the Period of Authorisation (that is, from the present day until the end of Active Institutional Control), taking into account the additional waste streams that might be disposed in the Extended Disposal Area.

The main outcome of the assessments presented is that calculated peak annual doses for the LLWR including the Extended Disposal Area are not increased compared with the Reference Disposal Area assessment.

- For most radionuclides, this is because the inventory of radionuclides in the Reference Disposal Area substantially exceeds that which would be disposed of in the Extended Disposal Area.

- The design of the future vaults is such that the generation of effluent will be minimised.

- The projected inventory of C-14 for the Extended Disposal Area is considerably larger than for the Reference Disposal Area. For this radionuclide, the key pathway during the Period of Authorisation is release as gas. However, the nature of the material that would be disposed of to the Extended Disposal Area is such that biogeochemical calculations predict that much less gas will be generated in the Extended Disposal Area compared with the Reference Disposal Area. As a result, peak gaseous release fluxes of C-14 from the Extended Disposal Area are calculated to be lower than those from the Reference Disposal Area.

The overall conclusion is that the additional disposal of wastes to the Extended Disposal Area will not increase radiological impacts during the Period of Authorisation, compared with those that will arise from wastes disposed of to the Reference Disposal Area. A person living to the east of the site could conceivably receive a peak annual dose of about 100 μSv as a result of exposure to radioactive gases and contaminated dust, ingestion of contaminated seafood, and external irradiation whilst walking close to the western edge of the site. If a person lived permanently to the west of the site, they could receive an annual dose of up to 150 μSv, although this could not happen in the foreseeable future due to the land's protected status, which precludes the building of dwellings.

Contents

1 Introduction

LLW Repository Limited (LLWR Ltd) is undertaking a programme of work that will result in the publication of a new Environmental Safety Case by May 2011 (the 2011 ESC). The 2011 ESC will be submitted to the Environment Agency in support of a formal application to permit continued disposal operations.

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An exploration of the potential design, capacity, and inventory that might be associated with implementation of the Extended Disposal Area is provided as a variant case within the 2011 ESC. An associated safety assessment has also been presented. The purpose of the variant case is to support planning for future LLW management in the UK. In particular, should such an extension to the lifetime and capacity of the LLWR be shown to be feasible, this could eliminate the need for another repository to accommodate anticipated future decommissioning wastes.

This document has been developed in support of this aim. It presents an assessment of environmental safety during the Period of Authorisation (PoA; that is, from the present day until the end of active institutional control), taking into account the additional waste streams that might be disposed to the Extended Disposal Area.

The assessment presented utilises similar assumptions and calculation methods to those applied for the main ESC calculations, reported in Penfold and Paulley (2011). *Therefore this document should be read in conjunction with the main ESC report.* It does not reproduce the details underpinning the approach to assessment, but provides a commentary on the differences required for the Extended Disposal Area calculations and their implications, focusing particularly on the identification and rationale for any substantial changes to assessment results.

To aid comparison with the main ESC report, this document is structured similarly.

- Section 2 summarises the background, context for, and aims of, the assessments, given the focus on the Extended Disposal Area.
- Section 3 provides an assessment of potential environmental safety impacts that might result from discharges of contaminants to air during the PoA, taking into account potential Extended Disposal Area disposals.
- Section 4 focuses on the environmental safety of discharges to surface waters during the PoA, again considering potential additional disposals.
- Section 5 considers potential environmental safety effects that might result from releases to groundwater.
- Section 6 summarises the potential radiation doses that could be received as a result of direct radiation from the operation of the site during the PoA.
- Conclusions are presented in Section 7.

2 Background

A full description of the aims of and context for arguments relating to environmental safety of the LLWR during the PoA is presented in an overarching ESC document that presents the environmental safety arguments, strategy and plan for the PoA (LLWR, 2011). This is supported by a report quantifying environmental safety during the PoA for the Reference Disposal Area case (Penfold and Paulley, 2011).

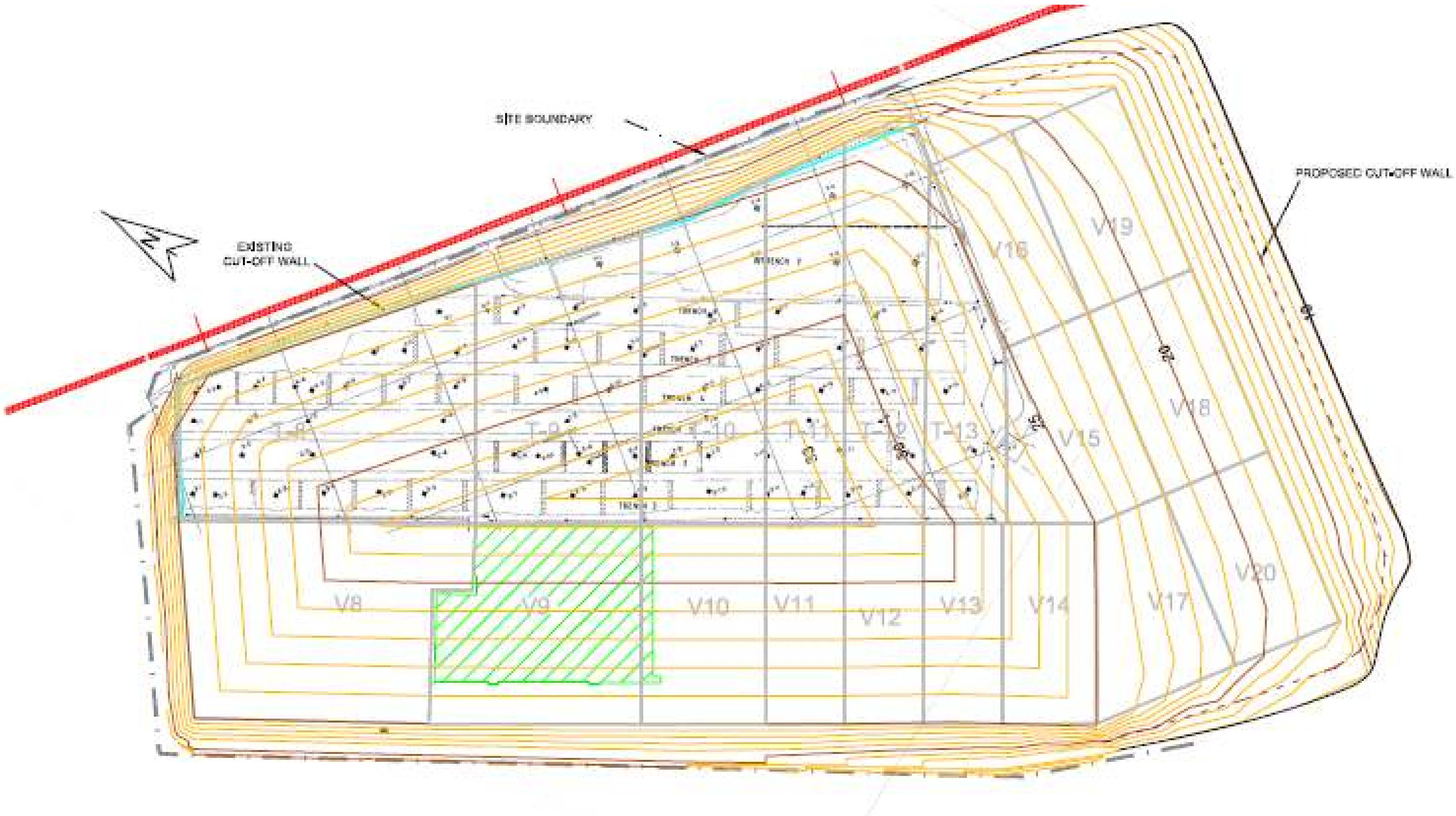
The present report builds upon the main report to assess the potential implications of the development of the Extended Disposal Area and the inventory that might be disposed to it. Therefore, this document draws on a number of key resources, including but not limited to the main assessment report. These are in described below.

Design

Paulley and Egan (2011) report the outcomes of the Extended Disposal Area design optimisation study. This is underpinned by Tonks (2011) which details the Extended Disposal Area engineering design. These documents describe the proposed location, design and geometries of any additional Extended Disposal Area vaults that may be created, and the closure engineering that might be implemented, in terms of changes required from the reference design as a result of the optimisation process.

Figure 1 shows a plan area schematic indicating some of the major outcomes of the design optimisation study. As documented in Paulley and Egan (2011), it was agreed that the vault layout shown in Figure 1 should be taken forward as the baseline for further design decisions, based upon the outcomes of the siting study and to assist consistency with the existing design approach.

Figure 1: Layout Schematic showing Potential Additional Vaults and the Possible Cap Profile for Inventory Case A



In addition the studies concluded that:

- ▲ The design for any additional vaults should be consistent with the reference design;
- ▲ The additional vault bases, and underlying passive drainage features, should be at a level consistent with that of Vault 14;
- ▲ The vault bases should be appropriately sloped to facilitate leachate management via a system of sumps and operational leachate from the southern end of the site;
- ▲ Trench leachate should be collected separately and pumped directly to the marine holding tank;
- ▲ The maximum cap dome height for the reference design should be retained, with the profile extended to the south to accommodate any additional vaults; and
- ▲ The cut-off wall should be implemented to 2 metres deeper than the reference design around the south and east perimeters of the additional vaults to provide confidence against lateral inflows.

Inventory

Studies concerning projections of the inventory to be disposed in the Extended Disposal Area are also important. Such projections inform the requirements for volumetric capacity and thus details of the above mentioned design process. The nature of the disposals, including the radioactive inventory associated with them, is fundamental to understanding the environmental impacts that may arise.

The inventory that could be consigned to the Extended Disposal Area represents a significant addition, both by volume and radioactivity content, compared with that assumed in the baseline ESC (Harper, 2011). These arisings relate to wastes currently identified as destined for LLWR, 'LLWR 2' or the deep geological disposal facility in WIDRAM '09, that are not included in the Reference Disposal Area inventory. It could amount to 573,000 m^3 (packaged waste volume) additional to the current baseline ESC ('Case A'). A large fraction of this additional volume is from Stage 3 reactor decommissioning. Taking into account potential arisings from new build ('Case B'), this could rise to 730,000 m^3 additional to the current baseline.

The assessments presented in this document are primarily based upon analysis of Case A, as it represents the reference inventory case.

Note that the additional disposals are projected to be complete by about 2130. The duration of the subsequent period of Active Institutional Control would be unchanged from the Reference Case (i.e. 100 years after completion of disposals). No extension is considered necessary due to the additional wastes (Paulley and Egan, 2011).

Assessment Approach

Penfold and Paulley (2011) describes an assessment approach that focuses on the use of monitoring data to substantiate arguments underpinning environmental safety during the PoA wherever possible, supported by predictive models where necessary (e.g. because results from monitoring cannot be reasonably extrapolated to the future). Arguments will also take into account the planned development of the facility.

It was identified that the following pathways need to be considered:

- Discharges to air of gas or dust;
- External off-site irradiation;
- Discharges to surface water, and subsequently discharge to marine systems via the marine holding tank; and
- Discharges to groundwater.

Impacts have been assessed for human ‘critical groups’ and ‘hypothetical critical groups’ and a range of other environmental receptors.

The assessments presented in this report use the same assessment approach presented in Penfold and Paulley (2011), updated to take into account the potential features of the Extended Disposal Area (in particular, the additional inventory).

3 Assessment of Discharges to Air

3.1 H-3 in Gas

Penfold and Paulley (2011) present a method for assessment of impacts that might be associated with gaseous discharges containing H-3, based upon a conservative release rate of 1% of the remaining inventory per year.

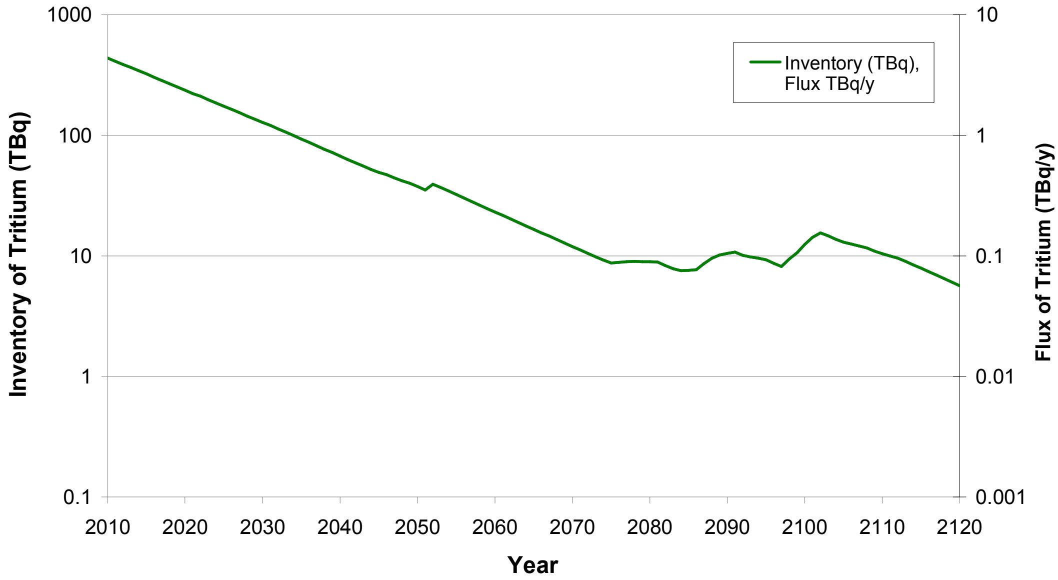
Although H-3 will not be disposed of to the LLWR in liquid form, the chemical behaviour of the element is such that it can be converted to this form in the future. In assessing potential releases in gas, however, it is cautiously assumed that none of the inventory is released in groundwater and the only releases are as gas. The resulting variation in the LLWR inventory of H-3 during the PoA, and the flux to atmosphere, is presented in Figure 2. Figure 3 shows the equivalent outcomes for the Reference Disposal Area calculations, for comparison.

This shows that the inventory is greatest at the present day, and reduces significantly over the next 30 years, when some significant additional disposals occur. Using this model, the peak rate of discharge is 4.4 TBq y^{-1}, in 2010, as for the Reference Disposal Area case.

The additional inventory causes a change to the tail of the inventory and flux plots. However as the Extended Disposal Area disposals are not expected to contain significant amounts of H-3 in comparison with the present-day inventory, there is no significant increase to the results of from the Reference Disposal Area calculations.

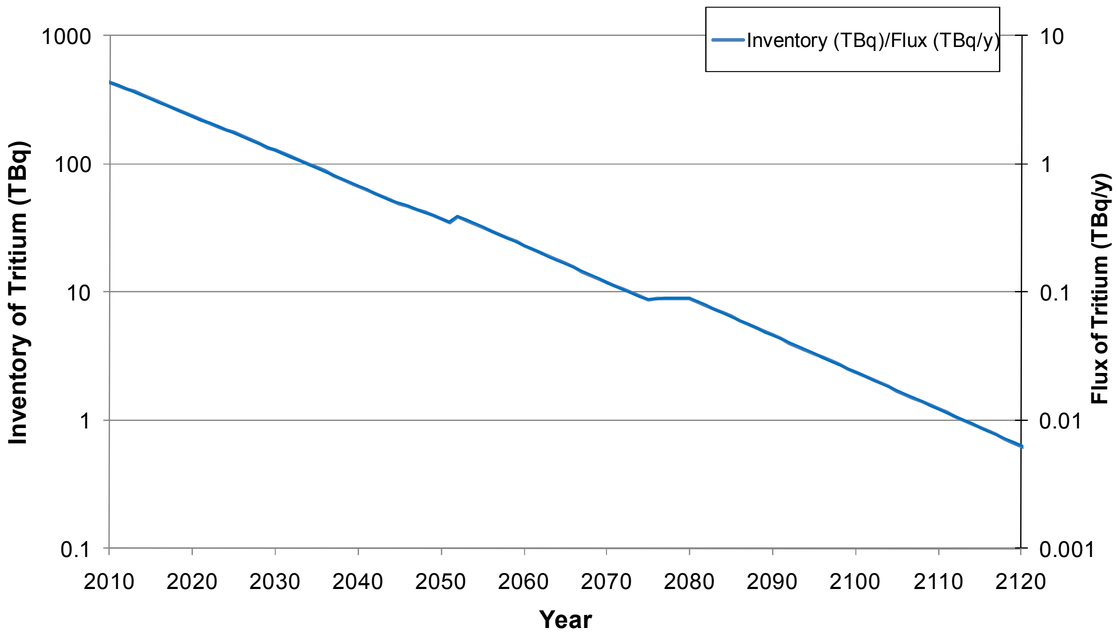
As a result, peak annual average ground level air concentrations beyond the site boundary and the potential peak annual dose to a member of the critical group are not significantly increased from the reference case (0.46 Bq m^{-3} and 0.082 µSv; see Section 3.2.1 of Penfold and Paulley, 2011). The peak annual dose from foodstuffs is 4.6 µSv, arising from the present day inventory. Milk dominates the exposure pathway in this case, contributing 90% of the foodchain dose.

Figure 2: Estimated Future Inventory of H-3 in Wastes and Rate of Discharge to Air (Extended Disposal Area)



Note: The flux is directly proportional to the inventory, so that only a single line shows on the graph. This corresponds to both the inventory and the flux by reading the appropriate scale.

Figure 3: Estimated Future Inventory of H-3 in Wastes and Rate of Discharge to Air (Reference Disposal area)



Note: The flux is directly proportional to the inventory, so that only a single line shows on the graph. This corresponds to both the inventory and the flux by reading the appropriate scale.

3.2 C-14 in Gas

Penfold and Paulley (2011) describe calculations assessing potential impacts that might arise following release of C-14 labelled gases from the disposal system, and subsequent dispersion in the atmosphere. Calculations considered the potential for uptake either directly by members of a human critical group through inhalation at the site perimeter, or via plant uptake and subsequent ingestion.

Limer (2011), drawing on results presented in Small and Lennon (2011), describes how peak release fluxes from the system for the Extended Disposal Area are anticipated to be lower than those from the Reference Disposal Area. Although the Extended Disposal Area is projected to have a higher total C-14 inventory than for the Reference case, the nature of the projected material types and volumes for disposal is such that biogeochemical calculations predict that a much lower proportion of the disposed C-14 will be released as gas.

Assessed doses for exposure to C-14 during the PoA scale directly with fluxes of the radionuclide in gas. Therefore peak doses during the PoA for the repository including the Extended Disposal Area are not significantly increased compared with those calculated for the Reference Disposal Area case in Penfold and Paulley (2011).

Peak calculated annual inhalation doses to a person outside of the LLWR site thus remain the same at 0.0002 µSv (CO_2) and $9\ 10^{-5}$ µSv (CH_4), and the peak occurs after about 70 y after present. The peak ingestion dose is 0.56 µSv if CO_2 is assumed (foodchain doses are much lower for CH_4).

3.3 Rn-222

The calculation described in Section 3.2.3 of Penfold and Paulley (2011) has been updated to take into account the additional Ra-226 inventory (and hence subsequent Rn-222 ingrowth) associated with potential disposals to the Extended Disposal Area.

Estimated Ra-226 disposals to the Extended Disposal Area are not significant compared with disposals to Vault 8, Vault 9 and the trenches; the estimated Extended Disposal Area inventory is 0.0055 TBq, whereas the Vault 8 inventory is 2 TBq, the projected total Vault 9 to Vault 14 inventory a further 0.08 TBq, and the trench inventory 0.29 TBq.

As the additional inventory being considered is very small by comparison to disposals in the Reference Disposal Area, the assessment results are not significantly different from the Reference Disposal Area case (peak annual dose of 52 µSv).

3.4 Dust

Section 3.2.4 of Penfold and Paulley (2011) outlines a conservative approach to estimating off-site impacts that could arise as a result of inhalation of any contaminated dust released from the disposed wastes.

Table 1 shows the results of updated calculations taking into account potential disposals to the Extended Disposal Area (equivalent to results presented in Table 5 of Penfold and Paulley (2011)).

The results show that the potential additional inventory does not lead to a significant increase in peak annual dose, as the calculated dose from the Extended Disposal Area is two orders of magnitude lower than doses calculated for the Reference Disposal Area vaults.

Table 1: Hypothetical Dose from the Inhalation of Contaminated Dust

Trench/Vault from which "dust" originates	Annual Dose (µSv)	Dominant radionuclide (% dose contribution)
Vault 8	12	Pu-239 (23%)
Vault 9	18	Pu-239 (23%)
Vault 10	13	Pu-239 (25%)
Vault 11	6.7	Pu-239 (33%)
Vault 12	8.7	Pu-239 (39%)
Vault 13	14	Pu-239 (34%)
Vault 14	1.2	Pu-239 (19%)
Extended Disposal Area	0.35	Am-241 (22%; Pu-241 contributes 14%)

4 Assessment of Discharges to Surface Waters

4.1 Leachate and Effluent Discharges

A method for calculating potential future doses to critical groups that might arise as a result of leachate and effluent discharges to the marine system is described in Section 4.2.1 of Penfold and Paulley (2011). Projections of future discharges were calculated by considering current discharge monitoring data and scaling to the estimated future vault inventory. The inventory of wastes that would be consigned to the EDA differs in terms of the mix of radionuclides from that currently disposed. For this reason, the extrapolation of the discharge data was undertaken by radionuclide, so that any differences in the inventory are reflected in the estimated doses. A range of critical groups were defined to assess the potential impacts that might be associated with such discharges.

The calculation has been updated to take into account the additional inventory that might be associated with disposals to the Extended Disposal Area.

The Reference Disposal Area case results indicate that doses are dominated by external irradiation from beach sediments. Co-60 is the principal radionuclide. The inventory of Co-60 in the Extended Disposal Area is projected to be much lower than for the other vaults (0.85 TBq compared with, for example, 99 TBq in Vault 13). Therefore, the additional wastes do not change the overall peak dose from that is calculated for the Reference Disposal Area case (0.83 µSv arising at 2026).

Figure 4 shows the calculated dose profile with time. Figure 5 shows the equivalent profile for the Reference Disposal Area case, for comparison. As disposals to the Extended Disposal Area are projected to occur post-2080, it is that part of the dose profile that has changed from the Reference Disposal Area case.

Figure 4: Estimated Annual Dose from Future Discharges of Aqueous Effluent via the Marine Pipeline for the Extended Disposal Area

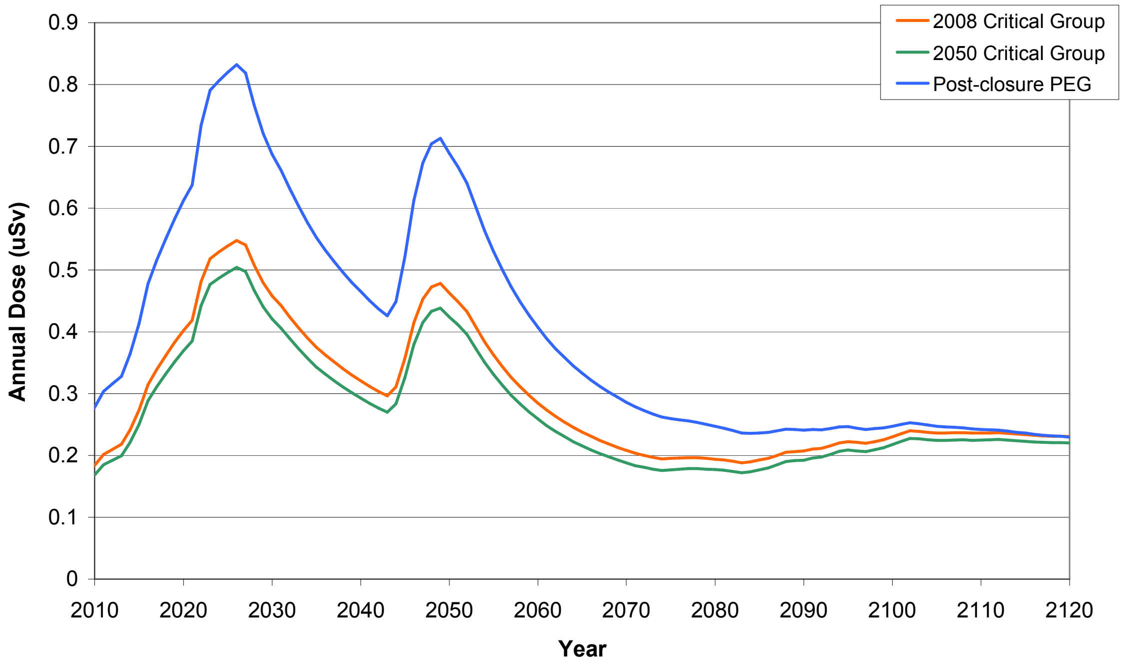
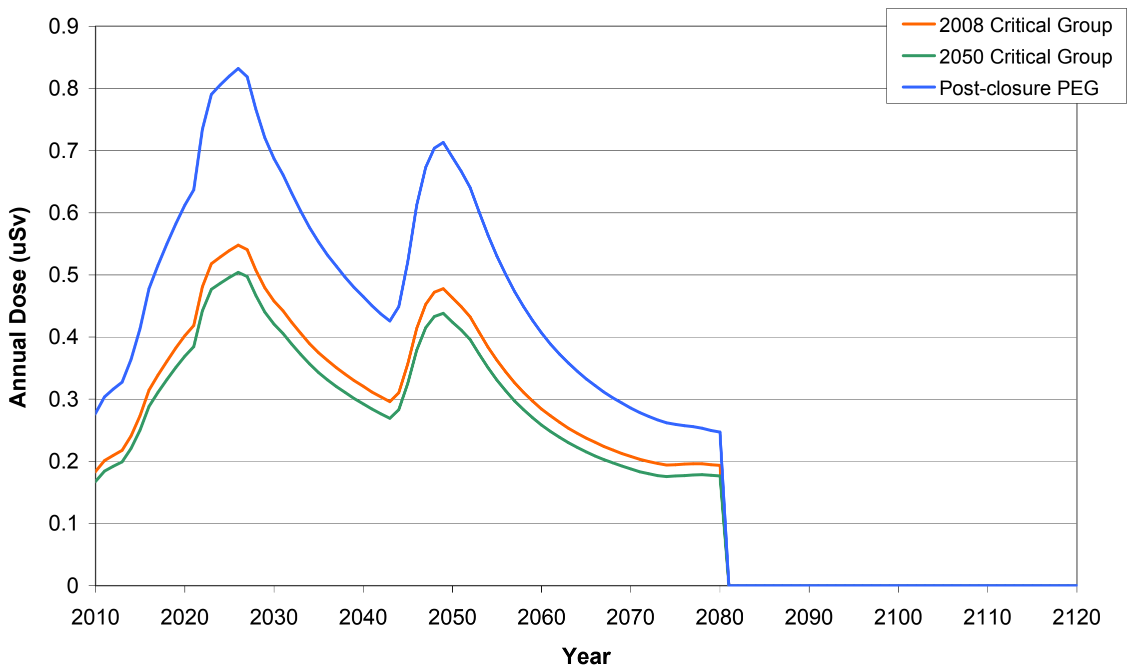


Figure 5: Estimated Annual Dose from Future Discharges of Aqueous Effluent via the Marine Pipeline for the Reference Case



4.2 Drigg Stream and Surface Water

The conclusions presented in Section 4.2.2 of Paulley and Penfold (2011) are the same for the Extended Disposal Area case.

The historic practice of routinely making authorised discharges of leachate to the stream will not occur in the future. Routine discharges are now directed to the marine holding tank, except for periods of exceptionally high rainfall. Furthermore, the design of future vaults will minimise the generation of leachate in the first place. As a consequence, there will be no future releases of any significance to the stream, and radionuclide concentrations in the Drigg Stream and surface water will decrease with time. Thus, associated potential doses will decline with time. The peak annual calculated dose is historic (2.8 μSv, due to Co-60 in 2007, decreasing to 2.1 μSv in 2015, 1.8 μSv in 2020, 1.3 μSv in 2040 and 0.7 μSv in 2050).

5 Assessment of Releases to Groundwater

Impacts to groundwater during the PoA are only expected to occur as a result of existing contamination and future releases from the trenches, given the design and operational approach for the vaults. Any differences in impacts that might be associated with implementation of the Extended Disposal Area would be limited to the influence of changes to the proposed geometry of the facility and engineering components, and to the timing of installation of aspects of the engineering.

Assessment results calculated for the Reference Disposal Area (Kelly et al, 2011) show that the dominant pathway would arise from the construction of a well. The highest annual doses to the hypothetical critical group would have occurred in the past (in 1989) and would have peaked at 90 μSv, with the dominant radionuclide being H-3. At the present date the peak annual dose is calculated to be 3 μSv. As groundwater abstraction has not and is not taking place, these exposures have not occurred, but provide a useful perspective on the trend in potential exposures. The calculated annual dose declines until about 2045 when it stabilises at about 0.2 μSv. The calculated annual doses are representative of the average that would be expected from locations between the site and the coast. The peak annual dose from the ingestion of marine biota of 0.005 μSv occurs at the present day and reduces in the future.

Overall no aspects have been identified that suggest implementation of the Extended Disposal Area would lead to significant changes to the groundwater impacts during the PoA calculated for the Reference Disposal Area. For example, there is no significant addition to the total inventory of H-3 that has been disposed of already. Therefore, the conclusions of Kelly et al (2011) are not significantly changed by the addition of wastes in the Extended Disposal Area.

6 Assessment of Direct Irradiation

Section 6.2 of Penfold and Paulley (2011) describes how present day dose rate measurements at the site perimeter can be used to help make projections of potential dose rates that might be associated with future disposals. The method used is to estimate doses to critical groups from different vaults on the basis of the inventories disposed to those vaults, applying external dose coefficients and critical group habit assumptions. The results are then used to scale the present-day measured dose rates for Vault 8.

Table 2 shows the results of applying this calculation to vaults in the Extended Disposal Area. The highest estimated annual dose, to a hypothetical resident at the site perimeter, peaks at over 100 µSv during the waste emplacement operations at Vault 9. Since the land adjacent to the vaults is protected as a Site of Special Scientific Interest (SSSI), the 'resident' group is highly unlikely as buildings are not present and would not be permitted. Nonetheless, it can be seen that even for the hypothetical case of a resident to the west of the site, doses associated with the Extended Disposal Area disposals are much lower, principally because disposals of the key radionuclide, Co-60 - which has a half live of around five years - are much lower than for Vaults 8 and Vaults 9 (by over three orders of magnitude).

Table 2: Estimated Future Doses by Direct Irradiation

Vault	Commencement of disposals (y after 2007)	Ratio of External Dose Rate to Vault 8	Estimated Annual Dose (µSv)		
			Dog Walker	Coal Worker	Resident*
Vault 8	0	1.0	1.2	12	24
Vault 9	4	6.0	7.2	72	145
Vault 10	15	2.0	2.4	24	48
Vault 11	20	0.11	0.13	1.3	2.6
Vault 12	23	0.05	0.06	0.58	1.1
Vault 13	27	0.72	0.86	8.6	17
Vault 14	46	0.0007	0.00082	0.0082	0.016
Extended Disposal Area	70	0.00012	0.00015	0.0015	0.003

* See text. This critical group is hypothetical only as the area adjacent to the vaults is an SSSI, with no permanent dwellings.

7 Conclusions

The assessments presented show that including additional vaults in the Extended Disposal Area would not result in any significant increase to the calculated peak annual doses arising from the LLWR compared with those from the Reference Disposal Area.[1]

A person living to the east of the site could conceivably receive a peak annual dose of about 100 µSv as a result of the combined exposure to radioactive gases and contaminated dust, ingestion of contaminated seafood, and external irradiation whilst walking close to the western edge of the site. If a person lived permanently to the west of the site, they could receive an annual dose of up to 150 µSv from all relevant pathways, although this could not happen in the foreseeable future due to the land's protected status.

[1] This conclusion is considered to also apply for other inventory variants e.g. Case B, as the differences in inventory compared to the reference inventory (Case A) would not be sufficient to change the relative outcomes.

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