LLW Repository Ltd

LLWR Environmental Safety Case

Assessment Calculations for Coastal Erosion 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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Assessment Calculations for Coastal Erosion for the LLWR 2011 ESC (Extended Disposal Area)

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Summary

The Low Level Waste Repository (LLWR) Site Licence Company is undertaking a programme of work that will result in the production of an Environmental Safety Case (ESC) for submission to the Environment Agency (EA) by May 2011. An important component of the arguments to be presented is quantitative long-term calculations of system performance.

Current projections of future climate change and the response of the coast in the vicinity of the LLWR indicate that coastal erosion will affect the facility in hundreds to thousands of years. This situation has therefore been the subject of a detailed analysis which presents the potential impacts to humans as a result of coastal erosion of the site considering a reference disposal area.

Within the 2011 ESC, LLWR is investigating the environmental safety implications associated with a possible extended disposal area, which could accommodate an additional six vaults. The potential radiological implications to humans associated with erosion of the extended repository have been assessed and are reported in this document.

The coastal erosion assessment model for the reference disposal area has been extended to include the six additional vaults. New assessment calculations have been undertaken for two inventory cases, and a number of other calculation cases. There are uncertainties associated with the radionuclide inventories that might be disposed of to the additional vaults in the extended disposal area. However, the two inventory cases considered in this assessment do not result in increased peak annual doses compared with calculations for the reference disposal area alone. This is because the inventory of key radionuclides is dominated by those disposed of to the reference disposal area.

Contents

1 Introduction

The Low Level Waste Repository (LLWR) Site Licence Company is undertaking a programme of work that will result in the production of an Environmental Safety Case (ESC) for submission to the Environment Agency (EA) by May 2011. An important component of the arguments to be presented is quantitative long-term calculations of system performance.

Current projections of future climate change and the response of the coast in the vicinity of the LLWR indicate that coastal erosion will affect the facility in a few hundred to thousands of years [Fish et al., 2010]. This situation has therefore been the subject of a detailed analysis by Towler et al. [2011], which presents the potential radiological impacts on humans as a result of coastal erosion of the site. The calculations assume the reference site development plan, namely that at closure, the LLWR will comprise seven trenches (numbered 1 to 7) and seven vaults (numbered 8 to 14) occupying an area termed the 'reference disposal area'.

LLWR is also investigating the potential radiological implications should the disposal area be extended to permit an additional six vaults. This is sufficient to dispose all the LLW in the UK national inventory (excluding low activity wastes and wastes where an alternative route is or is planned to be available). This report considers the potential radiological implications to humans associated with coastal erosion of the extended facility. The approach to assessing the potential radiological implications is identical to that described by Towler et al. [2011]. Therefore the focus of this report is on changes made to the assessment models to represent the extended repository, and the results of the calculations. It supplements the assessment of the reference disposal area and it is assumed that the reader is familiar with Towler et al. [2011].

Section 2 describes the potential layout and design of vaults in the extended disposal area. Section 3 describes the calculation cases required to assess the impacts of the additional vaults. Section 4 describes the changes made to the assessment model to represent the additional vaults, and Section 5 describes the results. The results are compared with those for the reference disposal area, as presented by Towler et al. [2011]. Conclusions are presented in Section 6.

2 The Extended Disposal Area and Additional Vaults

The layout of the additional vaults, Vaults 15 to 20, is shown in Figure 2-1. The vault numbering reflects the proposed construction and capping sequence. Further details are given by Tonks [2011].

The six additional vaults will extend the disposal area and hence the 'site frontage[1]' southwards by approximately by 220 m (from south west corner of Vault 14 to the south corner of Vault 20). This increases the length of beach that will in the future become contaminated with eroded wastes, and hence increases the amount of time that someone walking on the beach may be exposed to eroded waste.

In addition to extending the disposal site in a southerly direction, the additional vaults are also deeper than some of the existing/earlier vaults (e.g. Vault 8). The base of the additional vaults is assumed to be at the same elevation as the base of Vault 14, i.e. the operating floor is at 11.0 m AOD. This increases the likelihood that the wastes will directly eroded rather than undercut, especially for the most inland vaults, since sea level may rise as the erosion front passes through the site [Towler et al. 2011].

[1] The length of the section of the cliffs in which eroding material is exposed.

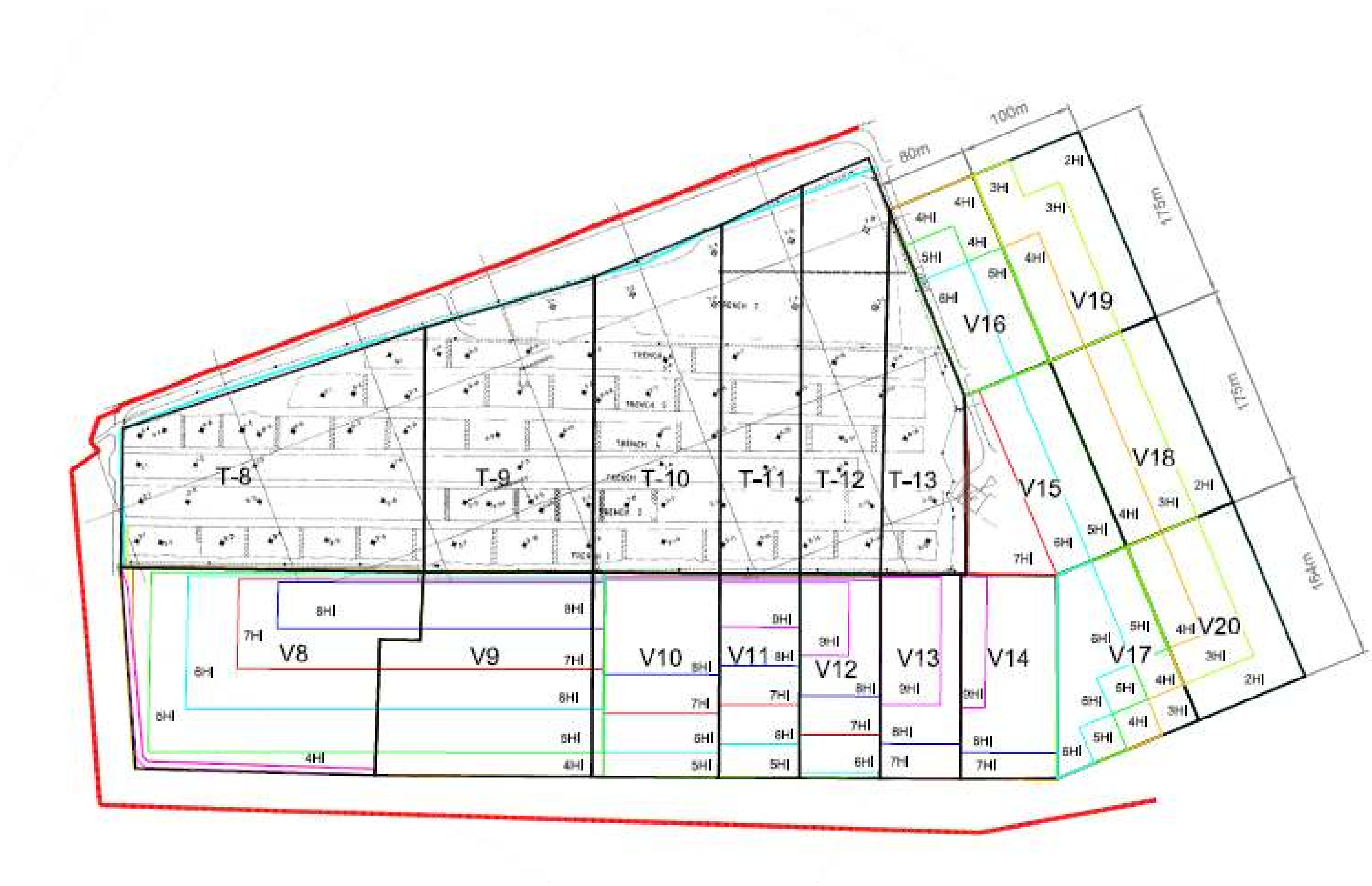

Figure 2-1: Layout of the extended facility, showing the six additional vaults (Vaults 15 to 20)

3 Assessment Assumptions

Two different disposal inventories have been assessed in calculations for the ESC:

- the reference inventory for the LLWR (WIDRAM 09), referred to here as 'Case A'; and
- the reference inventory with the inclusion of new-build wastes, referred to here as 'Case B'.

Wastes in the extended disposal area are in addition to these inventory assumptions. For both inventory options, the radiological impacts are assessed assuming that the erosion of the site commences 1,000 years from the present day, i.e. the reference case assumption described by Towler et al. [2011]. Assessment calculations are undertaken for the same exposure pathways and Potentially Exposed Groups (PEGs) described by Towler et al. [2011]. The three PEGs that are assessed are:

- recreational user of the shore adjacent to the LLWR site;
- occupational user of the shore anywhere between St Bees and Ravenglass; and
- high rate consumer of marine foodstuffs.

An occupational user of the most contaminated parts of the Drigg beach is also considered in a 'what-if' calculation. Such habits are not observed and would not be expected at such a location, therefore the PEG should be considered as being purely illustrative of maximising exposure conditions.

In addition, the following variant calculation cases (see Towler et al. [2011]) have also been assessed for the extended disposal area, inventory case A:

- Early (300 y) erosion case;
- Late (3000 y) erosion case;
- Direct erosion case; and
- Oblique erosion (south) case.

4 Assessment Model

The main difference compared with the assessment of the reference disposal area, described by Towler et al. [2011], is the inclusion of the additional vaults in the extended disposal area. The assessment model is therefore largely the same as that described by Towler et al. [2011], but a small number of changes are necessary. These are described in the following paragraphs.

4.1 Representation of the Additional Vaults

The GoldSim model for the reference disposal area was based on a regular Cartesian grid with the origin at the south west corner of Vault 14. This grid is used to calculate the timing of erosion of different parts of the site. The grid discretisation reflects the spatial distribution of radionuclides in the site. The x-axis is parallel to the long-axis of the reference disposal area, and the y-axis is perpendicular.

The grid has been extended to include the additional vaults, but it is noted that the additional vaults are not aligned with the existing grid (Figure 2-1). The existing co-ordinate system and origin has therefore been retained for the reference disposal area and new co-ordinates have been specified for the additional vaults using information from engineering drawings [Tonks, 2011]. Both sets of co-ordinates have a shared origin.

The additional vaults have been represented using one compartment per vault. Vertices have been specified for the east and west edges of the vaults, which define the start and end times of erosion respectively. For the additional vaults, the length of vault exposed in the cliff changes with time as the erosion front passes through the vault. For the majority of time the exposed length is constant (see Figure 4-1). Therefore, this constant value is used in the GoldSim model. The length of the vault exposed in the cliff line is calculated from the vault width. A mean width is used for Vaults 16 and 17.

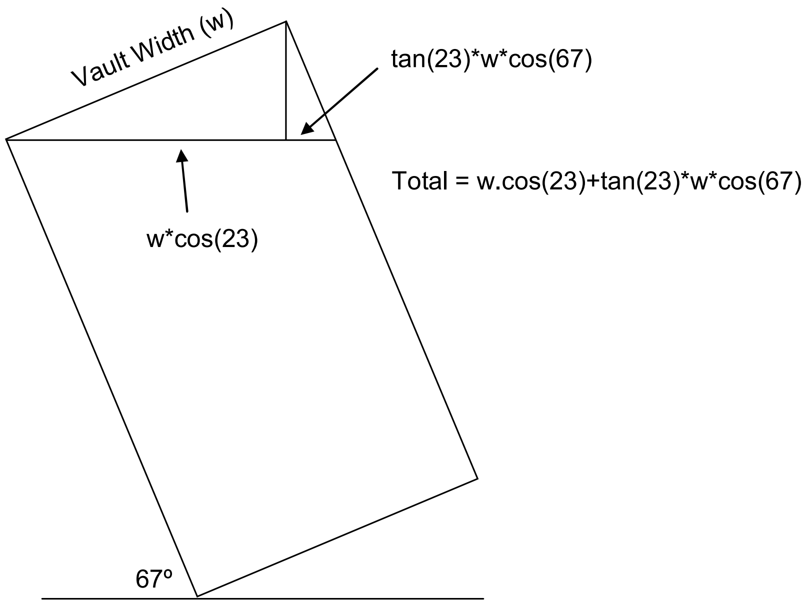

Figure 4-1. Calculation of the vault length exposed in the cliff

4.2 Length of the Site Frontage

For simplicity, Towler et al. [2011] did not account for any change in the length of the site frontage (i.e. the length of the section of the cliffs in which eroding waste material is exposed) with time. The length weighted average radionuclide concentrations in the wastes exposed in the cliffs were applied to the entire site frontage, even when this was less than the maximum associated with erosion of the vaults (810 m). This was considered acceptable as it only overestimates the length of exposed waste for trenches 6 and 7, which do not contain significant inventories of the key radionuclides for exposures during coastal erosion.

However, the assumption has been revisited in the calculations for the extended disposal area, as Figure 2-1 shows that the length of the site frontage may be significantly smaller when additional vaults 16 and 19 are eroding, compared with the other additional vaults. This has implications for the length of time the Recreational PEG is assumed to be exposed to contaminated areas. The model was therefore modified to enable the changing length of the site frontage to be calculated and used in the exposure calculations.

In the model, the site frontage is sub-divided into North, Mid and South Cliffs. The GoldSim model calculates radionuclide concentrations in the cliff for the whole site frontage and for the North, Mid and South cliff sub-sections. The evolving lengths of the site frontage and cliff sub-sections are used in these calculations. The contributions of the additional vaults to radionuclide concentrations in the whole site frontage and South cliff sub-section have been added to the model.

The length of the site frontage defines the length of contaminated cliff once erosion of the wastes has commenced. This is taken into account in dose calculations which assume a person walking along the beach. The recreational user is assumed to spend 300 hr y^{-1} occupying a 1.5 km length of the coastline. The time spent occupying the contaminated site frontage is equal to 300 hr y^{-1} x length of site frontage / 1.5 km (with a maximum of 300 hr y^{-1}). The occupancy time changes with the evolving length of the site frontage.

The occupancy times for the local occupational user ('what-if' PEG) do not change in response to the evolving length of the site frontage, as the exposed person is assumed, conservatively to frequent the most contaminated part of the beach.

As the length of the site frontage changes, the length of the associated beach (divided into North, Mid and South, correlating with the three cliff sections respectively), foreshore and local offshore sediment compartments change. The volume of material transported by longshore drift on the foreshore is assumed to vary linearly with the length of the foreshore. (Note there is no net drift of material, but lateral spread of contamination is considered, see Towler at al. [2011]).

The longshore drift volume assumed for the reference disposal area was scaled by the length of the site frontage compared with the reference length of 810 m. It is also noted that the evolving site frontage and associated changes to compartment dimensions have implications for compartment turnover rates. These are calculated by the model directly.

4.3 Inventory and timing

Radionuclide inventories have been calculated for each additional vault. There are two inventory cases to be considered for the additional vaults (Cases A and B described in Section 3). Table 4-1 shows the disposal timings for these two cases. Inventory data are taken from the 'PIERS' inventory spreadsheets (PIER V2_3_a 19 11 10 ART AH and PIER V2_3_b 19 11 10 ART AH)

The volume of disposed waste in each additional vault are also taken from the PIERS spreadsheets and is reproduced in Table 4-2. Note that the vault volumes differ for inventory cases A and B, due to different cap profiles.

Table 4-1. Disposal times for additional vault inventories, Cases A and B

Vault	Fill Date (years AD)	
	Case A	Case B
15	2086	2087
16	2092	2094
17	2100	2101
18	2106	2107
19	2111	2112
20	2127	2127

Table 4-2. Additional Vault Volumes

Vault	Volume (m^3)	
	Case A	Case B
V15	153000	202000
V16	98000	148000
V17	122000	136000
V18	72000	83000
V19	67000	83000
V20	61020	78000

A single average value was specified for the depth of the base of the vaults in the reference disposal area [Towler et al. 2011]. Because there are significant differences in the depth of the vaults in the extended disposal area, specific values have been specified for these vaults. This is necessary because the depth of the vault defines the amount of underlying geology that exposed below the wastes in the cliff. The volume of underlying geology is used when calculating the average radionuclide concentrations in the cliff. The depth assigned to vaults 15 to 20 is the same as Vault 14. However, the treatment of Vault 14 was not changed for these calculations to ensure consistency with calculations for the reference disposal area. Variations in the depths of the vaults, and of the beach elevation as the erosion front passes through the site, were bounded for the reference disposal area assessment by the reference and direct erosion calculation cases analysed by Towler et al. [2011].

4.4 Option Switches

A new 'switch' has been added to the existing model to control whether the model is run for the reference disposal area (recreating the calculations reported by Towler et al. [2011]) or for the reference and extended disposal area (the results reported herein). The inclusion of the additional vaults inventories, cliff length factors, cliff concentration calculations and coastal compartment dimensions all make use of this switch.

A second new switch was added, which provides the option to use a constant or time-varying length for the site frontage. While a constant site length was used for the reference disposal area calculations [Towler et al. 2011], a time varying site length is needed for this assessment (as discussed in Section 4.2).

A third new switch selects inventory Case A (reference inventory) or B (inclusion of new build inventory) for the extended disposal area (Section 4.3). This switch also controls the timing of disposal for each additional vault.

5 Results

5.1 Inventory Case A

Figure 5-1 shows the total radionuclide concentrations in environmental media compared with the results for the reference disposal area. Results for the reference disposal area calculated using an evolving rather than fixed length of the site frontage with time are also shown in Figure 5-1.

For the reference disposal area, when the evolving length of the site frontage is accounted for, radionuclide concentrations associated with erosion of the trenches are slightly higher than in the original results [Towler et al. 2011]. This is because the site frontage is slightly shorter than originally considered, such that sections of the cliff containing no waste are not included in the calculation of the length weighted average cliff concentration.

The concentrations are only slightly altered with inclusion of the additional vaults. The most noticeable impact is slightly higher radionuclide concentrations when the most inland parts of the site are eroding (Trenches 6 and 7 and additional vaults 16 and 19). However, the increased concentrations are still lower than the peak, which results from wastes in the reference disposal area (trenches).

Figure 5-2 and Figure 5-4 show the calculated effective doses compared with the original results for the reference disposal area, and the results for the reference disposal area accounting for the evolving length of the site frontage. Peak doses are summarised in Table 5-1 and are all dominated by the erosion of wastes from the reference disposal area.

Although accounting for the evolving length of the site frontage results in slightly higher peak radionuclide concentrations in the coastal environment compared with the results for the reference disposal area, the peak dose for the Recreational PEG is actually slightly decreased. This is because the exposure duration is decreased with the calculated length of site frontage (which defines the length of exposed wastes in the cliff and the contamination plume on the beach). Doses to the local occupational user have increased notably, but this PEG is assumed to preferentially frequent the contaminated area rather than use the whole beach. In this case, the increase in peak dose reflects the higher environmental radionuclide concentrations, particularly in the cliffs.

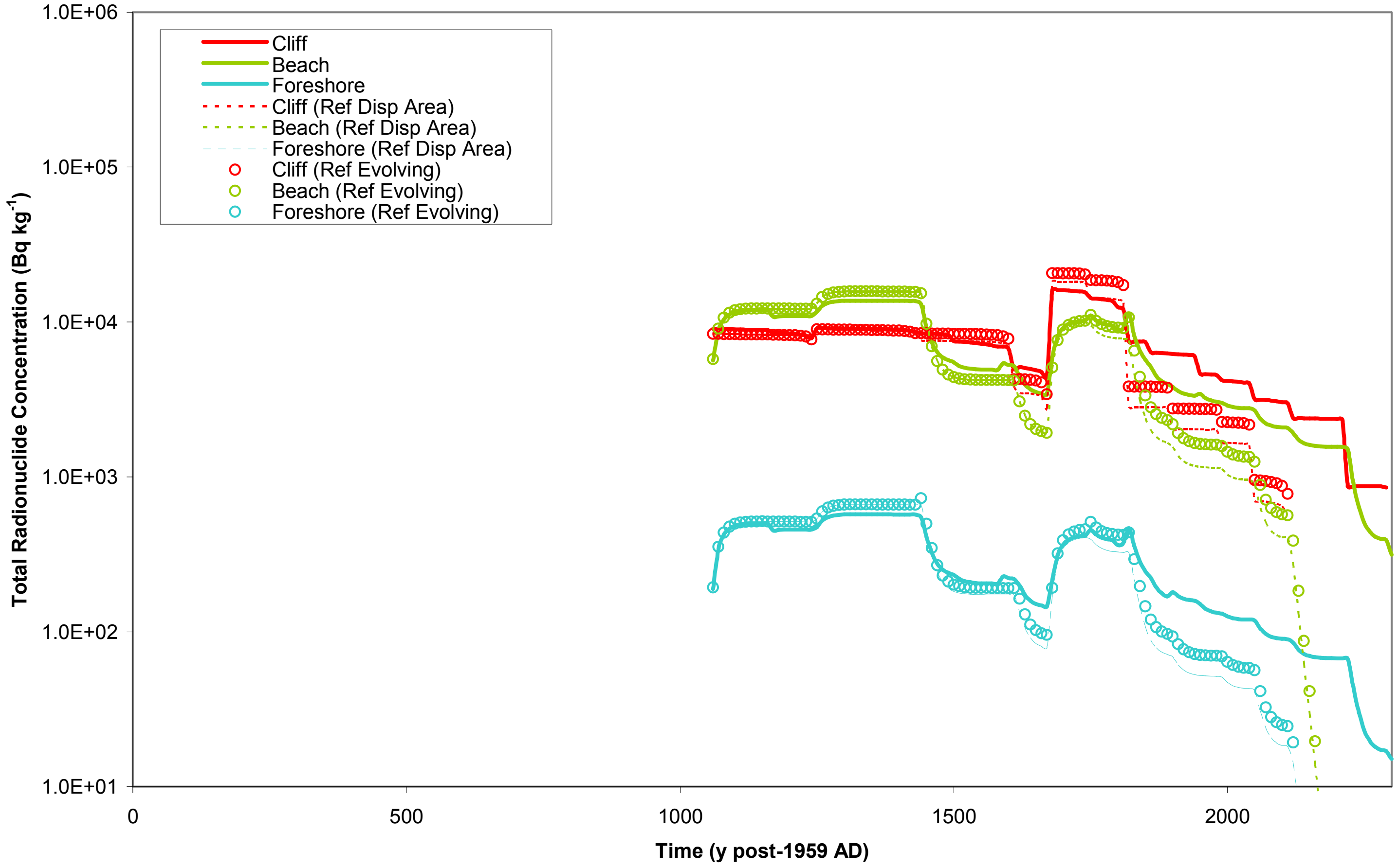

Figure 5-1. Case A: total environmental radionuclide concentrations for the reference and extended disposal area, compared with the equivalent results for the reference disposal area alone

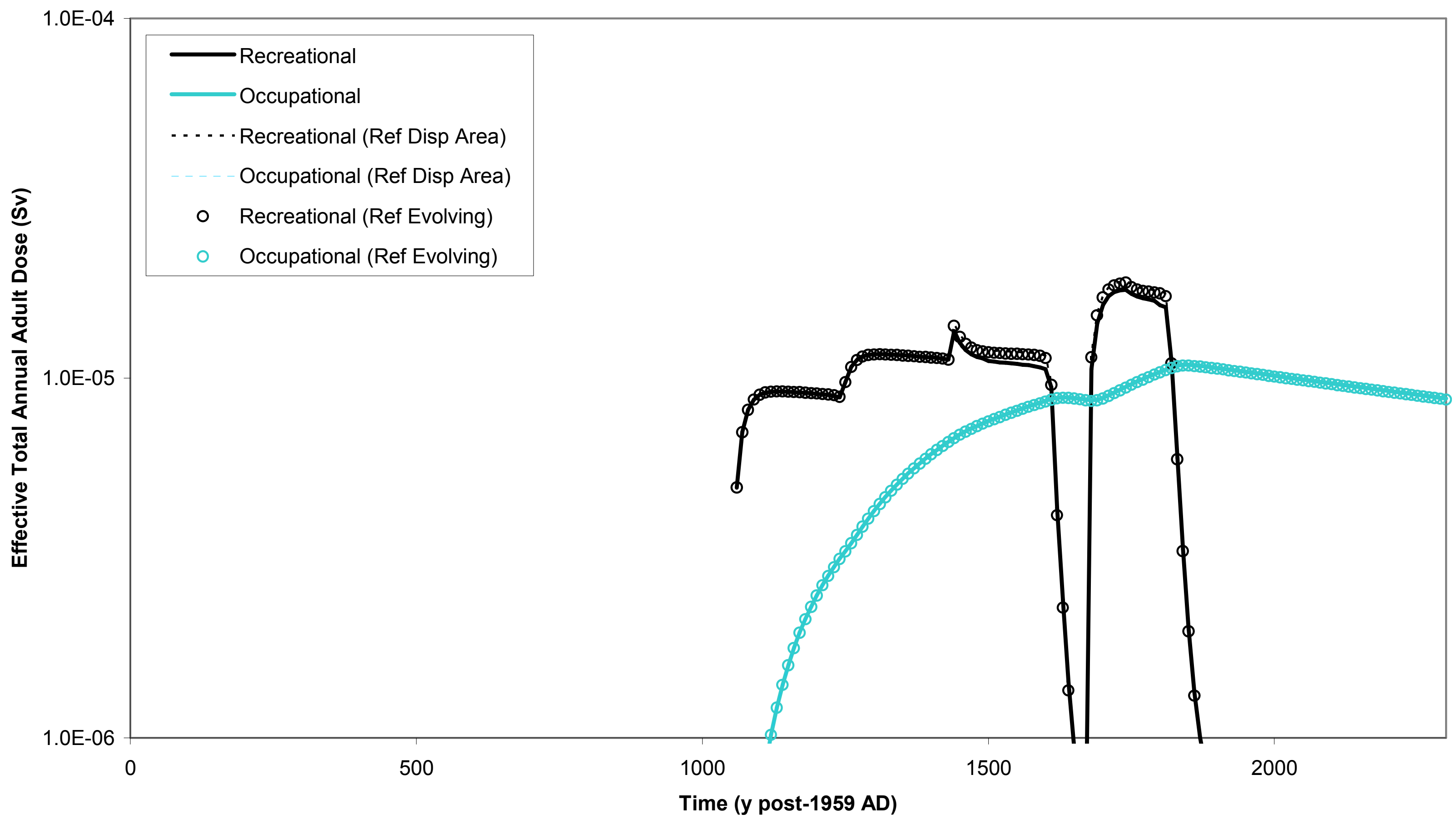

Figure 5-2. Case A: PEG doses or the reference and extended disposal areas, compared with the equivalent results for the reference disposal area alone

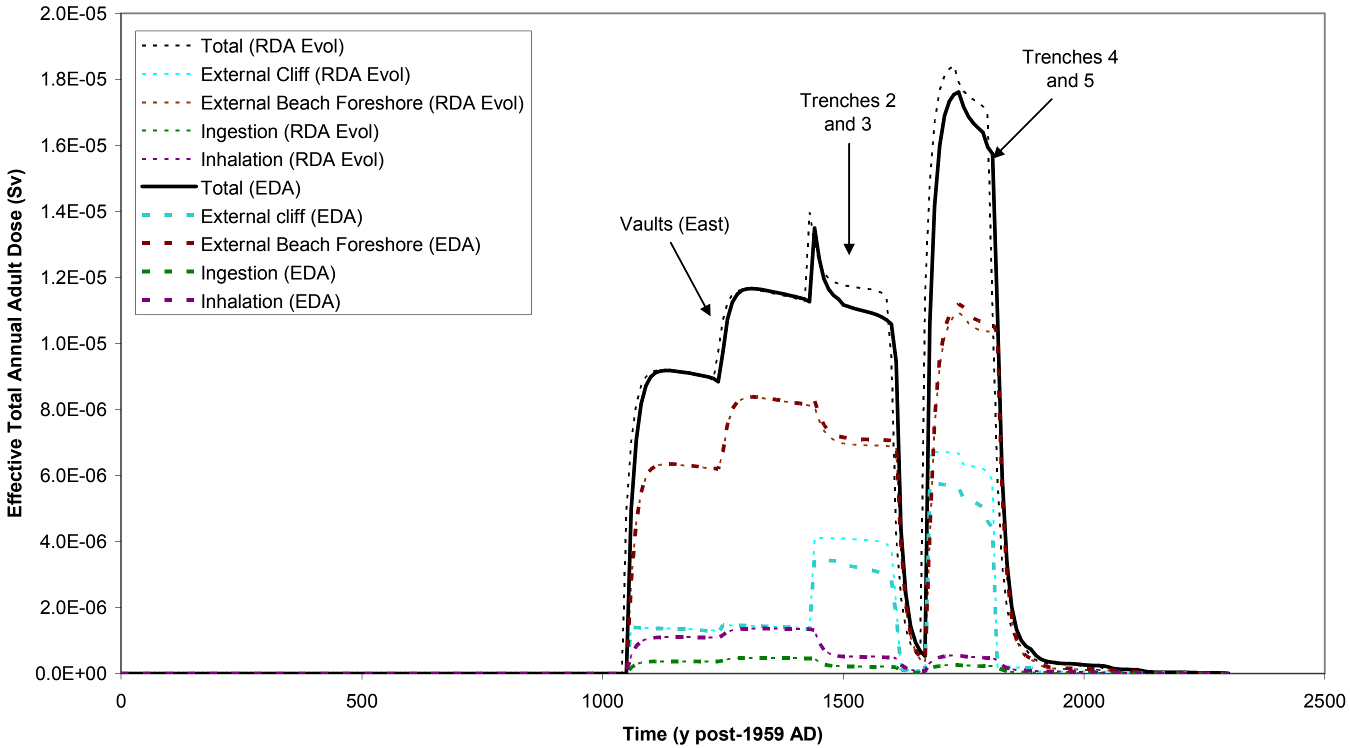

Figure 5-3. Case A: doses associated with individual exposure pathways for the recreational user compared with the reference case (with evolving site length)

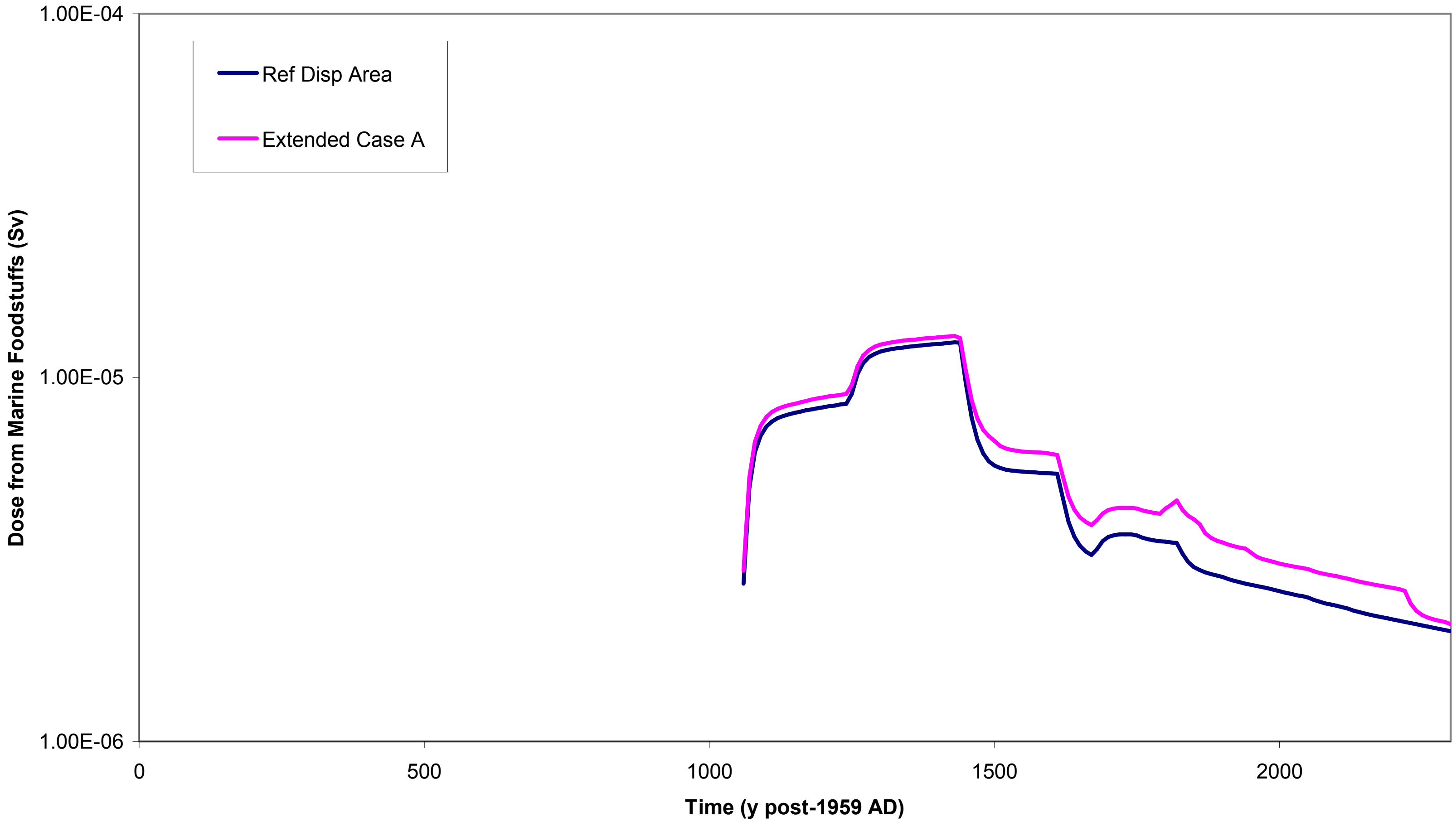

Figure 5-4. Case A: total dose from consumption of marine foodstuffs for the reference and extended disposal areas, compared with the equivalent results for the reference disposal area alone

Peak doses to the recreational and occupational users are not altered with the addition of vaults 15-20. Peak doses to the local occupational user decrease because the average radionuclide concentration in the cliffs, along the entire site frontage, is reduced when the additional vaults are included.

Figure 5-3 shows doses associated with each exposure pathway for the recreational user compared with the reference case (with evolving site length). Doses from the cliffs are slightly reduced, but otherwise doses are not significantly different.

Peak doses from consumption of marine foodstuffs are slightly increased when the additional vaults are included. However, doses are still dominated by Pb-210, ingrown from Ra-226 disposed to the reference disposal area.

Table 5-1. Calculated peak annual doses (µSv) for inventory case A

	Reference Disposal Area	Reference Disposal Area (Evolving Site Length)	Reference and Extended Disposal Area, Case A
Recreational user	19(12)	18(12)	18(12)
Occupational user	11(7)	11(7)	11(7)
Marine foodstuffs	12(12)	13(12)	13(13)
Local occupational user*	252(176)	298(176)	230(139)

Peak dose associated with the vaults shown in (). * Low probability "What-if?" PEG.

5.2 Inventory Case B

The results are almost identical to inventory case A. Peak doses for are given in Table 5-2.

Table 5-2. Calculated peak annual doses (Sv) for inventory case B

	Reference and Extended Disposal Area, Case B
Recreational user	18
Occupational user	11
Marine foodstuffs	13
Local occupational user*	229

Peak dose associated with the vaults has not been determined. *Low probability "What-if?" PEG.

5.3 Additional Calculation Cases

Peak doses for the additional calculation cases are summarised in Table 5-3. Addition of the extended disposal area has not significantly changed peak doses compared with the assessment results for the reference disposal area [Towler et al. 2011]. The only notable change is a reduction in the peak dose for the recreational user in the direct case. This is because the average cliff line concentration is lower for the extended disposal area than the reference disposal area.

Table 5-3. Summary of calculated peak annual doses (Sv)

Case	Recreational user, peak total annual dose (µSv)	Occupational user, peak total annual dose (µSv)	Marine foodstuffs, peak total annual dose (µSv)	Occupational user of the site frontage, peak total annual dose (µSv)
RDA Reference A	19 (12)	11(7)	12(12)	252(176)
RDA Reference Evolving	18(12)	11	13(12)	298(176)
EDA A	18(12)	11(7)	13(13)	230(139)
RDA Early	22 (19)	12(9)	47(47)	N/A
EDA A Early	21(19)	12	49	N/A
RDA Late	19 (7)	9(5)	3(3)	N/A
EDA A Late	18(7)	9	3	N/A
RDA Direct	57 (12)	11	ND	N/A
EDA A Direct	39(12)	11	ND	N/A
RDA Oblique S	16	13	ND	N/A
EDA A Oblique S	15	13	16	N/A
EDA B	18	11	13	229

Peak dose associated with vaults is shown in (). ND = not determined. N/A = not applicable.

6 Conclusions

The mathematical model for the assessment of potential radiological effects of the coastal erosion of the LLWR has been modified to represent a possible extended disposal area, which could contain five additional vaults and associated wastes.

There are uncertainties associated with the radionuclide inventories that might be disposed of to the additional vaults in the extended disposal area. However, the inventory cases considered in this assessment do not result in increased peak annual doses compared with calculations for the reference disposal area alone. This is because the inventory of key radionuclides is dominated by those disposed of to the reference disposal area.

References

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