Environment, Safety, Security and Safeguards Case Version 2, Tier 1, Chapter 30: Prospective Radiological Assessment

Record of Change

Date	Revision Number	Status	Reason for Change
30/03/2023	1	Issue	Formal version for issue.
31/03/2023	2	Issue	Final version for issue incorporating formatting changes for E3S consistency (full document)
15/03/2024	3	Issue	Updated version to include Details of RR SMR direct dose calculations. • Additional details of Stage 3 modelling assumptions and inputs (section 30.2) • Updated IRAT assessment (section 30.3 and Appendix B) • Additional details for individual (section 30.4.1-2), collective (section 30.4.3), and short term doses (section 30.6) assessment methodology • Additional details and inputs for sensitivity analysis (section 30.5).
31/05 2024	4	Issue	Updated to correct revision history status at Issue 3. Chapter changes include: • Improved linkage to evidence summarised in chapter to the Fundamental Claim (Executive Summary, section 30.7) • Additional discussion around model selection (section 30.1) • Clarification on selection of value for direct dose values (section 30.3.4) • Editorial and template changes to support E3S case consistency (all document)

Executive Summary

Environment, Safety, Security and Safeguards (E3S) Case Version 2, Tier 1, Chapter 30: Prospective Radiological Assessment outlines a prospective radiological impact assessment for predicted offsite discharges of gaseous and liquid radioactive effluent from the Rolls-Royce Small Modular Reactor (RR SMR) and reflects reference design 7 (RD7) and design reference point 1 (DRP1).

The aim of chapter 30 is to provide evidence to support the RR SMR fundamental claim that "impact on members of the public and the environment from disposals of aqueous and gaseous radioactive effluents from the RR SMR under normal operations is minimised and within the radiological dose limits and constraints set out in legislation and guidance". Development of the chapter is iterative, and this issue provides an update on progress to date.

An assessment of the radiological dose impact on members of the public and non-human species from continuous discharges of liquid and gaseous radioactive effluent to the environment was undertaken using the Environment Agency's (EA) initial radiological assessment tool (IRAT), using radioactive discharge values established from the design information for the RR SMR at preliminary concept design (PCD), and environmental information from the RR SMR generic site description (GSD). This assessment was repeated using updated discharge values based on a revised primary source term and updates to design information from RD7/DRP1. The results indicate that dose to members of the public and non-human species from liquid and gaseous radioactive effluent discharges, (including estimated contribution from direct radiation dose for members of the public), is well within statutory and guidance limits.

An approach for performing a detailed assessment of radiological impact, using environmental and habits parameters representative for the RR SMR generic site, is outlined. This will support the assessment of the dose to the representative person, collective dose, and further evaluation of the impact to non-human species. Also identified are the planned sensitivity analyses for evaluating the effects of key design, environmental and habits data on the assessed radiological impacts.

The methodology for an initial assessment of dose to members of the public arising from a short term radioactive gaseous discharge is described, including the derivation of the environmental activity concentration data and the environmental and RR SMR design parameters used in the modelling approach.

A summary of the findings of the radiological impact assessment to date, and the comparison with relevant limits and guidance is presented. Ongoing work to improve the dose estimates, through better understanding of the source terms and model inputs and assumptions is also provided in the form of a table of forward actions (FA).

Contents

Tables

Figures

30.0 Introduction to Chapter

30.0.1 Introduction

This chapter comprises chapter 30 of the Rolls-Royce Small Modular Reactor (RR SMR) environment, safety, security and safeguards (E3S) Case and is a Tier 1 chapter as defined in E3S Case Version 2, Tier 1, Chapter 3: Objectives and Design Rules for Structures, Systems and Components [1].

This chapter presents the overarching summary and entry point to information on the assessment of radiological dose to members of the public and non-human species from the discharge of radioactive effluents from the RR SMR to the environment under normal operating conditions. An initial radiological impact assessment was undertaken using the source term available at the RR SMR preliminary concept definition (PCD) in 2022. The radiological impact assessment has since been updated with discharge estimates from the design information available at reference design 7 (RD7) and design reference point 1 (DRP1). The final version of this chapter will support the fundamental claim for chapter 30, as detailed in section 30.0.3.

30.0.2 Scope and Maturity

The scope of this chapter is the radiological impact to members of the public and non-human species from discharges of aqueous and gaseous radioactive effluent to the environment during normal operations of the RR SMR.

A contribution to radiological dose to members of the public from direct radiation ("shine") has been determined separately (E3S Case Version 2, Tier 1, Chapter 12: Radiation Protection [2]) and is added to the dose arising from discharges to establish the total dose from the RR SMR.

The following are excluded from this chapter:

- The impact from radioactive contaminated material and/or discharges arising from construction works or from decommissioning at the end of the operational life.

- Discharges arising from accident scenarios or fault conditions are excluded; however, this assessment does include a contribution from reasonably foreseeable operational occurrences (i.e. expected events), as detailed in E3S Case Version 2, Tier 1, Chapter 29: Quantification of Discharges and Proposed Limits [3]. Offsite consequences of releases to the environment under fault conditions will be considered in E3S Case Version 2, Tier 1, Chapter 15: Safety Analysis [4].

- The radiological dose to employees and other workers on site is not in scope of this chapter but is considered in E3S Case Version 2, Tier 1, Chapter 12: Radiation Protection [2]

- Doses from radioactive waste disposed to offsite waste management facilities permitted under the Environmental Permitting (England and Wales) Regulations 2016 (EPR16) (as amended) are not considered. The dose to members of the public and the environment from disposal of radioactive waste disposed of to such a facility will be accounted for under the waste management facility's EPR16 permit. The minimisation of radioactive wastes for transfer to such facilities (e.g. solid wastes to landfill, incineration or long-term storage) is captured in E3S Case, Version 2 Tier 1 Chapter 11: Radioactive Waste Management Arrangements [5].

The Structures, Systems and Components (SSCs) associated with this topic include those SSCs from which discharges to the environment are made; specifically, the emissions stack for gaseous radioactive effluent from the Heating, Ventilation and Air Conditioning system (HVAC) [KL] and Gaseous Radioactive Effluent Treatment System (GRETS) [KPL], the Air Removal Exhaust System (ARES, formerly Condenser Air Removal System (CARS)) [MAJ], and the liquid effluent discharge point [UPK].

All SSCs within the site which contain radioactive material or waste, or are contaminated with radioactivity, may contribute to the direct dose to members of the public.

30.0.3 Claims, Arguments and Evidence Route Map

The information presented in this chapter provides some of the evidence supporting the fundamental claims for the radiological impact assessment of gaseous and aqueous effluent discharges from the RR SMR. Further information on the fundamental claims for environmental aspects can be found in E3S Case Version 2, Tier 1, Chapter 27: Demonstration of Best Available Techniques [6].

The top-level fundamental claim for E3S Case chapter 30 is:

Claim 30.0: Impact on members of the public and the environment from disposals of aqueous and gaseous radioactive effluents from the RR SMR normal operations is minimised and within the radiological dose limits and constraints set out in legislation and guidance.

There are no sub-claims for this chapter. Mapping to the relevant Tier 2 and Tier 3 information containing the detailed arguments and evidence, is presented in the E3S case route map [7]. Underpinning arguments and evidence may still be developed in future; the trajectory of this information, where possible, is also illustrated in the route map. A proportionate summary of the arguments and evidence from lower tier information, available at the current design stage, is presented within this chapter.

This chapter provides the following evidence to support the top-level claim for this chapter:

- Initial results of screening radiological impact assessments for members of the public and non-human-species performed using the Environment Agency's (EA) initial radiological assessment tool (IRAT) and preliminary estimates of radioactive effluent discharges from the RR SMR under normal operating conditions at a generic coastal site.

- The methodology adopted and initial results of detailed radiological impact assessments for gaseous and aqueous discharge of radioactive effluent from the RR SMR, based on a continuous discharge model, using PC-CREAM 08. This will include:
    - modelling dispersion and accumulation of radionuclides in the environment,
    - assessment of individual and collective dose to members of the public and identification of the "representative person" for the site, and
    - a sensitivity analysis for key environmental and habits parameters.

- The methodology used for assessing individual doses to members of the public resulting from short-term gaseous discharge of radioactive effluent from the RR SMR, using the atmospheric dispersion modelling system (ADMS 6), including a sensitivity analysis for key environmental and meteorological parameters.

- The methodology used for assessing the dose rates to non-human species resulting from continuous discharge of gaseous and liquid radioactive effluent from the RR SMR, using the environmental activity concentrations derived from PC-CREAM-08.

- Provide a comparison of the RR SMR predicted dose to members of the public and non-human species to national and international limits and constraints.

- Provide a summary of future work relating to data collection and design development of the RR SMR, which will be undertaken to reflect changes in design and source term and improve confidence in the assessment of the RR SMR radiological impact assessment.

30.0.4 Applicable Regulations, Codes and Standards

International and national obligations on the protection of people and the environment from harm resulting from radioactive discharges are defined in standards, legislation, policy and guidance. presented in subsections 30.0.4.1 to 30.0.4.3.

30.0.4.1 International Context

The International Commission on Radiation Protection (ICRP) Basic Safety Standards (BSS) [8] set out the principles and fundamentals for radiation protection, which are adopted worldwide. E3S Case Version 2, Tier 1, Chapter 27: Demonstration of Best Available Techniques [6] outlines how the fundamental principle of optimisation should be applied to ensure the impact of discharges of radioactive substances on members of the public is kept as low as reasonably achievable (ALARA). However, it is recognised that optimisation is not always sufficient, and there is also a need to set probability-based limits below which the risk of harm (stochastic effects) from exposure to radiation is considered tolerable by society relative to the benefits gained from the practice which causes the exposure (e.g. Reference [9]).

The ICRP recommends limits on the dose which may be received from planned exposure situations in different settings, for example medical, occupational or public exposure. The BSS Schedule III [8] sets a whole-body effective dose limit of 1 mSv/y for members of the public from all planned exposure situations.

ICRP also recommends the use of public exposure dose constraints from facilities managing radioactive materials or waste to support optimisation. These are not prescribed by ICRP but should be set by national regulatory or governing bodies.

The BSS also explicitly extends protections from exposure to radiation to ‘the environment’. No exposure limits for non-human species are defined in the BSS, but it is expected that the impact on species other than human beings should be considered in the regulation of radioactive discharges to the environment.

The European Commission (EC) Directive 2013/59/EURATOM (Basic Safety Standards Directive, or BSSD) [10] requires the BSS dose limits, the requirement for dose constraints and consideration of the impact on non-human species to be transposed into the domestic legislation of the European Union (EU) Member States[1].

For assessment of collective doses, the International Atomic Energy Agency (IAEA) has published a recommendation that exemption from regulatory requirements is possible if "the collective effective dose committed by one year of performance of the practice is no more than about 1 manSv" [11]. It should be noted that a more recent IAEA publication does not include a specific recommended threshold for exemption, instead stating "Collective dose should be used only in the comparison of options, and any truncation applied to the calculations has to be consistent for the comparisons to be meaningful. Collective dose must not be used to predict health effects." [12].

30.0.4.2 Regulation in England and Wales

Discharges of radioactive substances from nuclear power stations to the environment are controlled under the radioactive substances regulation (RSR), set out in Schedule 23 of EPR16 [13].

Schedule 23 of EPR16 sets out the controls on the radiological impacts associated with permitted discharges of radioactive effluents from sites discharging radioactive waste to the environment. It stipulates:

> **Optimisation and dose limits**
>
> 1. In respect of a radioactive substances activity that relates to radioactive waste, the regulator must exercise its relevant functions to ensure that —
>   a) all exposures to ionising radiation of any member of the public and of the population as a whole resulting from the disposal of radioactive waste are kept as low as reasonably achievable, taking into account economic and social factors, and
>   b) the sum of the doses resulting from the exposure of any member of the public to ionising radiation does not exceed the dose limits set out in Article 13 of the Basic Safety Standards Directive subject to the exclusions set out in Article 6(4) of that Directive [2]
>
> **Specific dose limits and calculation**
>
> 2. (1) In exercising those relevant functions in relation to the planning stage of radiation protection, the regulator must have regard to the following maximum doses to individuals which may result from a defined source—
>   a) 0.3 millisieverts per year from any source from which radioactive discharges are first made on or after 13th May 2000, or
>   *b)* 0.5 millisieverts per year from the discharges from any single site.

[1] Transposition of 2013/59/Euratom into UK legislation was completed by the deadline of February 2018, prior to the coming into force of the European Union (Withdrawal Agreement) Act 2020 on 31 December 2020

[2] Note that the Articles referred to in this excerpt from EPR16 reference the previous BSSD (Directive 96/29/Euratom), repealed and replaced by the BSSD laid down in 2013/59/Euratom.

Inclusion of the 1 mSv/y dose limit in EPR16 implements the BSS/BSSD requirements for protection of members of the public from exposure to ionising radiation. The dose constraint requirements are implemented through Schedule 23 (2), restricting the dose to individuals from single sources and sites. Following the introduction of the revised BSS in 2007 [8], the Health Protection Agency (HPA, now the United Kingdom Health Security Agency, UKHSA) recommended a more cautious 150 µSv/y dose constraint for new nuclear power stations, on the basis of uncertainties in health effects [14], however, this recommendation has not thus far been incorporated as a formal regulatory requirement or as guidance.

The dose assessments above focus on members of the public exposed in the locality of the RR SMR, where environmental radioactivity concentrations and thus exposure are likely to be highest. However, the prospective transboundary impacts of disposals of radioactive waste to the environment must also be assessed for certain RSR permit applications, including for disposals from the operation of nuclear reactors (except small research reactors) [15], [16].

30.0.4.3 Further Policies and Guidance in England and Wales

United Kingdom (UK) Government's Review of Radioactive Waste Management Policy [17] sets a 'threshold of optimisation' for exposure to members of the public of 20 µSv/y, equating to a risk of death of approximately 1.0E+06, as being broadly acceptable and in line with other common risks to the public.

In 2009, the then Department for Energy and Climate Change (DECC)[3] issued statutory guidance [18] to the EA[4]. This guidance provides that, for sources of radiation for which the dose to the most exposed member of the public is below 10 µSv/y the EA should not seek to further reduce the discharge limits that are in place, provided that the holder of the permit continues to apply best available techniques (BAT).

The main guidance document for dose assessments to members of the public is the Principles for the Assessment of Prospective Public Doses Arising from Authorised Discharges of Radioactive Waste to the Environment [19]. Further guidance on radiological assessments is provided by competent UK bodies such as the UKHSA (including its predecessor Public Health England (PHE) and earlier incarnations) and the National Dose Assessment Working Group (NDAWG). These sources of guidance are referenced in this report describing the approaches for detailed radiological assessments.

The assessment of potential radiological impact of radioactive effluent discharges on non-human species is not an explicit requirement under Schedule 23 of EPR16; however, it is a material consideration in the determination of applications for RSR environmental permits [20] and in the setting of annual limits on discharges of radioactive effluents to the environment [21]. Requesting parties (RPs) and prospective permit applicants are therefore required to assess the potential impact of their nuclear power station radioactive effluent discharges on non-human species.

There is no legal dose limit in the UK regarding collective doses. Regulatory states that "average annual individual doses for a population group in the nano-Sievert (nSv/y) range or below should be ignored in the decision-making process as the associated risks are minuscule" [19].

[3] Subsumed into the Department for Business, Energy & Industrial Strategy (BEIS) in July 2016.
[4] Since 2013, regulation of radioactive substances in Wales has been the responsibility of Natural Resources Wales (NRW).

The EA considers that there will be no adverse effects at population level to reference species for a dose below 40 μGy/h [22]. A more restrictive screening level of 1 μGy/h is used to determine whether a refined dose assessment is required [23].

30.1 The Radiological Assessment Approach

30.1.1 Radiological Assessment of Annual Discharges – Overview

The overall approach for assessing the radiological impacts of routine discharges (including expected events) of aqueous and gaseous radioactive effluents from the RR SMR to the environment is based on the staged approach advocated by the NDAWG [19], [24]. The staged approach comprises the following tiers of radiological assessments, characterised by increasing level of detail and complexity.

- Stage 1 is a simple and cautious assessment utilising dose per unit release (DPUR) factors published by the EA [23], [25] based on conservative environmental dispersion parameters and generic assumptions about the habits of exposed persons. This assessment is typically performed using the accompanying spreadsheet-based tool available on request from the EA, or proprietary spreadsheets incorporating DPUR values. The IRAT output also contains the dose rate to the worst affected non-human species.

- Stage 2 assessments are an extension of Stage 1 assessment and generally involve the adjustment of model parameters used in stage 1 assessments to reflect more realistic assumptions. Typically, the environmental dispersion parameters for aqueous and gaseous discharges to the environment – volumetric exchange rates for liquid discharges and the effective release height for gaseous emissions – are modified using project specific values.

- Stage 3 assessments entail detailed source and site assessment of radiological impacts from routine aqueous and gaseous discharges to the environment, as well as short-term discharges to air. It involves the assessment of individual and collective doses to members of the public, dose rates to non-human species and the assessment of the build-up of radionuclides in the environment over the life of the facility making the discharges. For site specific assessments, the contribution from any nearby sources of radioactivity and from historic sources is also assessed.

A detailed stage 3 assessment is not normally required where the outcome of the stage 1 and 2 assessments does not exceed 20 μSv/y [19] – except in the case of large installations such as nuclear power stations, for which a detailed stage 3 assessment is a requirement of the permitting process. A stage 3 assessment will therefore be undertaken for the RR SMR regardless of the outcome of the initial radiological assessments, to satisfy corporate business objectives and to provide the additional level of detail specified in generic design assessment (GDA) guidance [26].

30.1.2 Description of Generic Site and Modelling Parameters

The philosophy behind the RR SMR is the design of a modular SMR performing to a high environmental standard, which can be deployed in multiple locations. The generic site description (GSD) [27] is the set of characteristics which define the range of sites that the RR SMR will be assessed against to demonstrate environmental performance and show regulatory expectations can be met.

The generic site is assumed to be coastal with the site being located approximately 100 m from the sea. The RR SMR will be cooled using induced draft cooling towers, with the cooling water demand being met by abstracted seawater. The following general characteristics have been defined for the generic site:

- The site and its surrounding area are assumed to lie on a flat plain with no large buildings in the immediate vicinity other than the RR SMR nuclear power plant (NPP)
- The site is not located on an aquifer
- There is no standing water at the site
- No water bodies or watercourses cross the site
- There is no ground or groundwater contamination present on the site
- The site is located in a rural setting dominated by agricultural land use and fishing activity in the local seas
- There are no Protected Areas[5] within the immediate vicinity of the site.

The GSD informs the selection of modelling parameters used in assessing potential environmental impacts associated with the RR SMR. The parameters are selected to provide realistic but cautious criteria against which environmental impacts can be assessed and reflect the categories of site at which the RR SMR is likely to be deployed. It should be noted that, whilst the GSD for environmental modelling has the same broad general characteristics as the generic site envelope (GSE) outlined in E3S Case Version 2, Tier 1, Chapter 2: Generic Site Characteristics [28], the GSD parameters and assumptions differ from the bounding values which define the GSE.

A detailed description and justification of GSD characteristics and input data for modelling parameters is presented in Reference [29]. The key characteristics of the site are summarised in Table 30.1-1, with further detail presented in Appendix A (section 30.9).

Table 30.1-1 Environmental and Habits Characteristics used in RR SMR Radiological Dose Assessments

Parameter	Value/Description
Location	Coastal
Predominant land use	Agriculture and fishing
Meteorological conditions	70 % Pasquill 'D'
Gaseous release discharge height (height above ground level)	{REDACTED}
Residential dwelling location	300 m from discharge point

[5] Protected Areas in the UK may be established under national legislation (e.g. sites of special scientific interest and national nature reserves), international legislation (e.g. special areas of conservation and special protected areas) or international agreements (e.g. RAMSAR sites and marine conservation areas). Further information on Protected Areas can be found in reference [82].

Parameter	**Value/Description**	
Food production location	500 m from discharge point	
Marine dispersion	Local compartment	'Wylfa' values [30], [31], [32]
	Regional compartment	Irish Sea West
Food consumption rates	UK generic habits data [33]	
Time spent at exposure locations	UK generic habits data [33]	
Non-human species exposure groups	Gaseous Discharges	All terrestrial reference organisms [34]
	Liquid Discharges	All marine reference organisms [34]

30.1.3 Source Term

30.1.3.1 Annual Discharges of Radioactive Effluent

The radiological assessments presented in section 30.3 have been carried out using the proposed annual gaseous and aqueous discharge permit limits. These limits are derived from the predicted discharges from the Reactor Island (RI) waste processing systems and the RI HVAC system, multiplied by a headroom factor to account for variability in normal operations discharges. The predicted discharges are expected to provide a realistic but cautious estimate of the maximum discharge of radioactive effluent to the environment. Thus, whilst the RR SMR is designed with a 'minimal liquid discharge' philosophy, with reduced tritium concentration in primary coolant, recycling of treated effluents [35], and an expectation that discharge will not be required every year, for the purposes of radiological impact assessment to members of the public and wildlife, it is assumed that a release of aqueous radioactive effluent will take place. The conditions under which such a discharge would occur are summarised in Footnote 10 and discussed further in Reference [36].

The predicted permit limits from E3S Case Version 1, Tier 1, Chapter 29: Quantification of Discharges and Proposed Limits (March 2023) [36] are used as the source term in this initial assessment, and are based on the design of the RR SMR at PCD and an interim or sensitivity primary source term (PST) for the RR SMR, to which a generic headroom factor of 2 was applied.

The initial estimates of annual discharges of aqueous and gaseous radionuclides predicted to arise from the RR SMR, and associated proposed annual limits are presented in Table 30.1-2 and Table 30.1-3

Table 30.1-2 RR SMR Predicted Annual Discharges and Proposed Permit Limits for Liquid Effluent

Radionuclide	Predicted discharges (Bq/y)	Proposed limits (Bq/y)	Radionuclide	Predicted discharges (Bq/y)	Proposed limits (Bq/y)
Ag-110m	2.89E+06	5.78E+06	H-3	8.88E+10	1.78E+11
Ba-140	4.28E+07	8.56E+07	I-131	4.88E+06	9.76E+06
C-14	5.07E+07	1.01E+08	Mn-54	2.36E+06	4.72E+06
Ce-141	5.62E+05	1.12E+06	Nb-95	1.13E+06	2.26E+06
Ce-144	1.58E+07	3.16E+07	Ni-63	1.62E+05	3.24E+05
Co-58	4.07E+06	8.14E+06	Ru-103	2.85E+07	5.70E+07
Co-60	1.83E+06	3.66E+06	Ru-106	4.97E+03	9.94E+03
Cr-51	5.87E+06	1.17E+07	Sb-125	1.06E+06	2.12E+06
Cs-134	2.39E+08	4.78E+08	Sr-89	3.32E+06	6.64E+06
Cs-136	1.52E+08	3.04E+08	Sr-90	3.00E+05	6.00E+05
Cs-137	1.12E+08	2.24E+08	Zn-65	5.82E+06	1.16E+07
Fe-55	2.10E+07	4.20E+07	Zr-95	1.33E+06	2.66E+06
Fe-59	8.25E+05	1.65E+06	Other beta/gamma emitting nuclides[6]	2.89E+06	5.77E+06

[6] This category represents an aggregate of radionuclides which were considered in the aqueous discharge estimates in chapter 29, but for which the current version of IRAT does not model individual radionuclides (Ag-108m, Nb-94, Ni-59, Pr-143, Sb-124 and Y-91). The contribution from these radionuclides is calculated using the conservative DPUR value assigned to 'other beta/gamma' in the IRAT spreadsheet.

Table 30.1-3 RR SMR Predicted Annual Discharges and Proposed Permit Limits for Gaseous Effluent

Radionuclide	Predicted discharges (Bq/y)	Proposed limits (Bq/y)	Radionuclide	Predicted discharges (Bq/y)	Proposed limits (Bq/y)
Ag-110m	9.63E+04	1.93E+05	Kr-85	4.45E+10	8.90E+10
Ar-41	8.04E+11	1.61E+12	Kr-85m	2.39E+10	4.78E+10
Ba-140	2.62E+05	5.24E+05	La-140	5.51E+05	1.10E+06
Br-84[7]	1.45E+09	2.91E+09	Mn-54	2.95E+04	5.90E+04
C-14	1.80E+11	3.59E+11	Mn-56	1.68E+05	3.35E+05
Ce-144	7.73E+04	1.55E+05	Mo-99	9.56E+02	1.91E+03
Co-58	2.10E+06	4.20E+06	Na-24	1.06E+05	2.13E+05
Co-60	4.48E+04	8.96E+04	Nb-95	5.98E+03	1.20E+04
Cr-51	2.58E+05	5.15E+05	Ni-63	5.29E+04	1.06E+05
Cs-134	1.61E+04	3.22E+04	Ru-103	1.49E+05	2.98E+05
Cs-136	2.77E+03	5.54E+03	Sb-125	1.59E+04	3.19E+04
Cs-137	9.82E+03	1.96E+04	Sr-89	2.79E+03	5.58E+03
Fe-55	3.05E+06	6.11E+06	Sr-90	2.38E+02	4.76E+02
Fe-59	1.27E+05	2.55E+05	Tc-99m	4.92E+02	9.83E+02
H-3	4.08E+10	8.16E+10	Xe-133	6.22E+11	1.24E+12
I-131	6.76E+07	1.35E+08	Zn-65	1.43E+05	2.86E+05
I-132	6.22E+08	1.24E+09	Zr-95	6.76E+03	1.35E+04
I-133	2.63E+08	5.25E+08			
I-134	1.02E+09	2.03E+09	Other beta/gamma-emitting nuclides	3.15E+07	6.29E+07
I-135	5.40E+08	1.08E+09	Other noble gases[8]	4.92E+11	9.85E+11

The source term calculated at RD7/DRP1 is presented in Appendix B (section 30.10). The refined PST [37] provides an estimate of radionuclide activities in the primary circuit which is more specific to RR SMR chemistry and operations than the previous sensitivity PST. Activity concentrations in some of the key primary systems (the primary systems source term, or PSST)

[7] A DPUR value for Br-84 is not included in IRAT, so Br-82 has been used as surrogate radionuclide, in line with approach in the IRAT user guide [23].

[8] The category of 'other noble gases' includes the contribution from Kr-87, Kr-88, Xe-131m, Xe-133m, Xe-135, Xe-135m and Xe-138. The discharges of these radionuclides were aggregated and assessed as, Xe-133 – the only fission product noble gas in IRAT. This is in line with approach in the IRAT user guide **[23]**.

such as the Spent Fuel Pool [FAB10] and Chemistry and Volume Control System (CVCS) [KB-], derived from the updated PST are also available. These have been used to produce updated estimates of liquid and gaseous radioactive effluent discharges from the RR SMR (references [38] and [39]) and updated proposed discharge permit limits using appropriate headroom factors [40].

The source term at RD7/DRP1 will be used to undertake the radiological impact assessments up to stage 3. This work is underway and will be presented in full in a future issue of this chapter. The revised discharge estimates and proposed limits are presented in Appendix B (section 30.10), along with a preliminary IRAT assessment using the RD7/DRP1 source term, for comparison with the initial estimates derived from the sensitivity PST presented above.

30.1.3.2 Mode of Discharge

Liquid Discharges

It is recognised that the soluble boron-free, potassium-based chemistry adopted for the RR SMR operating regime should facilitate minimal discharge of aqueous radioactive effluent to the environment under normal operating conditions; discharges to the environment are likely to only be required on rare occasions, for instance in the event of fuel pin failure or for tritium management purposes. The requirement for, management of, and impact of such events on liquid discharges to the environment is still to be determined for the RR SMR and may be influenced by other factors (for example timing of fuel pin failure in the cycle and extent of damage), However, the expectation is that they will be minimised through BAT and will occur infrequently.

Such infrequent discharges to the environment are akin to a short-term discharge (defined in Reference [41] as the release of 2 % or more of annual discharges over a relatively short period of 1 day or less). However, NDAWG [42] observed that:

- Dispersion in estuarine and coastal environments is driven by tidal currents which do not vary significantly over the course of a year.
- The dose from aqueous discharges to coastal or estuarine waters is dominated by the ingestion of fish and shellfish; given the preference for consumption of fresh seafood among fishermen, the worst affected group for this discharge, the associated habits (bait digging and seafood consumption) do not show significant seasonal variation.
- Fish are mobile in coastal and estuarine waters and are therefore unlikely to be constantly exposed to a plume from a short-term release.

The NDAWG concluded that the total dose predicted to arise if the 12 monthly limits are discharged as short-term releases will not differ significantly from the dose that would arise if the same discharges occurred as a continuous release [42]. Thus, for purposes of the RR SMR stage 3 assessment, discharges of aqueous radioactive effluent are assumed to follow a continuous discharge profile to facilitate the assessment of the radiological impacts from this effluent stream using the DORIS module of PC-CREAM 08. This approach is considered relevant good practice (RGP) for a generic site at this stage of the assessment [42].

Gaseous Discharges

Short-term discharges of radioactive gaseous effluent are anticipated to arise during plant shutdown and maintenance outages. Such discharges are expected to be dominated by volatile tritium (H-3) originating from the Spent Fuel Pool [FAB10] and associated pools, and noble gases from the GRETS [KPL]. These discharges are anticipated to peak during a few days over the shutdown and refuelling outage phases - when the primary coolant is degassed and radioactive gases are purged from vessels containing primary coolant and exhausted from containment to allow personnel to access the building for maintenance.

Thus, the estimates of dose to members of the public based on a continuous discharge model will be supplemented by an assessment of the impact of short-term releases. This assessment is described further in section 30.1.4.4

FA 30.1 Review assumptions on discharge strategy as information on expected events impacts and management becomes available.

30.1.4 Selection and Justification of Modelling Tools (Continuous Discharge)

30.1.4.1 Stage 1 and 2 Modelling Tool – IRAT

The EA's GDA Guidance for RPs [26] recommends the use of the IRAT model for stage 1 and 2 radiological dose assessment modelling. The IRAT permits assessment of the impact of various radioactive discharges to environmental pathways, including discharge of liquid radioactive effluent to the marine environment, to waste treatment plants or to rivers, and discharge of gaseous radioactive effluent to atmosphere.

IRAT calculates the dose to the worst affected individual by multiplying the embedded DPUR factors (µSv/y per Bq/y) with predicted discharges of radionuclides. DPUR factors are provided for over 100 different radionuclides, internal and external exposure pathways, and four age groups (adult, child, infant and offspring). The annual dose for a given discharge route (e.g. discharges to air or sea) is a summation of the doses for each radionuclide–exposure pathway–worst age group combinations.

Dose rates to non-human species are estimated in a similar manner to that for humans. Doses are determined by multiplying DPURs for a suite of non-human species (µGy/h per Bq/y) in marine, terrestrial or freshwater environments by the predicted radioactive effluent discharges. The resulting dose rates for each radionuclide-organism combination are summed to derive the total dose rates for a given discharge route.

The IRAT model provides a cautious estimate of doses to members of the public and non-human species using conservative environmental and habits parameters. IRAT includes radionuclides and discharge routes which are applicable to the RR SMR GSD. It is therefore considered appropriate to use IRAT for stage 1 and 2 of the RR SMR dose assessment.

The assessments were carried out using the updated 'IRAT 2' spreadsheet tool [23], [25] released in 2022 and supplied by the EA. The stage 1 assessment uses the default environmental dispersion parameters in the IRAT model and the predicted discharge data in Table 30.1-2 and Table 30.1-3.

The stage 2 assessment modifies the default volumetric exchange rates in the coastal IRAT and the effective release height in the atmospheric IRAT. The parameters were adjusted as follows:

- A relatively conservative volumetric exchange rate of 100 m^3/s (around 3.2E+09 m^3/y) is adopted as being representative of the local marine compartment of the GSD and will be used to refine the assessment of dose from aqueous discharges to the marine environment.

- An effective release height of {REDACTED}, corresponding to a third of the height of the RR SMR shell structure of {REDACTED}, has been assumed on a conservative basis. This accounts for the impact of building wake effects on dispersion and is consistent with established practice [43]. The effective release height will be reviewed when further information is available on the height of the shell structure, the main gaseous effluent discharge stack [KLS] design, and if other significant radioactive gaseous discharge points are identified.

30.1.4.2 Stage 3 Modelling Tool – PC-CREAM 08

The detailed dispersion and accumulation of radionuclides in food and the environment from continuous release of liquid and gaseous discharges from the RR SMR is modelled using the PC-CREAM 08 software [30]. PC-CREAM 08 is a well-documented and tested software package for assessing radiological impacts due to releases of radioactive material from nuclear facilities into the environment.

PC-CREAM 08 comprises a suite of models for assessing the dispersion and accumulation of radionuclides in food and the environment from continuous release of liquid and gaseous effluent discharges.

- Model for assessing dispersion of liquid discharges:
  - **DORIS:** models the activity concentrations in the marine environment and seafood resulting from continuous discharges into European coastal waters.

- Models for assessing dispersion of gaseous discharges:
  - **PLUME:** is a Gaussian Plume model that calculates the activity concentrations in air, deposition rates and external exposure to gamma rays from the plume resulting from continuous discharges to the atmosphere.
  - **GRANIS:** models the migration of deposited radionuclides through soil to calculate the activity concentration of radionuclides at different soil depths and the external gamma dose rate from layers of contaminated material.
  - **FARMLAND:** models the transfer of deposited radionuclides from the soil or plant surface into terrestrial foods to calculate the activity per unit mass of food.
  - **RESUS:** calculates the activity concentrations in air arising from the resuspension of previously deposited radionuclides.

The dose impact of radionuclides distributed in the environment on individual members of the public and collective public groups are modelled using ASSESSOR modules. The outputs of the models listed above form the inputs into the ASSESSOR modules.

- ASSESSOR modules for assessing dose impact on the public resulting from liquid discharges:
  - **DORIS Individual Dose:** uses activity concentrations from the DORIS model combined with the actual discharge rates, site specific data, habits data and dose coefficients to calculate the time integrated effective dose to individual members of the public for relevant exposure pathways.
  - **DORIS Collective Dose:** uses activity concentrations from the DORIS model to calculate the time integrated effective dose to a given population group.

- ASSESSOR modules for assessing dose impact on the public resulting from gaseous discharges:
  - **PLUME Individual Dose:** uses the outputs from PLUME, GRANIS, FARMLAND and RESUS models, combined with the actual discharge rates, site specific data, habits data and dose coefficients to calculate the time integrated effective dose to individual members of the public for relevant exposure pathways.
  - **PLUME Collective Dose:** uses the outputs from PLUME, GRANIS, FARMLAND and RESUS models to calculate the time integrated effective dose to a given population group, based on information about population distribution and assumed habits, as well as agricultural production around a site.

PC-CREAM 08 was primarily developed by the UK HSA for use in western Europe, with default parameters applicable to the UK environment and existing NPP sites included within the software. The radionuclides, exposure pathways and population groups included within the software meet the requirements of this assessment. The generic RR SMR site is coastal, and the software includes modelling of dispersion of radioactivity in marine environments. PC-CREAM 08 was therefore considered appropriate for use in the detailed modelling of radiological impact of RR SMR discharges on members of the public.

Since PC-CREAM was initially launched in 1997 and PC-CREAM 08 succeeded it in 2008, various assessments have been performed on the modelling approaches incorporated within the software (for example [44], [45]). In 2022, the UK HSA published a summary report outlining the findings of several of these studies with the aim of verifying and validating the models used in PC-CREAM 08 [46]. In this report, the UK HSA determined that the models implemented in PC-CREAM 08 *"are adequate representations of the real world and can be used with confidence for the purposes for which they were created"*. This affirms the suitability of the PC-CREAM 08 and supports the decision to select it.

Other dispersion models, such as those used in the comparison exercise in reference [45] are available and considered to adequately support the assessment of the dose impact of radioactive effluent discharges to the environment Overall, PC-CREAM 08 offers the best balance of: coverage of typical UK environments and exposure pathways of interest to RR SMR; developer support (including underpinning documentation, training and model updates), level of detail required for a generic assessment for coastal and atmospheric discharges, and scalability. The limitations of the model are understood (e.g. absence of a building wake effects or short-term release models) and can readily be accounted for by adjusting model inputs or using additional more sophisticated short term release models).

Further, the selection of PC-CREAM 08 is consistent with previous submissions to the EA in support of GDA and EPR16 applications for similar types of generic or specific UK coastal sites. For example PC-CREAM 08 was used in the GDA dose assessments for previous RP (References [47], [48], [49] and [50])

As inferred earlier, PC-CREAM 08 is not suitable for assessing radiological impacts arising from short-term releases to the environment (e.g. enhanced discharges to air during shutdown or maintenance outages) or direct radiation emanating from the main plant and associated structures. This section addresses only impacts arising from routine continuous discharges. The approaches for assessing the impacts of short-term radioactive discharges and direct radiation are discussed in sections 30.6 and 30.3.4 respectively.

30.1.4.3 Stage 3 Modelling Tool – ERICA

The effects of liquid and gaseous discharges from the RR SMR on marine and terrestrial non-human species are modelled using the ERICA Tool 2.0. ERICA 2.0 is a software system that uses the tiered ERICA integrated approach for assessing the radiological risk to non-human species.

The ERICA 2.0 and integrated approach are well documented and tested for use in assessing the radiological impacts of radioactivity in the environment on non-human species. The radionuclides and reference organisms included within the software comprehensively cover the requirements of this assessment. It is noted that the selection of reference organisms in ERICA 2.0 enables most protected species within Europe to be addressed in assessments [51]. Since the ERICA tool was initially released in 2007, various studies have been performed to verify and validate the modelling approaches incorporated within the software (for example [52] and [53]). Based on this, ERICA 2.0 was considered the most appropriate tool for use in this assessment.

Selection of ERICA 2.0 is consistent with submissions to the EA in support of other GDA and EPR16 applications. For example the previous version of the ERICA tool was used for GDA dose assessments for UK EPR [47], AP1000 [48], HPR1000 [49] and ABWR [50]. The updated version of the ERICA tool was launched in 2023 and reflects methodological development for dose calculation included in ICRP Publication 136 [54] and includes modelling of noble gases.

There is significant overlap between the environmental/habits parameters assumed in the IRAT non-human species model and the parameters in the RR SMR GSD. However, the stage 3 ERICA assessment will consider the environmental activity concentrations predicted by the PC-CREAM 08 modules (a description of the applicable modules can be found in section 30.1.4.2) after 60 years of RR SMR operation, and will also consider the location of non-human species in relation to the location of maximum environmental activity concentrations derived from PC-CREAM 08 model outputs.

30.1.4.4 Short-term Dose Assessment

The requirement to consider the impact of short-term gaseous releases is described in section 30.0.4. The atmospheric dispersion code ADMS 6 [55]. has been used to model atmospheric dispersion of radionuclides entrained in short term gaseous effluent discharges from the RR SMR. The ADMS 6 is an advanced, new generation Gaussian plume air dispersion code which uses the boundary layer depth and the Monin-Obukhov length to characterise the atmospheric boundary layer properties, rather the single parameters associated with the traditional Pasquil stability categories. This allows for more realistic estimation of atmospheric concentration of gaseous emissions than traditional Gaussian plume models such as NRPB-R91 [56]. Further, the ADMS 6 comprises subroutines that facilitate modelling the effects (on a dispersing plume) of buildings, complex terrain, coastlines and variable surface roughness; dry and wet deposition; short term releases (puffs); and allowance for radioactive decay including gamma-ray dose [55].

The code is frequently validated against measured data from field campaigns and wind tunnel experiments by the model developers, Cambridge Environmental Research Consultants (CERC), and is shown to have good agreement with the measured data. Details of validation studies for buildings, complex terrain and flat terrain can be found on the CERC website [57].

The ADMS 6 code has good precedence over comparable codes such as AERMOD [58] for assessing short-term discharges to the atmosphere in the UK and has been widely adopted in previous GDA and permit application submissions. It has therefore been selected over other dispersion modelling codes such as AERMOD and NRPB-R91.

For the RR SMR assessments, the ADMS 6 will be used to calculate air concentrations and deposition rates at receptor locations (dwelling and food source locations) for a 12-hour short-term gaseous discharge from the RR SMR. Short term doses will then be calculated using a bespoke spreadsheet tool implementing the methodologies described in Reference [59].

30.2 Discussion of Input Parameters

30.2.1 Approach to Selection of Input Parameters

Input data were compiled based on information and assumptions provided in the RR SMR GSD and RR SMR discharge data. Where parameters were not specified, appropriate model default or UK generic data were selected.

The justification of the choice of a GSD as a basis for the RR SMR design is described in section 30.1.2. The use of a generic site means the preferred approach of using site-specific information as input parameters for dose assessment modelling cannot be applied, and generalised habits data and methods have to be used [33], [60].

When selecting generic values for this assessment, publications from the EA, HSA, NDAWG and National Radiological Protection Board (NRPB) (now UK Health Security Agency (UK HSA)) were reviewed in conjunction with the methodology reports for PC-CREAM 08 and ERICA 2.0 to determine the most recent and appropriate values for coastal sites around the UK. Evidence from national surveys (e.g. Reference [61]) demonstrates that public exposure is dominated by food ingestion, inhalation; external dose from the plume, deposited radioactive material, contaminated sediment, and direct radiation pathways. These major pathways are included in our approach.

The full set of input values and assumptions made for assessment of doses to members of the public and non-human species from continuous discharge of radioactive effluents to the environment from the RR SMR are described in Reference [29] along with the associated references and full justification for selection. Key input data are summarised in sections 30.2.2 and 30.2.3. The selection of appropriate model inputs and identification of exposure pathways will be reassessed at the site-specific permitting stage, when further information on local and regional habits is available.

30.2.2 Inputs Used to Assess Dose to Members of the Public

Generic/default values from the sources below, regarded as being representative of a potential nuclear site, in England or Wales were used for input parameters.

- The generic site is regarded as being a rural, coastal UK site approximately 100 m from the sea [27], [28]). The generic site is not located on an aquifer, and there is no standing water, water bodies or watercourses on the site. The generic site and its surrounding area are assumed to lie on a flat plain with no large buildings in the vicinity of the facility. Therefore, the appropriate PC-CREAM 08 default values (such as surface roughness) for a rural environment were used accordingly [30].

- Where a specific site is required to be selected in PC-CREAM 08 (e.g., for the local marine compartment parameters), Wylfa was selected as being reflective of typical conditions of potential nuclear sites in a coastal location. Wylfa has also been selected as the basis for generic sites in previous GDA applications (e.g. Reference [50]).

- As the assessment considers a generic site, the PC-CREAM 08 default habits data detailed in HPA-RPD-058 [30], derived from NRPB-W41 [33] are used. At this stage of assessment, the use of generic habits data is considered more appropriate than habits data for a specified population group - for example, the Centre for Environment, Fisheries and Aquaculture Science (CEFAS) food consumption or occupancy data periodically collected for UK nuclear sites [62]. Therefore, pathways which may be significant at specific sites, such as consumption of seaweed or houseboat dwelling are excluded from the scope of the assessment as no generic habits data for this activity is available. Further justification for their exclusion from scope is provided in Reference [29].

The input values specific to the RR SMR were derived from the GSD [27], [28] and available RR SMR design.

- The gaseous effluent discharge stack [KLS] is at an early stage of design. Although small quantities of gaseous radioactive effluent may be released from leakages to the Turbine Island (TI), and future additional routes may arise as the design develops (for example ventilation of waste stores), these discharge routes are still under development. For the purpose of this assessment, it is assumed at present that all gaseous effluent discharge will be released from the [KLS] stack. The estimated height {REDACTED} of the RR SMR shell at PCD was used as the stack height. The effective release height was taken as one third of the shell height based on the approach recommended by PHE in NRPB-R157 [43]. The impact of varying the effective release height is tested in the sensitivity analysis described in Section 30.2.4.

  FA 30.2 Gaseous release dose assessments to be recalculated using main gaseous effluent stack [KLS] height defined by optimisation process, and available information on radioactive gaseous effluent discharge points.

- Proposed annual limits for radionuclide discharge were used in the main assessments. This is based on the requirement "The RP must provide a radiological assessment of proposed limits […]" included in the EA GDA requirements [26].

- The fraction of fish caught in the local compartment was taken as 50 % for consistency with the IRAT assessment [25]. This value is more conservative than the 10 % in the default assumptions in PC-CREAM 08. Default PC-CREAM 08 assumptions were used for the fraction of crustaceans and molluscs caught locally.

- The receptor distance of the local population (local resident family) from the discharge source was taken as 300 m. This value represents a reasonable estimate of the closest practicable habitation based on the current estimated distance between the stack location (main source of emissions) and the outer site boundary fence of approximately 200 m [63]. This distance is also expected to be close to the location of peak activity concentration in air {REDACTED} and will therefore provide a reasonably conservative estimate of radiological dose impacts.

- The local resident family population are assumed to source all their food from a local farm situated 500 m from the main stack. This distance is considered to make allowance for "sufficient land to produce enough food to reasonably be considered to form a major part of a family's diet" [25] and aligns with previous GDA submissions (References [47], [49], and [50]). The impact of varying food production distance is tested in the sensitivity analysis.

- The terrestrial foodstuffs modelled are restricted to those which are reasonably expected to be sourced locally; i.e. locally grown crops or grass-fed livestock. Consumption of grain is excluded, as grain is not typically grown for local consumption, but bulked with grain produced elsewhere, and significantly diluted before entry into the consumer market.

Similarly, the contribution of pig and poultry products is highly dependent on feeding/rearing practices [30]. Dose from grain consumption, and consumption of pig and poultry products are excluded from both IRAT [25] and the RR SMR Stage 3 radiological impact assessment modelling (Appendix A, section 30.9).

30.2.3 Inputs Used to Assess Dose to Non-human Species

ERICA 2.0 uses activity concentrations in environmental media (air, soil, unfiltered seawater, and seabed sediment) as input values. These activity concentrations are derived from the outputs of the PLUME, FARMLAND and DORIS models in PC-CREAM 08. ERICA 2.0 requires that for carbon-14, tritium and noble gases, the activity concentrations in air are entered instead of activity concentrations in soil, as these radionuclides do not deposit freely. Modelled activity concentrations in air for these radionuclides will be used as input into ERICA 2.0 accordingly.

Non-human species are assumed to be located at the point of highest activity concentration in environmental media, ensuring bounding values for risk quotients (RQs) and dose rates are calculated. Liquid effluent is assumed to be mixed near-instantaneously through the local compartment, thus local compartment environmental activity concentration is applicable. For gaseous effluent discharges, the point of highest activity was determined to be the activity concentration at 250 m from the stack (based on the modelling of four key radionuclides: carbon-14 to represent non-depositing radionuclides[9], caesium-137 to represent particulate activity, iodine-131 to represent halogens, and tritium) [64]. Activity concentrations of radionuclides at 250 m were therefore used as inputs into ERICA 2.0, giving a location for non-human species of approximately 250 m distance from the stack.

{REDACTED}

Figure 30.2-1 Activity Concentrations of Key Radionuclides Based on Stack Height of {REDACTED} and Discharges at Proposed Annual Limits

ERICA 2.0 generic/default values for terrestrial and marine ecosystem will be used for all other inputs; specifically the reference organism sets for marine and terrestrial ecosystems, marine distribution coefficients (Kd), concentration ratios, and occupancy factors shall be those in the ERICA 2.0 default database.

ERICA 2.0 default values for Kd and concentration ratios will be used; where these are unavailable, values will be those presented in IAEA TRS422 [65]. If no information is available in IAEA TRS422, the most limiting values for an element in that environment shall be used.

[9] Carbon-14 is conservatively assumed to be discharged in the form of CO_2, which enters the terrestrial food chain via photosynthesis.

30.2.4 Sensitivity Analysis

In accordance with recommendations in Reference [19], an assessment of uncertainty and variability arising from key assumptions and model parameter values used in the RR SMR radiological impacts assessments has been undertaken to provide an understanding of the impact of assumptions and selected input data.

The sensitivity analysis is performed by varying model parameter values, to evaluate the effects of assumptions and uncertainties associated with key model parameter on the assessment results.

The evaluation of uncertainty and sensitivity analysis will focus on continuous discharges of aqueous and gaseous effluent to the environment, normally responsible for most of the annual dose to the public.

Input parameters used in the sensitivity analysis, with justification for their selection are presented in Reference [29] and summarised below:

- **Effective release height:** gaseous discharges from effective release heights of {REDACTED} (equivalent to a physical discharge height of {REDACTED} above ground level, based on [43]) and {REDACTED} (equivalent to a physical discharge height of {REDACTED} above ground level) were evaluated to compare with the conservative {REDACTED} effective release height modelled in the main assessment.

- **Local compartment marine dispersion parameters**

    - The minimum volumetric exchange rate for coastal NPP sites in England or Wales (7.3E+09 m^3/y at Bradwell) was evaluated against the Wylfa volumetric exchange rate (3.20E+10 m^3/y) used in the main assessment.

    - The maximum suspended sediment load (SSL) for coastal NPP sites in England or Wales (6.9E-04 t/m^3 at Berkeley) was evaluated against the Wylfa SSL (4.90E-06 t/m^3) used in the main assessment.

- **Food consumption rates:** observed maximum consumption rates from CEFAS habits surveys for NPP sites in England and Wales were compared against the generic critical consumption rates used in the main assessment.

- **Food production distances:** fruit and vegetable production distances of 300 m (i.e., produced in the local resident family garden) were evaluated against the 500 m production distances (i.e., from a local farm) utilised in the main assessment.

30.3 Results of Initial Radiological Assessment

30.3.1 Overview

The staged approach for assessing the radiological impacts of routine discharges [19], [24] is described in section 30.1.1, and the models, input data and assumptions summarised in 30.1.2, 30.1.4 and 30.2. This section sets out the initial results for the stage 1 and stage 2 assessments using the IRAT and the predicted discharges of aqueous and gaseous radioactive effluents from the RR SMR, at proposed annual limits.

30.3.2 Results of Stage 1 Radiological Assessment

The stage 1 assessment uses the default IRAT parameters and is designed to be a cautious estimate of dose to members of the public and non-human species. The results of the stage 1 assessment are presented in Table 30.3-1 and
Table 30.3-2. Radionuclides contributing less than 1 % of the total dose (other than tritium[10]) have not been included in the tables but are reflected in the total dose.

Table 30.3-1 Estimated Doses from Stage 1 Initial Radiological Assessment for Liquid Discharges to the Environment

Radionuclide	External dose (μSv/y)	Fish/shellfish dose (μSv/y)	Total dose (μSv/y)	Contribution (%)
Tritium	0.0E+00	5.4E-04	5.4E-04	0.1
Carbon-14	7.0E-08	1.5E-01	1.5E-01	18
Manganese-54	4.9E-03	5.8E-05	5.0E-03	1
Cobalt-60	4.4E-02	7.3E-04	4.5E-02	5
Zinc-65	4.9E-03	1.0E-01	1.1E-01	13
Silver-110m	4.2E-03	7.0E-02	7.4E-02	9
Caesium-134	2.3E-01	6.1E-02	2.9E-01	35
Caesium-136	3.2E-03	3.9E-03	7.1E-03	1
Caesium-137	1.3E-01	2.0E-02	1.5E-01	17

[10] Tritium has been identified as a 'significant radionuclide' for monitoring RR SMR plant performance under the EA's assessment criteria and has thus been included in Table 30.3-1 to Table 30.3-4. However, the low predicted tritium discharges relative to similar nuclear power plant [3] result in a comparatively minor contribution of RR SMR tritium effluent discharges to the total dose received by members of the public and non-human species when assessed using the IRAT. It is further noted that the tritium concentration presented represents the maximum activity which could be discharged as the result of a tritium bleed to meet reactor pressure vessel head lift criteria. Head lift criteria and the volume of discharge required to meet these criteria are yet to be determined, but it is not anticipated such a discharge would be required for several cycles after commencement of operations of the RR SMR, nor that it would be required for every cycle thereafter. Further information is provided in E3S Case Version 2, Tier 1, Chapter 29: Quantification of Radioactive Discharges and Proposed Limits [3].

Radionuclide	External dose (µSv/y)	Fish/shellfish dose (µSv/y)	Total dose (µSv/y)	Contribution (%)
Total	4.3E-01	4.1E-01	8.5E-01	

Table 30.3-2 Estimated Doses from Stage 1 Initial Radiological Assessment for Gaseous Discharges to the Environment

Radionuclide	Inhalation dose (µSv/y)	External dose (cloud & deposited) (µSv/y)	Food dose (µSv/y)	Total dose (µSv/y)	Contribution (%)
Tritium	5.8E-02	0.0E+00	2.2E-02	8.0E-02	0.3
Carbon-14	1.3E+01	2.3E-05	1.2E+01	2.5E+01	78.7
Argon-41	0.0E+00	5.3E+00	0.0E+00	5.3E+00	16.5
Iodine-131	4.8E-02	5.3E-03	5.5E-01	6.0E-01	1.9
Other beta/gamma emitting nuclides	6.5E-03	4.1E-01	2.9E-02	4.5E-01	1.4
Total	1.3E+01	5.9E+00	1.3E+01	3.2E+01	

A total dose of less than 1 µSv/y to the worst affected member of a fishing family was estimated for aqueous discharges. The dose due to aqueous discharges was dominated by contributions from the radioisotopes of caesium (53 %), carbon-14 (18 %) and zinc-65 (13 %).

The total dose to the worst affected local inhabitant for gaseous discharges from the RR SMR was estimated at 32 µSv/y. The dose from gaseous discharges was comprised largely of the doses from carbon-14 (79 %) and argon-41 (17 %).

The dose rate to the worst affected organism for aqueous discharges (Polychaete worm) is less than 0.01 µGy/h, dominated by barium-140 (52 %) and radioisotopes of caesium (35 %). The dose rate to the worst affected organisms for gaseous discharges (bird, mammal and reptile) is around 0.04 µGy/h, 90 % of which is attributable to carbon-14.

30.3.3 Stage 2 Radiological Assessment

The stage 2 assessment applied the effective gaseous stack discharge height estimated for the RR SMR {REDACTED} and GSD marine compartment volumetric exchange rate of 100 m^3/s (around 3.2E+09 m^3/y) to the IRAT. Results of the stage 2 assessments are presented in Table 30.3-3 and Table 30.3-4. Radionuclides contributing less than 1 % of the total dose (other than tritium) have not been included in the tables but are reflected in the total dose.

Table 30.3-3 Estimated Doses from Stage 2 Initial Radiological Assessment for Liquid Discharges to the Environment

Radionuclide	External dose (μSv/y)	Fish/shellfish dose (μSv/y)	Total dose (μSv/y)	Contribution (%)
Tritium	0.0E+00	1.6E-04	1.6E-04	0.1
Carbon-14	2.1E-08	4.6E-02	4.6E-02	18
Manganese-54	1.5E-03	1.7E-05	1.5E-03	1
Cobalt-60	1.3E-02	2.2E-04	1.3E-02	5
Zinc-65	1.5E-03	3.1E-02	3.3E-02	13
Silver-110m	1.3E-03	2.1E-02	2.2E-02	9
Caesium-134	7.0E-02	1.8E-02	8.8E-02	35
Caesium-136	9.6E-04	1.2E-03	2.1E-03	1
Caesium-137	3.8E-02	6.1E-03	4.4E-02	17
Total	1.3E-01	1.2E-01	2.5E-01	

Table 30.3-4 Estimated Doses from Stage 2 Initial Radiological Assessment for Gaseous Discharges to the Environment

Radionuclide	Inhalation dose (μSv/y)	External dose[11] (μSv/y)	Food dose (μSv/y)	Total dose (μSv/y)	Contribution (%)
Tritium	2.4E-03	0.0E+00	1.1E-02	1.3E-02	0.2
Carbon-14	5.3E-01	9.6E-07	5.9E+00	6.5E+00	92.0
Argon-41	0.0E+00	2.2E-01	0.0E+00	2.2E-01	3.1
Iodine-131	2.0E-03	2.2E-04	2.7E-01	2.7E-01	3.8
Other beta/gamma emitting nuclides	2.7E-04	1.7E-02	1.4E-02	3.2E-02	0.4
Total	5.4E-01	2.4E-01	6.3E+00	7.0E+00	

A total dose of around 0.3 μSv/y to the worst affected member of a fishing family and 7 μSv/y to the worst affected local inhabitant were calculated for aqueous discharges to sea and gaseous discharges to atmosphere, respectively. As with the stage 1 assessment, the radioisotopes of caesium, zinc-65 and carbon-14 accounted for over 80 % of the dose from aqueous discharges,

[11] External dose includes both the dose from the radiation cloud and from radionuclides deposited on the ground

whilst the dose arising from gaseous discharges is largely attributable to the intake of carbon-14 (>90 %).

The dose rate to the worst affected organism for aqueous discharges (Polychaete worm) is around 0.002 μGy/h, again dominated by barium-140 (52 %) and radioisotopes of caesium (35 %). The dose rate to the worst affected organism for gaseous discharges (bird, mammal and reptile) is around 0.02 μGy/h, over 90 % of which is attributable to carbon-14.

30.3.4 Initial Estimates of Total Dose

30.3.4.1 Direct Dose to Members of the Public

In addition to the dose from discharges, members of the public may also be exposed to radiation emanating from direct shine from the SMR. Initial calculations of direct shine have been performed [66] (noting that the shielding design is still in progress and may be subject to change), based on the key assumptions presented below:

- Shielding was considered around the Reactor Pressure Vessel (RPV) as bulk shielding and does not include penetrations.
- The layout of the primary containment and hazard shield is based on the layout as per August 2023.
- The geometry of the berm was unavailable at the time of assessment. Therefore, the potential shielding provided by the berm has not been included as a conservative assumption.
- The peak direction for the dose rate was seen to the north of containment (based on the layout at RD7/DRP1).
- The reactor source term is an average of all of the time steps within a fuel cycle.
- The primary circuit source term is based on the Design Basis (DB) preliminary primary source term values [67][12].
- The distances presented for the dose rates are measured from the centre of the reactor (which also represents the central point for all of the primary circuit source terms).

Further detail on the calculation of direct dose is presented in Reference [66]. Estimates of direct dose were derived for members of the public at various distances from the site boundary, are presented in Table 30.3-5.

[12] The dose estimates from the reactor source term were based on an earlier version of the PST and will be updated for future versions of Reference [66]. Preliminary analysis indicates that the difference in source term and the relative contribution of PST dose to whole-site dose rates means the impact will be negligible.

Table 30.3-5 Direct Dose to Members of the Public from the RR SMR at Selected Distances from the Reactor

	Dose Rate (µSv/y)			
Location (from site centre)	**Primary Circuit Source Term (Best Estimate)**	**Reactor Source Term – Neutron[13]**	**Reactor Source Term – Secondary Gamma**	**Total**
100 m	1.67E-02	1.01E-06	4.52E-02	6.19E-02
300 m	1.28E-03	1.92E-08	3.72E-03	5.01E-03
500 m	2.38E-04	2.00E-09	7.56E-04	9.94E-04

A full time (outdoors) occupancy (8760 hours) was assumed in order to conservatively estimate annual dose. Based on this assumption, a dose of 5.01E-03 µSv/y would be received by an inhabitant at the local residence location. The maximum dose received at the site fence was assessed as 2.96E-06 µSv/h [66]. A member of the public with maximum occupancy (8760 h) at the location of the site fence peak dose would receive an annual dose of 2.59E-02 µSv/y.

It should be noted that the direct dose estimate will be subject to change as the design evolves; for example, variation of hazard shield thickness, inclusion of shielding penetrations into calculations will impact direct dose received.

The dose of 5.01E-03 µSv/y in Table 30.3-5 represents the dose to a local inhabitant from direct radiation from RI only. Additional sources of direct radiation from the RR SMR may include waste and spent fuel treatment and storage facilities, which may contribute significantly to the total direct dose; for example, Reference [49] suggests the Spent Fuel Interim Storage Facility is predicted to be the largest contributor to direct dose. The contributions from such facilities to direct dose have not yet been determined for RR SMR and therefore the direct dose presented above is likely to be a significant underestimate. Total direct radiation doses of 5.0E+00 to 6.0E+00 µSv/y have been estimated from previous GDAs, (References [47], [48] and [51], and thus a conservative value of 5.00E+00 µSv/y, will be applied pending RR SMR-specific estimates.

As the confidence in the RR SMR direct radiation dose rates increases, the dose to members of the public will be assessed in more detail, to include more realistic estimates of time spent at location, time spent indoors/outdoors and shielding factors, based on generic habits data, e.g. [30], [33].

FA 30.3 The direct radiation dose estimate to be reviewed and updated in light of RR SMR-specific information.

30.3.4.2 Assessment of Total Dose from the RR SMR

To assess the total annual dose to an individual, it is assumed that–the worst affected local inhabitant also receives the dose for their age group predicted to arise from liquid discharges from the RR SMR, thus dose from both gaseous and liquid discharges is accounted for. The

[13] It should be noted that the dose rate results for the neutron source term do not meet a 5 % error target. However, this is not considered an issue based on the low overall contribution to the total dose rate.

conservative estimate of dose from all sources of direct radiation from the RR SMR (5.00E+00 μSv/y) is also added to obtain the total dose, presented in Table 30.3-6.

Table 30.3-6 Total Annual Dose at Stage 2 Radiological Impact Assessment

Exposure pathway	Stage 2 Dose (μSv/y)
Aqueous discharges	2.5E-01
Gaseous discharges	7.0E+00
Direct radiation	5.0E+00
Total dose	1.23E+01

30.3.5 Conclusion

Results of the stage 2 initial radiological assessment based on the proposed permit limits at PCD show that the total dose to a representative member of the public from all the pathways considered is well below the source dose constraint of 300 μSv/y [19], as well as the more restrictive constraint of 150 μSv/y recommended to be applied at the design stage of new nuclear facilities [14]. Similarly, the estimated dose rate to the worst affected organisms for both aqueous and gaseous discharges predicted to arise from the operation of an RR SMR are well below the guideline value of 40 μGy/h [22]. Furthermore, the assessed total dose is below the threshold of 20 μSv/y at which further refinement of assessed doses using more realistic data are required [18].

Appendix B (section 30.10) provides details of a further assessment using the proposed permit limits derived from the revised RR SMR PST [37]. The doses to members of the public and wildlife continue to be below revised proposed permit limits for the RR SMR radioactive effluent discharge. Further discussion on this revised assessment is included in Appendix B (section 30.10).

30.4 Detailed Assessment of the Radiological Impacts from Continuous Discharges

30.4.1 Overview

A detailed stage 3 radiological assessment shall be undertaken in line with the Rolls-Royce SMR corporate objectives, the GDA requirements outlined in reference [26] and permitting requirements for new nuclear power stations [19]. The models used, input data and assumptions are described in sections 30.1.2, 30.1.4 and 30.2. This section sets out the methodologies and considerations for the detailed radiological assessment from continuous discharges, using PC-CREAM 08 and ERICA.

The remainder of this section will detail:

- Identification of the exposure pathways and candidates for the representative person
- Methodology for the individual dose assessments
- Methodology for the collective dose assessments
- Methodology for non-human species assessments.

30.4.2 Approach to Individual Dose Assessments

30.4.2.1 Exposure Pathways and Candidates for the Representative Person

The potential exposure pathways considered for the assessment are those associated with the discharge of liquid effluent directly to the marine environment, and gaseous radioactive effluent to atmosphere. As described in section 30.2.1, the assessment is for a generic site, and it is considered appropriate at this stage to focus on representative pathways which have been identified as key exposure routes [25], [68] and for which generic habits data is available [33].

The “representative person” is the individual that is representative of the more highly exposed persons in a population group because of their circumstances or habits. To identify a representative person for the facility, assessments of the dose impact on candidates for representative person (CRP) were completed. Based on the results of these assessments, a representative person (i.e., a specific member from one of the representative groups) was selected.

Two potential CRP groups were identified from the groups described in EA’s methodology for the IRAT, [25]. The ‘fishing family’ and ‘local resident family’ from the EA IRAT were selected as potential CRPs due to their exposure to marine and atmospheric effluent discharges respectively; this approach is considered proportionate for a generic site where it is not possible to identify site-specific population groups. As the habitation location for the RR SMR GSD has been identified as 300 m, i.e. approximately at the current anticipated site boundary, both CRP groups are cautiously assumed to receive the assumed direct dose of 5.00E+00 μSv/y experienced by a member of the public at the site boundary. A separate CRP for direct dose is therefore not considered.

The CRP and relevant exposure pathways identified for each group are:

- CRP1: a fishing family (adult, child aged 10 and infant aged 1) is the representative group for liquid discharges to the marine environment. The exposure pathways identified for the RR SMR assessment align with the main marine discharge pathways identified in [68] and used in reference [25]:
    - External irradiation from exposure to beach sediments
    - External irradiation from handling fishing gear
    - Internal irradiation from inhalation of sea-spray when on the coast
    - Internal irradiation from consumption of seafood caught locally
    - Internal irradiation from consumption of contaminated terrestrial foods grown or reared locally.
- CRP2: a local resident family (adult, child aged 10 and infant aged 1) is the representative group for gaseous discharges to the atmosphere. The exposure pathways identified for the RR SMR assessment align with the main atmospheric discharge pathways identified in [68] and used in Reference [25]:
    - Internal irradiation from inhalation of radionuclides in the plume and radionuclides resuspended following deposition on the ground
    - External irradiation from radionuclides in the plume
    - External irradiation from radionuclides deposited on the ground
    - Internal irradiation from consumption of contaminated terrestrial foods grown or reared locally
    - Internal irradiation from consumption of seafood caught locally.

It is noted that Reference [69] recommends that assessment of doses to offspring (embryo, foetus and new-born child) should be carried out if phosphorus-32, phosphorus-33, calcium-45 or strontium-89 “form a significant part of any release of radioactivity to the environment”. The contribution of strontium-89 to total discharges is very low (<0.1 % of total annual RR SMR discharge for both liquid and gaseous routes), and phosphorus-32, phosphorus-33 and calcium-45 are not predicted to be present at all in the expected discharges from the RR SMR. It was therefore considered that the contribution of these radionuclides to total dose was not sufficiently high to warrant a standalone assessment of dose to offspring.

30.4.2.2 “Top Two” Food Consumption Approach

Identification of the representative person for the facility requires consideration of exposure pathways from contaminated terrestrial food types and seafood grown, reared or caught locally were modelled. The “top two” approach is adopted for modelling of food consumption by the CRPs.

The “top two” approach is outlined in NDAWG guidance [70] and states that, for prospective radiological impact assessments, “the preferred approach where no site-specific habits data are available is the top two method using generic data". The "top two" approach is therefore considered to be the most appropriate for this assessment. This method is consistent with the GDA dose assessments for the UK EPR [47], AP1000 [48], HPR1000 [49], and ABWR [50].

The "top two" approach is based on the observation that only a very small percentage of the population (i.e., not a representative proportion) typically consume more than two food groups at critical 97.5th percentile consumption rates. Consumption of more than two foods at the 97.5th percentile could result in unrealistically high total calorific intakes. Therefore, adoption of a "top two" approach was considered the most representative method of modelling food consumption rates at the generic site.

For CRP1, the "top two" food consumption approach involves performing a screening assessment to model the dose impact of consuming all marine foods at 97.5th percentile rates, based on discharges at proposed limits in the 60th year of operation. The two foods with the highest dose impact to each age group are identified. The dose impact from total food consumption for CRP1 is then modelled as:

- Critical (97.5th percentile consumption rates) for the two marine foods with the highest dose impact.
- Mean (50th percentile consumption rates) for all other marine foods and for all terrestrial foods.

This approach is replicated for CRP2, such that the screening assessment models the dose impact of consuming all terrestrial foods at 97.5th percentile rates, based on discharges at proposed limits in the 60th year of operation. The two foods with the highest dose impact to each age group are identified. The dose impact from total food consumption for CRP2 is then modelled as:

- Critical (97.5th percentile consumption rates) for the two terrestrial foods with the highest dose impact.
- Mean (50th percentile consumption rates) for all other terrestrial foods and for all marine foods.

30.4.2.3 Individual Dose Calculation

- The prospective annual dose to the most exposed member of the public from all discharges from the facility is calculated as follows.
    - For CRP1 (fishing family) the following doses are summed for each of the adult, child and infant age groups:
        - External irradiation from exposure to beach sediments
        - External irradiation from handling fishing gear
        - Internal irradiation from inhalation of sea-spray when on the coast
        - Internal irradiation from consumption of the "top two" seafoods at critical rates
        - Internal irradiation from consumption of all other seafoods at mean rates
        - Internal irradiation from consumption of all terrestrial foods at mean rates.
    - For CRP2 (local resident family) the following doses are summed for each of the adult, child and infant age groups:

- Internal irradiation from inhalation of radionuclides in the plume and radionuclides resuspended following deposition on the ground
- External irradiation from radionuclides in the plume
- External irradiation from radionuclides deposited on the ground
- Internal irradiation from consumption of the "top two" terrestrial foods at critical rates
- Internal irradiation from consumption of all other terrestrial at mean rates
- Internal irradiation from consumption of all marine foods at mean rates.

The representative person is the age group in either CRP1 or CRP2 exposed to the highest radiological dose from liquid and gaseous discharges in the 60th year of operation, as it is assumed for the generic site that all potential CRPs will receive the same exposure to direct radiation.

FA 30.4 Stage 3 dose assessment to be undertaken using PC CREAM 08 and proposed permit discharge limits presented in Appendix B (section 30.10).

Dose assessments will be reiterated as further information on discharges and proposed limits becomes available.

30.4.3 Approach to Collective Dose Assessment

Collective dose to the UK, European and world populations from routine discharges of gaseous and aqueous radioactive effluent to the environment, truncated at 500 years, is assessed using the PC-CREAM 08 ASSESSOR subroutine for collective dose assessment. Truncation at 500 years allows the long-term dose impact of long-lived radionuclides such as carbon-14, which remain in circulation long after their discharge has stopped, to be evaluated.

ASSESSOR considers 'first pass' and 'global circulation' of radionuclides. The first pass component is the contribution to collective dose that arises as the dispersing plume initially passes over the target population; whereas the global component applies to certain long-lived radionuclides (tritium, carbon-14, krypton-85 and iodine-129) which are globally dispersed in the biosphere and continue to contribute to the collective dose over long time [30], [71]. Collective doses to world populations are only calculated for globally circulating radionuclides.

The collective dose calculation step draws upon the results of all the supporting models within PC-CREAM 08 (PLUME, GRANIS, FARMLAND and RESUS for discharges to air; and DORIS for discharges to the marine environment) and combines these with embedded database of population grids and the associated food production data. Per-caput dose (dose per unit head of population) will be determined by dividing the collective doses for UK, Europe and World populations to the number of individuals within each population group [19], [72].

The model parameters for collective dose are the same as described for the radiological impact to individuals as described above. The default PC CREAM 08 population and agricultural production grids are adopted. Collective dose is modelled as first pass (initial discharge and accumulation into environmental media) or global collective dose (includes circulation of mobile, longer-lived radionuclides in the oceans and atmosphere). The output time for collective dose is set at 500 years, consistent with RGP [26].

Table 30.4-1 presents the population figures used in the calculation of collective doses in PC-CREAM 08. "EU12" refers to countries in the European Union (EU) from 1986, and "EU25" to countries in the EU from 2004. There is no option to model EU25 collective dose from liquid discharges. It is only possible to calculate first pass dose due to gaseous discharges to UK and EU populations, as the world population is only exposed to the longer-lived radionuclides found in global atmospheric circulation. The total dose to UK and EU populations is calculated by summing the first pass and global circulation doses. The models do not consider future population growth because of uncertainties and instead use static populations.

Table 30.4-1 Population Groups Assessed for Collective Dose

	Liquid effluent discharge			Gaseous effluent discharge		
Region	**Population**	**First pass Collective dose**	**Global Collective dose**	**Population**	**First pass Collective dose**	**Global Collective dose**
UK	5.96E+07	Y	Y	5.96E+07	Y	Y
EU12	3.60E+08	Y	Y	3.60E+08	*	Y
EU25	4.56E+08	-	-	4.56E+08	*	Y
World	1.00E+10	Y	Y	1.00E+10	-	Y

* Note that for gaseous effluent discharge, a first pass collective dose is calculated for "EU" population, and is applicable to both EU12 and EU25

FA 30.5 Collective dose to be assessed using PC-CREAM 08 and proposed permit discharge limits presented in Appendix B (section 30.10)

30.4.4 Approach to the Assessment of Radiological Doses to Non-human Species

30.4.4.1 Methodology

An assessment of potential dose rates to non-human species predicted to arise from discharges of aqueous and gaseous radioactive effluents from the RR SMR is performed on species inhabiting the terrestrial and marine environments adjacent to the power plant, consistent with assumptions in the GSD.

The results of the IRAT assessment described in section 30.3.3 indicated that doses to wildlife fell below the screening level, and no further assessment is required by regulatory guidance [51]. However, in line with the approach for assessment of radiological dose to members of the public, a Tier 2 assessment for dose to non-human species shall be performed. A Tier 2 assessment enables calculation of the total dose rate for each reference organism and the likelihood of the dose rate screening value being exceeded.

The non-human species assessment is carried out using the environmental activity concentration data generated by the PC-CREAM 08 PLUME and DORIS dispersion models described in section 30.1.4, based on 60 years' discharge to the environment at the proposed annual limits. The gaseous environmental activity concentrations used are those at the peak concentration of the environmental dispersion profile, 250 m from release point, as described in section 30.2.3.

Tier 1 and 2 ERICA 2.0 assessments were completed to assess the significance of radiological risk to marine and terrestrial non-human species. All default organisms for marine and terrestrial environments are included in the assessment, as described in [29]. The assessment did not include assessment of radiological risk to freshwater non-human species, consistent with the assumptions in the GSD.

If the sum of the RQs for all of the limiting marine or terrestrial organisms is less than one, then the dose rates are expected to be lower than the threshold posed by the dose rate screening value. When calculating the RQ, the ERICA dose rate screening value of 10 μGy/h was used for all organisms. This screening level is intended to be protective of the structure and function of generic ecosystems and organism groups, corresponding to a predicted no-effect dose rate which has no adverse effects on species at the population level, and is more conservative than the EA guidance levels discussed in section 30.0.4.

An uncertainty factor (UF) of 5 is selected for the Tier 2 assessment. This allows testing of whether the probability of exceeding the dose screening value is less than 1 % (based on the assumption that the RQ distribution is exponential). The use of this UF and screening value represents a conservative approach to calculating the RQ. Further information on UFs is included in the ERICA integrated approach documentation [73].

30.5 Sensitivity Analysis

30.5.1 Approach to Sensitivity Analysis

The purpose of conducting the sensitivity analysis is to quantify the extent to which the calculated doses to individual members of the public are affected by the selection of input parameters. This informs and provides assurance of the reliability of the conclusions drawn from the generic assessment dose calculations.

The scope of the uncertainty and sensitivity analysis encompasses the stage 3 continuous discharge assessment for members of the public, described in section 30.4. This is anticipated to be the main contributor to annual dose to the public from radioactive effluent discharges.

The selection of input parameters tested in the sensitivity analysis is intended to reflect those which (i) have a high level of uncertainty based on current information about the RR SMR and generic site parameters, and (ii) have the largest influence on the calculation of dose to individual members of the public. The following input parameters are selected for the sensitivity analysis:

- Effective release height
- Local compartment marine dispersion parameters
  - Volumetric exchange rate
  - Suspended sediment load (SSL)
- Food consumption rates
- Food production distances.

30.5.2 Sensitivity Analysis Parameters

30.5.2.1 Effective Release Height

To evaluate the effects of stack height on radiological impacts to the local population, activity concentrations of key representative radionuclides will be modelled for other effective release heights of {REDACTED} and compared to results from the {REDACTED} effective release height used in the main assessment. The following radionuclides are selected for the analysis: carbon-14 to represent non-depositing radionuclides[14], caesium-137 to represent particulate radionuclides, iodine-131 to represent halogens, and tritium.

30.5.2.2 Local Compartment Marine Dispersion Parameters

The marine dispersion characteristics for the coastal environment at Wylfa ([30], [31]) have been selected for the main radiological impact assessment as representative of the typical conditions of potential nuclear sites at UK coastal locations. The sensitivity analysis will consider the impact of the volumetric exchange rate and SSL on the environmental activity concentrations in unfiltered seawater and seabed sediments. The Wylfa values used in the main assessment were compared against other available data from References [30] and [31] for other coastal nuclear

[14] Carbon-14 is conservatively assumed to be discharged in the form of CO_2, which enters the terrestrial food chain via photosynthesis.

sites in England and Wales, to determine bounding values with which to compare the main assessment.

Bradwell has the lowest volumetric exchange rate for coastal NPP sites in England and Wales, and thus this value was chosen to represent a low-dispersion environment. Reduced dispersion would be expected to increase the activity concentration in the local environment; Bradwell volumetric exchange rate can therefore be considered to represent the bounding condition.

Wylfa has the lowest SSL for coastal nuclear sites in England and Wales. Suspended sediment load will impact the transfer of activity from the water column to the seabed to varying degrees, dependent on the Kd for each element. The sensitivity analysis used the value for the highest SSL (from Berkeley) to consider the impact of increasing the SSL on activity concentration in seabed sediments and in removal of radionuclides from the water column.

Table 30.5-1 presents the model inputs for the marine dispersion main assessment and sensitivity analysis.

Table 30.5-1 Marine Dispersion Values Used in Sensitivity Analysis

	Main Assessment	Sensitivity Analysis
Volumetric exchange rate (m^3/y)	3.2E+10 (Wylfa)	7.3E+09 (Bradwell)
Suspended Sediment Load (t/m^3)	4.9E-06 (Wylfa)	6.9E-04 (Berkely)

30.5.2.3 Food Consumption Rates

Reference [70] notes that it is unrealistic to consider consumption of all foodstuffs at the critical 97.5th percentile consumption rates presented in Reference [33]. The approach taken to considering sensitivity to food consumption rates is therefore to compare the consumption of foodstuffs by the CRP1 and CRP2 groups derived from the “Top Two” methodology using generic habits data (section 30.4.2) with maximum consumption rates for the same foodstuffs published in habits survey reports for existing nuclear sites in England and Wales. A review of data from CEFAS habits surveys [62] indicates that the observed maximum consumption data for terrestrial foods is found at Hinkley Point and maximum consumption of marine foods at Hartlepool. With some adjustment to the CEFAS data to allow for direct comparison to the generic habits data (Reference [74]), the food consumption data from these locations shall be considered realistic bounding cases for food consumption. The food consumption values used in the sensitivity analysis are presented in Table 30.5-2 and Table 30.5-3.

Table 30.5-2 Marine Food Consumption Rates Used in Sensitivity Analysis

Age Group	Marine Food consumption, kg/y		
	Marine Fish	**Crustaceans**	**Molluscs**
Adult	71.0	45.8	17.8
Child	27.6	30.3	7.3

Age Group	Marine Food consumption, kg/y		
	Marine Fish	Crustaceans	Molluscs
Infant	18.4	8.9	0.9

Table 30.5-3 Terrestrial Food Consumption Rates Used in Sensitivity Analysis

Age Group	Terrestrial foods consumption, kg/y or l/y (milk)								
	Cow liver	Cow meat	Cow milk	Cow milk products	Fruit	Green veg.	Root veg.	Sheep liver	Sheep meat
Adult	17.2	77.4	331.7	82.9	58.0	110.8	162.2	3.7	9.3
Child	6.8	40.5	307.4	57.6	8.7	66.7	49.5	0.0	0.0
Infant	3.1	11.5	90.9	12.8	0.0	0.0	0.0	0.0	0.0

30.5.2.4 Food Production Distance

Food production location impacts dose due to the change in activity concentration in air and in soil, and therefore the uptake and concentration in foodstuffs, with distance from the discharge point. The effects of varying the terrestrial food production distance were modelled in order to consider the potential impact of consumption of fruit and vegetables grown in gardens or allotments adjacent to the habitation location. The production distance for these foodstuffs is reduced to 300 m for the sensitivity analysis. It is not anticipated livestock would be kept in the garden of the local resident family, and so production distance for animal-derived foodstuffs will be retained at 500 m for the sensitivity analysis.

The sensitivity analysis will indicate both the changes to the total dose to each CRP as a consequence of the change in food production distance, and whether the change in location of fruit and vegetables relative to animal-derived products affects selection of the “top two” foodstuffs for any of the CRPs.

30.5.2.5 Impacts of Climate Change

The UK climate is changing and is expected to continue doing so over the 60-year operational life of the RR SMR. The modelling performed in the RR SMR dose assessment used input parameters considered to be most appropriate based on the current climatic conditions in the UK. The potential impacts of climate change over relevant parameters such as behaviour of radionuclides in the environment, human habits such as food production/consumption and occupancy, and distribution of non-human species in the environment will require consideration at the site-specific stage for the selected site.

30.6 Short-term Discharge Assessment

30.6.1 Overview

Short-term discharges of gaseous radioactive effluent to air from normal operations may arise from routine shutdown and plant maintenance operations discharges and are characterised by enhanced releases of radionuclides. Such discharges are expected to be dominated by volatile tritium originating from the Spent Fuel Pool [FAB10] and Refuelling Pool, and noble gases from the GRETS [KPL] over short period of time at plant shutdown and outage phases. Such releases could result in higher doses to members of the public, especially if the timing of discharges coincides with seasonal factors such as peak growing season, or if they occur during a time of day when people are outdoors for occupational or leisure purposes and should be considered alongside the annual dose from continuous release.

The short-term dose assessment methodology presented below is based on the recommendations published in NDAWG Guidance Note 6B [41] and the methodologies described in References [59] and [75].

30.6.2 Methodology

30.6.2.1 Source Term

The likely sources of short-term discharge of gaseous radioactive effluents are:

- Non-condensable gases discharged from the [KPL], following the degassing of primary coolant during planned shutdown sequences.
- Volatile radionuclides (predominantly tritiated vapours) exhausted by the HVAC [KL-] subsystem serving the containment area and Spent Fuel Pool [FAB10] and associated pools. These discharges are anticipated to peak early on during the refuelling outage phase when the RPV head is lifted, and radioactive gases are exhausted from containment to allow personnel access for plant maintenance.

The timing and sequence of activities for the RR SMR plant shutdown and refuelling operating phases are currently under development, and a detailed description of the activity and timing of the short-term release is not yet available. Thus, a realistic short term discharge scenario based on the assumption that $1/12^{th}$ of the proposed annual limits for significant radionuclides (roughly equivalent one month's discharge) is released over a 12-hour release duration, has been adopted for this assessment. This approach is comparable to those implemented in References [49] and [76].

The 'significant radionuclides' for this assessment are tritium, carbon-14, iodine-131 and xenon-133. These radionuclides are representative of the physical and chemical properties of gaseous radionuclides predicted to be discharged from the RR SMR.

30.6.2.2 Atmospheric Dispersion Modelling

The ADMS 6 model described in section 30.1.4 will be used to model the dispersion of gaseous radionuclides released to air over a 12-hour period. The modelling approach assumes the same key environmental parameters and habitation and food source locations as for the continuous assessment. The release point (assumed stack height) {REDACTED} is also applied. Additional modelling parameters, including values for the emission parameters, meteorological parameters and dimensions of the building are justified in Reference [77] and summarised in Table 30.6-1 below.

Table 30.6-1 Summary of Short-term Modelling Assumptions and Parameter Values

Parameters (units)	Values	Parameters (units)	Values	
Emission Parameters		**Meteorological parameters**		
Volumetric flow (m^3/s)	45	Wind direction (degrees from North)	180	
Efflux velocity (m/s)	15	Boundary layer height (m)	800	
Effluent gas temp. (degrees Celsius)	20	Mean windspeed (m/s)	5	
Release rates (Bq/s)	1	Air temperature (degrees Celsius)	25	
Effluent gas composition	H-3	Dry deposition velocities (m/s)	H-3	0.005
	Xe-133		Xe-133	0
	I-131		I-131	0.01
	Cs-137		Cs-137	0.001
		Washout coefficient (1/s)	2.3E-05	
Building dimensions		**Environmental parameters**		
Proximate dimensions of RR SMR shell structure (m)	H: {REDACTED} W: 75 L: 180	Location	Coastal, rural	
		Topography	Flat terrain	
Release point (assumed stack height) (m)	{REDACTED}	Surface roughness (m)	0.3	
		Downwind distance (m)	300 and 500	

The assumed parameter values relating to emissions and building dimensions shall be reviewed as the design develops. It also is recognised that some of the meteorological parameters applied in the initial assessment are different to the cautious values recommended by NDAWG [59], and will be updated in later revisions of this assessment.

30.6.2.3 Dose Assessment

Food Exposure Pathways

The environmental activity concentrations of deposited radionuclides in soil at 500 m from the discharge point from ADMS 6 modelling shall be used to determine the concentration of radionuclides in foodstuffs. ADMS 6 output includes the concentration in air, and deposition rates, which can be further combined to derive activity concentration on the ground. The transfer of deposited radionuclides from soil to plant (from air to plant in the case of carbon-14) and animal products is modelled using the food concentration factors published by NDAWG [59]. The activity concentration in foodstuffs and the food consumption rates identified from the "Top Two" methodology for terrestrial foods in the continuous discharge assessment (section 30.2.2) shall be used to establish the total activity ingested from the short-term release. Dose from ingestion of contaminated foodstuffs can then be calculated using the ingestion dose coefficients from ICRP Publication 119 [78].

Inhalation Pathways

The environmental activity concentrations of radionuclides in air at 300 m from the discharge point, derived from ADMS 6 modelling, shall be used to assess internal exposure through inhalation of radionuclides in the plume. It is conservatively assumed that the exposed members of the public are outdoors and engaged in some form of physical activity at the habitation location for the entire 12 h release duration. Thus, breathing rates associated with physical activity ('heavy' work for adults), taken from Reference [30] are assumed, and used to calculate the total activity inhaled over the release period. No consideration of shielding from buildings is applied. Dose from inhalation of radionuclides in the plume is then calculated using the inhalation dose coefficients from ICRP Publication 119 [78].

External Exposure Pathways

External exposure may arise from direct exposure to radioactivity in the plume as it passes through the habitation location, and from contaminated material deposited on the ground. The members of the public exposed to the plume are assumed to be outdoors for the duration of the release, as above, and dose from plume exposure calculated from the cloud dose coefficients derived from Reference [79].

External exposure from ground contamination is considered over a period of 1 year and was determined from the concentration of radionuclides in soil. Outdoor/indoor occupancy and indoor dose reduction factors from Reference [30], and ground dose coefficient from Reference [79] are applied to determine exposure from this source.

30.6.2.4 Total Dose from Short-term Releases

Total dose rates from the short-term assessment are derived by combining exposure from the three pathways described above. The assessed short-term dose will be incorporated into the total dose and compared to the source dose constraint (300 μSv/y and the 150 μSv/y recommendation proposed by HPA), taking account of the contribution from releases of the remaining fraction of the annual discharge limits via the continuous discharge mode.

FA 30.6 Dose to members of the public due to short-term gaseous discharge to be determined using initial assessment of environmental activity concentration derived from ADMS 6 code, environmental and meteorological characteristics based on the GSD, and proposed permit discharge limits presented in Appendix B (section 30.10). A further short-term assessment will be undertaken using conservative environmental and meteorological characteristics proposed in Reference [59].

30.7 Conclusions

30.7.1 ALARP, BAT, Secure by Design, Safeguards by Design

The analysis presented in this chapter supports the top-level claim that the dose to members of the public and the environment from discharges of liquid and gaseous radioactive waste has been minimised and is within regulatory constraints. The ongoing development of the design, analysis, and verification of SSCs, as described throughout the E3S case ensures the E3S fundamental objective can be met by the RR SMR at all life cycle phases and design stages, demonstrating that risks are or will be reduced to as low as reasonably practicable (ALARP), that BAT is applied, and the design incorporates secure by design and safeguards by design principles. The results of the radiological impact assessment will in turn, feed into the consideration of waste generation and waste management processes in the design to ensure BAT is applied.

30.7.2 Assumptions and Commitments on Future Dutyholder, Licensee, Permit Holder

Table 30.7-1: Assumptions and Commitments on Future Dutyholder/Licensee/Permit holder

Assumption/Commitment	ID	Description
Commitment	C30.1	The future dutyholder/licensee/permit holder will be required to undertake a site-specific radiological impact assessment as part of any RSR EPR16 permit application.
Commitment	C30.2	The future dutyholder/licensee/permit holder will be required to undertake consideration of potential impacts of climate change on exposure of members of the public and non-human species over the anticipated lifetime of the plant)
Commitment	C30.3	The future dutyholder/licensee/permit holder will be required to periodically review the normal operations dose assessment to ensure it is still RGP.

30.7.3 Conclusions and Forward Look

The generic E3S case objective at Issue 2 is ‘to provide confidence that the RR SMR design will be capable of delivering the E3S fundamental objective as it developed from a concept design into a detailed design’. This confidence is built through development and underpinning of top-level claims across each chapter of the E3S case, through supporting arguments and evidence. The top-level claim for chapter 30 is ‘impact on members of the public and the environment from disposals of aqueous and gaseous radioactive effluents from the RR SMR normal operations is minimised and within the radiological dose limits and constraints set out in legislation and guidance'.

The arguments and evidence presented to meet the generic E3S case objective at Issue 2 include the proposed approaches and methodologies for carrying out radiological impact assessment of the liquid and gaseous discharges arising from RR SMR normal operations for members of the public and non-human species, consistent with RGP.

An initial assessment of the radiological impacts associated with radioactive effluent discharges (at proposed annual limits, based on an interim PST and discharge estimate) and direct radiation emanating from the RR SMR has been carried out. Results from the EA IRAT assessment, based on an assumption of continuous discharge of radioactive effluents, show that the total dose to a representative member of the public, including a contribution from direct dose, is well below the source dose constraint of 300 μSv/y, and the more restrictive constraint of 150 μSv/y recommended to be applied at the design stage of new nuclear facilities [14].

Similarly, the estimated dose rates to the worst affected organisms predicted to arise from the operation of an RR SMR are well below the statutory guidance value of 40 μGy/h and investigation level of 1 μGy/h, when assessed in IRAT.

Development of the RR SMR design, operation philosophy and source term is ongoing. The radiological impact assessments will be revised as RR SMR-specific design and source term information informs the estimates of radioactive effluent discharges, improving confidence in the evidence supporting the fundamental claim. A forward action plan (Table 30.7-2) indicates the key actions to be undertaken prior to future revisions of this document.

Table 30.7-2 Forward Action Plan for Radiological Dose Assessment for Members of the Public and Non-human Species

ID	Description	Date
FA 30.1	Review assumptions on discharge strategy as information on expected events impacts and management becomes available.	Ongoing
FA 30.2	Gaseous release dose assessments to be recalculated using main gaseous effluent stack [KLS] height defined by optimisation process, and available information on radioactive gaseous effluent discharge points.	Dec 2024
FA 30.3	The direct radiation dose estimate will be reviewed and updated in light of RR SMR-specific information.	Dec 2024
FA 30.4	Stage 3 dose assessment to be undertaken using PC CREAM 08 and proposed permit discharge limits presented in Appendix B (section 30.10). Dose assessments will be reiterated as further information on discharges and proposed limits becomes available.	Sept 2024 and ongoing
FA 30.5	Collective dose to be assessed using PC-CREAM 08 and proposed permit discharge limits presented in Appendix B (section 30.10)	Sept 2024

ID	Description	Date
FA 30.6	Dose to members of the public due to short-term gaseous discharge to be determined using initial assessment of environmental activity concentration derived from ADMS 6 code, environmental and meteorological characteristics based on the GSD, and proposed permit discharge limits presented in Appendix B (section 30.10). A further short-term assessment will be undertaken using conservative environmental and meteorological characteristics proposed in Reference [59].	Sept 2024 and ongoing

30.8 References

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30.9 Appendix A

30.9.1 GSD Characteristics and Modelling Input Parameters

The GSD site characteristics, and the proposed input parameters for the stage 3 radiological impact assessment for members of the public using PC-CREAM 08 and non-human species using the ERICA tool (which in turn uses the environmental activity concentration from the PC CREAM models) are presented in Table 30.9-1 and Table 30.9-2.

The IRAT Stage 2 model also adopts the source term data, volumetric exchange rate and effective stack height presented in the tables below, all other parameters being default IRAT values. IRAT Stage 1 uses only the RR SMR source term.

Table 30.9-1 Liquid Effluent Modelling Parameters

<table>
<tr><th>Topic</th><th>Approach / Model Parameter</th><th>Description /Value</th><th>Data Sources</th></tr>
<tr><td>Source Term</td><td>Liquid discharges at proposed annual limits</td><td>See Table 30.1-2 for assessment presented in Section 30.3.2 (discharge at permit limits based on Sensitivity PST).
See Table 30.10-1 Revised Predicted Discharges and Proposed Permit Limits for Liquid Radioactive Effluent Table 30.10-1 for assessment presented in Appendix B (section 30.10) (discharge at permit limits based on PST).</td><td>E3S Case Version 2 Tier 1 chapter 29 Issue 2 [3]
This document, derived from References [38], [39] and [40].</td></tr>
<tr><td rowspan="2">Marine Dispersion Modelling (DORIS)</td><td>Site information (local and regional marine compartment details)</td><td><table>
<tr><th>Parameter</th><th>Local compartment (Wylfa)</th><th>Regional compartment (Irish Sea West)</th></tr>
<tr><td>Volume (m^3)</td><td>2.70E+09</td><td>6.62E+11*</td></tr>
<tr><td>Depth (m)</td><td>2.70E+01</td><td>6.30E+01*</td></tr>
<tr><td>Coastline length (m)</td><td>1.00E+04</td><td>-</td></tr>
<tr><td>Volumetric exchange rate (m^3/y)</td><td>3.20E+10</td><td>-</td></tr>
<tr><td>Suspended sediment load (t/m^3)</td><td>4.90E-06</td><td>3.00E-06*</td></tr>
<tr><td>Sedimentation rate ($t/m^2/y$)</td><td>1.00E-04</td><td>1.00E-03*</td></tr>
<tr><td>Sediment density (t/m^3)</td><td>2.60E+00*</td><td>2.60E+00*</td></tr>
<tr><td>Diffusion rate (m^2/y)</td><td>3.15E-02*</td><td>3.15E-02*</td></tr>
</table></td><td>EA Evidence Report [31]
PHE Review Report [32]
HPA-RPD-058 [30]</td></tr>
<tr><td>Element dependent parameters (sediment</td><td>Default Kd values in PC-CREAM 08 DORIS</td><td>HPA-RPD-058 [30]</td></tr>
</table>

<table>
<tr><th>Topic</th><th>Approach / Model Parameter</th><th>Description /Value</th><th>Data Sources</th></tr>
<tr><td></td><td>distribution coefficients, Kd)</td><td></td><td></td></tr>
<tr><td></td><td>Element dependent parameters (concentration ratios, CR)</td><td>Default CR values in PC-CREAM 08 DORIS</td><td>HPA-RPD-058 [30]</td></tr>
<tr><td></td><td>Output materials</td><td>Unfiltered seawater, Seabed sediments, Fish, Crustaceans, Mollusc</td><td>HPA-RPD-058 [30]</td></tr>
<tr><td>Candidates for representative persons (CRPs)</td><td>CRPs</td><td>CRPs for liquid discharges: fishing family
Age groups: Adult, Child (10 years old) and Infant (1 year old).</td><td>NDAWG Guidance Note [80]
HPA Guidance Note [69]</td></tr>
<tr><td>Habits data</td><td>Location</td><td>Terrestrial food production distance from SMR: 500 m</td><td>RR SMR E3S case tier 1 chapter 2 [28], GSD [27],
EA IRAT Guidance [25]</td></tr>
<tr><td></td><td>Marine foodstuff source</td><td>
<table>
<tr><th>Foodstuff</th><th>Origin</th><th>Fraction of total consumption</th></tr>
<tr><td>Fish</td><td>Local compartment</td><td>0.5</td></tr>
<tr><td>Fish</td><td>Regional compartment</td><td>0.5</td></tr>
<tr><td>Crusta-ceans</td><td>Local compartment</td><td>1.0</td></tr>
<tr><td>Molluscs</td><td>Local compartment</td><td>1.0</td></tr>
</table>
</td><td>EA IRAT Guidance [25]</td></tr>
<tr><td></td><td>Food consumption rates</td><td>
<table>
<tr><th></th><th colspan="4">Food consumption rates (kg/y)</th></tr>
<tr><th></th><th>Fish</th><th>Crusta-ceans</th><th>Molluscs</th><th>Sea-weed</th></tr>
<tr><td>Adult (critical)</td><td>100</td><td>20</td><td>20</td><td>0</td></tr>
<tr><td>Adult (mean)</td><td>15</td><td>1.75</td><td>1.75</td><td>0</td></tr>
<tr><td>Child (critical)</td><td>20</td><td>5</td><td>5</td><td>0</td></tr>
<tr><td>Child (mean)</td><td>6</td><td>1.25</td><td>1.25</td><td>0</td></tr>
</table>
</td><td>NRPB-W41 [33]</td></tr>
</table>

<table>
<tr><th>Topic</th><th>Approach / Model Parameter</th><th>Description /Value</th><th>Data Sources</th></tr>
<tr><td></td><td></td><td><table>
<tr><td>Infant (critical)</td><td>5</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>Infant (mean)</td><td>3.5</td><td>0</td><td>0</td><td>0</td></tr>
</table></td><td></td></tr>
<tr><td rowspan="2">Exposure pathways</td><td>External pathways</td><td>Irradiation from contaminated intertidal sediment and from handling of fishing equipment.
<table>
<tr><th>Parameter</th><th>Adult</th><th>Child</th><th>Infant</th></tr>
<tr><td>Time spent on the beach / near the sea in the local compartment (h/y)</td><td>2000</td><td>300</td><td>30</td></tr>
<tr><td>Time spent on the beach in the regional compartment (h/y)</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>Distance from the sea (m)</td><td>100</td><td>100</td><td>100</td></tr>
<tr><td>Time spent handling fishing equipment in the local compartment (h/y)</td><td>2000</td><td>0</td><td>0</td></tr>
<tr><td>Time spent handling fishing equipment in the regional compartment (h/y)</td><td>0</td><td>0</td><td>0</td></tr>
</table></td><td>NRPB-W41 [33]</td></tr>
<tr><td>Internal pathways: Inhalation of sea-spray</td><td>Inhalation of contaminated sea-spray during time spent on the beach in the local compartment. See beach occupancy rates above. Default PC-CREAM 08 inhalation rates are also applied.
<table>
<tr><th colspan="3">Inhalation rates (m^3/y)</th></tr>
<tr><th>Adult</th><th>Child</th><th>Infant</th></tr>
<tr><td>8,100</td><td>5,600</td><td>1,900</td></tr>
</table></td><td>NRPB-W41 [33]</td></tr>
<tr><td rowspan="2">Dose assessment (Individual)</td><td>Doses to CRP for atmospheric discharges (PC-CREAM 08)</td><td>ASSESSOR module draws on the output of other modules (PLUME, GRANIS, FARMLAND and RESUS) and scales them with the habits data, actual discharge rates and dose coefficients to calculate doses to the CRP.
The dose from consumption of seafood will be calculated using the method described in section 30.4.2.</td><td>HPA-RPD-058 [30]</td></tr>
<tr><td>Output time</td><td>60 years (anticipated RR SMR plant operation lifetime)</td><td>RR SMR E3S Case Version 2, Tier 1, Chapter 1 [81]</td></tr>
<tr><td rowspan="2">Dose assessment (collective)</td><td>Output time</td><td>500 years</td><td>GDA Guidance for RPs [26]
HPA-RPD-058 [30]</td></tr>
<tr><td>Receptor points and habits</td><td>Default PC-CREAM 08 population and agricultural production grids.</td><td>HPA-RPD-058 [30]</td></tr>
</table>

<table>
<tr><th>Topic</th><th>Approach / Model Parameter</th><th>Description /Value</th><th>Data Sources</th></tr>
<tr><td></td><td>Model parameters</td><td>As for individual assessment.</td><td>HPA-RPD-058 [30]</td></tr>
<tr><td></td><td>Population data</td><td><table><tr><th>Region</th><th>Population</th></tr><tr><td>UK</td><td>5.96E+07</td></tr><tr><td>EU12</td><td>3.60E+08</td></tr><tr><td>World</td><td>1.00E+10</td></tr></table></td><td>HPA-RPD-058 [30]</td></tr>
</table>

Table 30.9-2 Gaseous Effluent Modelling Parameters

Topic	Approach / Model Parameter	Description / Value	Data Sources
Source term	Gaseous discharge at proposed annual limits	See Table 30.1-3 for assessment presented in Section 30.3.2 and 30.3.3 (discharge at permit limits based on Sensitivity PST). See Table 30.10-1 Revised Predicted Discharges and Proposed Permit Limits for Liquid Radioactive Effluent Table 30.10-2 for assessment presented in Appendix B (section 30.10) (discharge at permit limits based on PST).	E3S Case Version 2, Tier 1, Chapter 29 [3] This document, derived from References [38], [39] and [40]
	Physical stack height	{REDACTED}	RR SMR E3S case Version 2 Tier 1 Chapter 2 [28], GSD [27]
Atmospheric dispersion modelling (PLUME)	Effective release height	{REDACTED}	NRPB-R157 [43]
	Roughness length	Agricultural areas: 0.30 m	RR SMR E3S Case Version 2, Tier 1 Chapter 2 [28], GSD [27], HPA-RPD-058 [30]

<table>
<tr><th>Topic</th><th>Approach / Model Parameter</th><th>Description / Value</th><th>Data Sources</th></tr>
<tr><td></td><td>Meteorological sampling scheme</td><td>70 % Pasquill Stability Category D
Windrose: uniform
Rainfall rate: 1 mm/h (10 % of the time spent in categories C and D only)
Met categories:
<table><tr><th>Stability category</th><th>Wind speed at 10m (m/s)</th><th>Mixing layer depth (m)</th></tr><tr><td>A</td><td>1</td><td>1300</td></tr><tr><td>B</td><td>2</td><td>900</td></tr><tr><td>C</td><td>5</td><td>850</td></tr><tr><td>D</td><td>5</td><td>800</td></tr><tr><td>E</td><td>3</td><td>400</td></tr><tr><td>F</td><td>2</td><td>100</td></tr><tr><td>C+Rain</td><td>5</td><td>850</td></tr><tr><td>D+Rain</td><td>5</td><td>800</td></tr></table></td><td>RR SMR E3S Case Version 2, Tier 1, Chapter 2 [28], GSD [27]
HPA-RPD-058 [30]</td></tr>
<tr><td rowspan="2">Environ-mental activity concentrat-ion modelling (GRANIS, FARMLAND and RESUS models)</td><td>Element dependent parameters</td><td>The following element-dependent default values are not available for potassium and sodium in the FARMLAND model of PC-CREAM 08:
Animal equilibrium transfer factors
Soil to plant equilibrium concentration ratios
Element dependent parameters (bio half-lives of meat and liver and element mobility)
Therefore, the relevant default values within PC-CREAM 08 for rubidium were used.</td><td>-</td></tr>
<tr><td>Soil concentration (GRANIS)</td><td>Default GRANIS parameter values:
Deposition rate: 1 Bq/m^2/s
Soil profile: undisturbed
Soil type: generic wet soil
Soil density: 1.5 g/cm^3
Soil composition:
<table><tr><th>Elements in material</th><th>Mass fraction</th></tr><tr><td>Aluminium</td><td>0.03</td></tr><tr><td>Carbon</td><td>0.07</td></tr><tr><td>Hydrogen</td><td>0.04</td></tr><tr><td>Iron</td><td>0.01</td></tr></table></td><td>HPA-RPD-058 [30]</td></tr>
</table>

<table>
<tr><th>Topic</th><th>Approach / Model Parameter</th><th>Description / Value</th><th>Data Sources</th></tr>
<tr><td></td><td></td><td><table><tr><td>Oxygen</td><td>0.60</td></tr><tr><td>Silicon</td><td>0.25</td></tr></table></td><td></td></tr>
<tr><td></td><td>Food concentration (FARMLAND)</td><td>Deposition rate: 1 Bq/m²/s
Default FARMLAND model parameters:
Plant dependent model parameters
Animal dependent model parameters
Plant concentration ratios
Animal equilibrium transfer factors
Element dependent parameters</td><td>HPA-RPD-058 [30]</td></tr>
<tr><td></td><td>Re-suspended activity (RESUS)</td><td>Deposition rate: 1 Bq/m²/s</td><td>HPA-RPD-058 [30]</td></tr>
<tr><td>Candidates for representative persons (CRPs)</td><td>CRPs</td><td>CRPs for gaseous discharges: local resident family
Age groups: Adult, Child (10 year old) and Infant (1 year old).</td><td>NDAWG Guidance Note [80]
HPA Guidance Note [69]</td></tr>
<tr><td>Habits data</td><td>CRP Location</td><td>Habitation distance from SMR: 300 m
Food production distance from SMR: 500 m</td><td>RR SMR General Arrangement Site Plan [63]
RR SMR E3S Case Version 2, Tier 1, Chapter 2 [28], GSD [27], IRAT [25]</td></tr>
<tr><td></td><td>Occupancy</td><td><table><tr><th></th><th>Adult</th><th>Child</th><th>Infant</th></tr><tr><td>Time at location (h/y)</td><td>8,760</td><td>8,760</td><td>8,760</td></tr><tr><td>Fraction of time spent indoors</td><td>0.5</td><td>0.8</td><td>0.9</td></tr></table></td><td>IRAT [25]</td></tr>
<tr><td>Food consump-tion rates (kg/y or l/y)</td><td colspan="2"></td><td>HPA-RPD-058 [30]
NRPB-W41 [33]</td></tr>
</table>

<table>
<tr><th>Topic</th><th>Approach / Model Parameter</th><th>Description / Value</th><th>Data Sources</th></tr>
<tr><td></td><td colspan="2">
<table>
<tr><th></th><th>Cow liver</th><th>Cow meat</th><th>Cow milk</th><th>Cow milk products</th><th>Fruit</th></tr>
<tr><td>Adult (critical)</td><td>10</td><td>45</td><td>240</td><td>60</td><td>75</td></tr>
<tr><td>Adult (mean)</td><td>2.75</td><td>15</td><td>95</td><td>20</td><td>20</td></tr>
<tr><td>Child (critical)</td><td>5</td><td>30</td><td>240</td><td>45</td><td>50</td></tr>
<tr><td>Child (mean)</td><td>1.5</td><td>15</td><td>110</td><td>15</td><td>15</td></tr>
<tr><td>Infant (critical)</td><td>2.75</td><td>10</td><td>320</td><td>45</td><td>35</td></tr>
<tr><td>Infant (mean)</td><td>0.5</td><td>3</td><td>130</td><td>15</td><td>9</td></tr>
<tr><td colspan="6"></td></tr>
<tr><th></th><th>Green veg.</th><th>Root veg.</th><th>Sheep liver</th><th>Sheep meat</th><th></th></tr>
<tr><td>Adult (critical)</td><td>80</td><td>130</td><td>10</td><td>25</td><td></td></tr>
<tr><td>Adult (mean)</td><td>35</td><td>60</td><td>2.75</td><td>8</td><td></td></tr>
<tr><td>Child (critical)</td><td>35</td><td>95</td><td>5</td><td>10</td><td></td></tr>
<tr><td>Child (mean)</td><td>15</td><td>50</td><td>1.5</td><td>4</td><td></td></tr>
<tr><td>Infant (critical)</td><td>15</td><td>45</td><td>2.75</td><td>3</td><td></td></tr>
<tr><td>Infant (mean)</td><td>5</td><td>15</td><td>0.5</td><td>0.8</td><td></td></tr>
</table>
</td><td></td></tr>
<tr><td>Exposure pathways</td><td>External pathways</td><td>Irradiation from immersion in radioactive cloud and from ground deposition.
Default PC-CREAM 08 location factors:
Cloud gamma indoor location factor: 0.2
Deposited gamma location factor: 0.1</td><td>HPA-RPD-058 [30]</td></tr>
<tr><td></td><td>Internal pathways: inhalation</td><td>Inhalation of radioactive plume and re-suspended material: Default PC-CREAM 08 model parameter values.
Inhalation rates (m^3/y)</td><td>HPA-RPD-058 [30]</td></tr>
</table>

<table>
<tr><th>Topic</th><th>Approach / Model Parameter</th><th>Description / Value</th><th>Data Sources</th></tr>
<tr><td rowspan="2"></td><td></td><td><table><tr><th>Adult</th><th>Child</th><th>Infant</th></tr><tr><td>8,100</td><td>5,600</td><td>1,900</td></tr></table></td><td>NRPB-W41 [33]</td></tr>
<tr><td>Internal pathways: food intake</td><td>All terrestrial foods are assumed to be 100% locally sourced.</td><td>NRPB-W41 [33]</td></tr>
<tr><td rowspan="2">Dose assessment (Individual)</td><td>Doses to CRP for atmospheric discharges (PC-CREAM 08)</td><td>ASSESSOR module draws on the output of other modules (PLUME, GRANIS, FARMLAND and RESUS) and scales them with habits data, actual discharge rates and dose coefficients to calculate doses to the CRP.
The dose from consumption of seafood was calculated using the method described in Section 30.2.2.</td><td>HPA-RPD-058 [30]</td></tr>
<tr><td>Output time</td><td>60 years (anticipated RR SMR plant operation lifetime)</td><td>RR SMR E3S Case Version 2, Tier 1, Chapter 1 [81]</td></tr>
<tr><td rowspan="5">Dose assessment (Collective)</td><td>Output time</td><td>500 years</td><td rowspan="2">HPA-RPD-058 [30]
GDA Guidance for RPs [26]</td></tr>
<tr><td>Population</td><td>UK, EU25, EU12 and World.</td></tr>
<tr><td>Receptor points and habits</td><td>Default PC-CREAM 08 population and agricultural production grids.</td><td rowspan="3">HPA-RPD-058 [30]</td></tr>
<tr><td>Model parameters</td><td>Same model parameters as for the individual assessment.</td></tr>
<tr><td>Population data</td><td><table><tr><th>Region</th><th>Population</th></tr><tr><td>UK</td><td>5.96E+07</td></tr><tr><td>EU25</td><td>4.56E+08</td></tr><tr><td>EU12</td><td>3.60E+08</td></tr><tr><td>World</td><td>1.00E+10</td></tr></table></td></tr>
</table>

30.10 Appendix B

30.10.1 Radiological Impact Assessment Based on Revised Discharge Estimates

Stage 1 and 2 IRAT assessments were undertaken as described in Section 30.3.2 and 30.3.3, using a new source term consisting of revised radioactive effluent discharges at proposed permit limits. These limits were derived from updated annual discharge estimates from the RI waste systems [KNF] and [KPL] [38], and the nuclear HVAC [KL-] and Air Removal Exhaust System[MAJ], based on a more realistic, RR SMR-specific PST, and statistically-derived headroom factors based on variations of discharges from comparable pressurised water reactors (PWR) [40]. All radionuclides which were discharged at a rate greater than 1 Bq/y were included in the assessment.

The revised source terms are presented in Table 30.10-1 and Table 30.10-2.

Table 30.10-1 Revised Predicted Discharges and Proposed Permit Limits for Liquid Radioactive Effluent

Radio-nuclide	Predicted Annual Discharge (Bq/y)	Headroom Factor	Discharge at Annual Limits (Bq/y)	Radio-nuclide	Predicted Annual Discharge (Bq/y)	Headroom Factor	Discharge at Annual Limits (Bq/y)
Ba-140	5.74E+03	3.03	1.74E+04	Mn-54	9.45E+01	3.03	2.86E+02
C-14	8.11E+02	1.62	1.31E+03	Mo-99	8.38E+00	3.03	2.54E+01
Ce-141	6.83E+01	3.03	2.07E+02	Na-24	9.18E+02	3.03	2.78E+03
Ce-144	1.92E+03	3.03	5.81E+03	Nb-95	1.37E+02	3.03	4.16E+02
Co-58	2.41E+02	3.03	7.31E+02	Ni-63	1.79E+02	3.03	5.42E+02
Co-60	3.56E+01	3.03	1.08E+02	Ru-103	3.47E+03	3.03	1.05E+04
Cs-134	2.07E+05	3.03	6.27E+05	Sr-89	7.24E+01	3.03	2.19E+02
Cs-136	2.45E+04	3.03	7.43E+04	Sr-90	6.54E+00	3.03	1.98E+01
Cs-137	1.32E+05	3.03	4.00E+05	Y-91	2.46E+00	3.03	7.45E+00
Fe-55	5.21E+02	3.03	1.58E+03	Zn-65	1.30E+02	3.03	3.94E+02
Fe-59	2.04E+01	3.03	6.19E+01	Zr-95	1.61E+02	3.03	4.89E+02
H-3	8.58E+10	6.29	5.39E+11	Other beta/ gamma emitting	9.72E+04	3.03	2.95 E+05
I-131	2.34E+02	2.73	6.38E+02				
I-133	5.58E+01	2.73	1.52E+02				
La-140	2.47E+03	3.03	7.47E+03				

Radio-nuclide	Predicted Annual Discharge (Bq/y)	Headroom Factor	Discharge at Annual Limits (Bq/y)	Radio-nuclide	Predicted Annual Discharge (Bq/y)	Headroom Factor	Discharge at Annual Limits (Bq/y)
				nuclides [15]			

Table 30.10-2 Revised Predicted Discharges and Proposed Permit Limits for Gaseous Radioactive Effluent

Radio-nuclide	Predicted Annual Discharge (Bq/y)	Headroom Factor	Discharge at Annual Limits (Bq/y)	Radio-nuclide	Predicted Annual Discharge (Bq/y)	Headroom Factor	Discharge at Annual Limits (Bq/y)
Ar-41	5.69E+11	3.98	2.26E+12	Mn-54	7.46E+03	6.21	4.64E+04
Ba-140	1.08E+03	6.21	6.73E+03	Mn-56	1.91E+04	6.21	1.19E+05
Br-84[16]	3.67E+07	6.21	2.28E+08	Mo-99	6.02E+03	6.21	3.74E+04
C-14	2.00E+10	1.64	3.29E+10	Na-24	4.30E+04	6.21	2.67E+05
Ce-141	4.05E+02	6.21	2.52E+03	Nb-95	2.85E+03	6.21	1.77E+04
Ce-144	4.39E+01	6.21	2.73E+02	Ni-63	5.75E+02	6.21	3.57E+03
Cl-36	2.24E+02	6.21	1.39E+03	Ru-103	1.74E+02	6.21	1.08E+03
Co-58	2.77E+05	6.21	1.72E+06	Ru-106	2.46E+00	6.21	1.53E+01
Co-60	7.62E+03	6.21	4.73E+04	Sb-125	9.06E+02	6.21	5.63E+03
Cr-51	2.24E+04	6.21	1.39E+05	Sr-89	2.12E+02	6.21	1.32E+03
Cs-134	3.75E+03	6.21	2.33E+04	Sr-90	1.25E+00	6.21	7.77E+00
Cs-136	5.97E+03	6.21	3.71E+04	Tc-99m	9.75E+03	6.21	6.05E+04
Cs-137	2.83E+03	6.21	1.76E+04	Y-91	2.25E+02	6.21	1.40E+03
Fe-55	7.63E+03	6.21	4.74E+04	Y-91m	2.50E+04	6.21	1.55E+05
Fe-59	3.24E+03	6.21	2.01E+04	Y-92	3.23E+04	6.21	2.01E+05

[15] This category includes radionuclides which are included in the aqueous discharge estimates, but for which the current version of IRAT does not model individual radionuclides. The contribution from these radionuclides has been assessed conservatively by aggregating the activities and assessing contribution to dose using the 'all other beta and gamma emitters' DPUR in IRAT. The radionuclides encompassed by this category are: Ce-143, K-42, Nb-94, Ni-59, Pr-143, Te-142, Y-91 and Zr-97. Note that noble gases (dominated by Xe-133m, with smaller contributions from Kr-85, Kr-85m, Xe-131m, Xe-133 and Xe-135) are present in the liquid effluent discharge, at a combined contribution of 2.71 E+09, but are not included here.

[16] A DPUR value for Br-84 is not included in IRAT, so Br-82 has been used as surrogate radionuclide, in line with approach in the IRAT user guide [23]

Radio-nuclide	Predicted Annual Discharge (Bq/y)	Headroom Factor	Discharge at Annual Limits (Bq/y)	Radio-nuclide	Predicted Annual Discharge (Bq/y)	Headroom Factor	Discharge at Annual Limits (Bq/y)
H-3	4.08E+10	2.52	1.03E+11	Zn-65	1.76E+03	6.21	1.09E+04
I-131	1.91E+07	3.02	5.78E+07	Zr-95	3.35E+03	6.21	2.08E+04
I-132	1.52E+07	3.02	4.60E+07	Other beta/ gamma emitting nuclides[17]	2.79E+06	6.21	1.73E+07
I-133	8.25E+06	3.02	2.49E+07				
I-134	2.71E+07	3.02	8.19E+07				
I-135	1.55E+07	3.02	4.68E+07				
Kr-85	9.74E+12	3.98	3.88E+13	Other noble gases[18]	3.06E+11	3.98	1.22E+12
Kr-85m	6.59E+09	3.98	2.62E+10				
La-140	7.18E+03	6.21	4.46E+04				

A stage 2 IRAT assessment, applying the effective gaseous stack discharge height estimated for the RR SMR {REDACTED} and GSD marine compartment volumetric exchange rate of 100 m^3/s (around 3.2E+09 m^3/y) was undertaken.

Results of the stage 2 assessments are presented in Table 30.3-3 and Table 30.3-4. Radionuclides contributing less than 1% of the total dose (other than carbon-14 for liquid discharges, and other beta/gamma emitters for gaseous discharges, to allow comparison with previous results) have not been included in the tables but are reflected in the total dose.

[17] This category includes radionuclides which included in the gaseous discharge estimates, but for which the current version of IRAT does not model individual radionuclides. The contribution from these radionuclides s as described in footnote 12. The radionuclides encompassed by this category are: Ag-108m, Ag-110m, Ce-143, Cs-138, K-42, Nb-94, Ni-59, Np-239, Pr-143, Rb-88, Rb-89, Ru-105, Sr-91, Sr-92, Te-131, Te-132, Te-133m, Te-134, Y-91, Y-91m, Y-92 and Zr-97.

[18] The category of ‘other noble gases’ includes the contribution from Kr-87, Kr-88, Xe-131m, Xe-133m, Xe-135, Xe-135m and Xe-138. The discharges of these radionuclides were aggregated and assessed as, Xe-133 – the only fission product noble gas in IRAT. This is in line with approach in the IRAT user guide [23]

Table 30.10-3 Estimated Doses from Stage 2 Initial Radiological Assessment for Liquid Discharges to the Environment

Radionuclide	**External dose (μSv/y)**	**Fish/shellfish dose (μSv/y)**	**Total dose (μSv/y)**	**Contribution (%)**
Tritium	0.0E+00	4.9E-04	4.9E-04	65.6
Carbon-14	2.7E-13	5.9E-07	5.9E-07	0.1
Caesium-134	9.1E-05	2.4E-05	1.2E-04	15.6
Caesium-137	6.8E-05	1.1E-05	7.8E-05	10.6
Other beta/gamma emitting nuclides	5.1E-05	8.0E-06	5.8E-05	7.8
Total	2.1E-04	5.3E-04	**7.4E-04**	

Table 30.10-4 Estimated Doses from Stage 2 Initial Radiological Assessment for Gaseous Discharges to the Environment

Radionuclide	**Inhalation dose (μSv/y)**	**External dose (cloud and deposited) (μSv/y)**	**Food dose (μSv/y)**	**Total dose (μSv/y)**	**Contribution (%)**
Tritium	3.0E-03	0.0E+00	1.4E-02	1.7E-02	1.6
Carbon-14	4.9E-02	8.8E-08	5.4E-01	5.9E-01	55.7
Argon-41	0.0E+00	3.0E-01	0.0E+00	3.0E-01	28.6
Krypton-85	0.0E+00	2.0E-02	0.0E+00	2.0E-02	1.9
Iodine-131	8.4E-04	9.3E-05	1.1E-01	1.2E-01	10.9
Other beta/gamma-emitting nuclides	7.4E-05	4.7E-03	4.0E-03	8.7E-03	0.8
Total	5.3E-02	3.3E-01	6.8E-01	**1.1E+00**	

The doses in the revised assessment are significantly lower than in the assessment presented in section 30.3.3. A total dose of around 0.001 μSv/y to the worst affected member of a fishing family and 1.2 μSv/y to the worst affected local inhabitant were calculated for liquid discharges to sea and gaseous discharges to atmosphere respectively.

The doses from liquid radioactive effluent discharges to the coastal environment were dominated by tritium in the revised assessment (66 %) with other significant contributions from radioisotopes of caesium (26 %) and 8 % from the combined ‘all other beta/gamma emitting radionuclides’ category. The change in total dose from the initial assessment of around three orders of magnitude, and of distribution between dose contributors is primarily a result of the significant reductions in activity with the updated source term data, compared to that undertaken using the sensitivity PST. As tritium is not removed by either the CVCS Purification System [KBE] or by the [KNF] effluent treatment system, its contribution to total dose becomes proportionally larger.

As described in footnote 12, noble gases (isotopes of Krypton and Xenon) discharged via the liquid radioactive effluent stream have been excluded from the calculations. It is considered the 'all other beta/gamma emitting radionuclides' category would be overly conservative for modelling uptake of noble gases via this discharge route, as noble gases are inert and will not accumulate in water, sediment or the seafood chain, but will likely dissipate slowly back to the atmosphere. Table 30.10-4 highlights contributions from noble gases argon-41 and krypton-85 to the doses from gaseous radioactive effluent discharges; however, it should be noted that the discharges via the liquid effluent stream are a small fraction of the discharges to atmosphere, and thus the contribution to the dose from liquid discharges is considered negligible and not considered further.

Carbon-14 contributes just over half (55 %) the total dose from gaseous radioactive effluent discharges, compared to over 90 % in the initial assessment presented in section 30.3.3. Dose from iodine -131 (11 %) and argon-41 (28 %) has become more prominent, and a small contribution from krypton-85 is evident, primarily due to a significant increase in predicted activity for this radionuclide in the new source term data, and subsequent increase in discharges. The predicted annual activity of carbon-14 discharge is reduced by around an order of magnitude from the calculations in Table 30.3-4.

The dose rate to the worst affected organism for liquid discharges (Polychaete worm) is around 2.7E-06 µGy/h, dominated by tritium (53 %), isotopes of caesium (31 %) and barium-140 (9 %). The dose rate to the worst affected organism for gaseous discharges (grasses and herbs) is around 0.005 µGy/h, with the main contributors being argon-41 (39 %), carbon-14 (35 %) and krypton-85 (20 %)

30.11 Glossary of Terms and Abbreviations

ABWR	Advanced Boiling Water Reactor
ADMS	Atmospheric Dispersion Modelling System
ALARA	As Low As Reasonably Achievable
ALARP	As Low As Reasonably Practicable
AP1000	Advanced Passive 1000 reactor
ARES [MAJ]	Air Removal Exhaust System (formerly CARS)
BAT	Best Available Techniques
BE	Best Estimate
BEIS	Business, Energy and Industrial Strategy
BSS	Basic Safety Standards
BSSD	Basic Safety Standards Directive (2013/59/Euratom)
CARS [MAJ]	Condenser Air Removal System (now ARES)
CEFAS	Centre for Environment, Fisheries and Aquaculture Science
CERC	Cambridge Environmental Research Consultants
CR	Concentration Ratio
CRP	Candidate for the Representative Person
CVCS [KB-]	Chemistry and Volume Control System
DB	Design Basis
DECC	Department for Energy and Climate Change
DPUR	Dose Per Unit Release
DRP	Design Reference Point
E3S	Environment, Safety, Security & Safeguards
EA	Environment Agency
EC	European Commission
EPR	European Pressurised Reactor
EPR16	Environmental Permitting (England and Wales) Regulations 2016 (as amended)
EU	European Union
EURATOM	European Atomic Energy Community

FA	Forward Action
FAB10	Spent Fuel Pool
GDA	Generic Design Assessment
GSD	Generic Site Description
GSE	Generic Site Envelope
GRETS [KPL]	Gaseous Radioactive Effluent Treatment System
HPA	Health Protection Agency
HPR1000	Hualong Pressurised Water Reactor 1000
HSA	(UK) Health Security Agency
HVAC [KL]	Heating, Ventilation & Air Conditioning
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
IRAT	Initial Radiological Assessment Tool
KBE	Chemistry and Volume Control System Purification System
Kd	Distribution coefficient (partitioning of a radionuclide between two media)
KLS	Main Gaseous Effluent Stack
MAB	Mass-Activity Balance
NDAWG	National Dose Assessment Working Group
NPP	Nuclear Power Plant
NRPB	National Radiological Protection Board
NRW	Natural Resources Wales
PCD	Preliminary Concept Definition
PHE	Public Health England
PST	Primary Source Term
PSST	Primary Systems Source Term
PWR	Pressurised Water Reactor

RD	Reference Design
RGP	Relevant Good Practice
RI	Reactor Island
RP	Requesting Party
RPV	Reactor Pressure Vessel
RQ	Risk Quotient
RR SMR	Rolls-Royce Small Modular Reactor
RSR	Radioactive Substances Regulations
SMR	Small Modular Reactor
SSC	Structures, Systems and Components
SSL	Suspended Sediment Load
TI	Turbine Island
UF	Uncertainty Factor
UK	United Kingdom
UKHSA	UK Health Security Agency
UPK	Cooling Water Outfall Pond
US	United States
µGy/h	Micro Grays per hour
µSv/y	Micro Sieverts per year
mSv/y	Milli Sieverts per vear
nSv/y	Nano Sieverts per year