EA - NCAS - 2002

National Compliance Assessment Service
Technical Report

ENVIRONMENT AGENCY

Assessment of Radioactive Discharge Screening Levels for Biota Protected under the Habitats Regulations

NCAS/TR/2001/019 **April 2002**

NCAS Technical Report: NCAS/TR/2001/019

Address for Enquiries

National Compliance Assessment Service
Environment Agency
Cameron House
White Cross Industrial Estate
South Rd
Lancaster
LA1 4XQ

Tel: 01524 842704 Fax: 01524 842709

Dissemination status
Internal: Released to Environment Agency Head Office.
External: English Nature, available for release to public.

Statement of use
To support the Environment Agency's implementation of the Habitats Regulations.

Authors
M L Dunn

EXECUTIVE SUMMARY

The UK Habitats Regulations 1994 implement the Habitats Directive (Council Directive 92/43/EEC on the conservation of natural habitats of wild flora and fauna), and provide mechanisms to protect sites designated under the Birds Directive. The regulations require measures to be taken to maintain or to restore to favourable conservation status in their natural range, habitats and species of wild flora and fauna of Community interest, as listed in the Annexes to the Directive.

The Environment Agency has produced guidance on the implementation of the UK Habitats Regulations in England and Wales. The implementation of the Habitats Regulations consists of a 'Review of Consents' which is in four stages. The stages are concerned with identification of those authorised permissions to discharge, which are likely to have a significant effect on biota protected by the Habitats Regulations in designated Natura 2000 sites, and where appropriate, the assessment of the potential impact of those permissions. Once the relevant permissions have been identified, by means of two screening processes (Stages 1 and 2) the impact of the potential discharges will be assessed (Stage 3) and the status of the permissions will be determined (Stage 4).

In the past, the Stage 2 screening assessment criterion has relied on the assumption, stated by the International Commission on Radiological Protection (ICRP), that: 'if man is adequately protected from ionising radiation, then so are other species'. This assumption has been increasingly challenged, mainly due to a lack of evidence to support the ICRP position, and the inconsistency with situations where the precautionary approach has been adopted to protect the environment from non-radioactive discharges. In addition there has been increasing public and political pressure for the environment to be protected in its own right.

The Environment Agency and English Nature have commissioned and jointly funded an R&D project to examine the impact of ionising radiation on wildlife. The findings of the project were published in R&D Publication 128, entitled: "Impact Assessment of Ionising Radiation on Wildlife" (2000). As a result of the findings in R&D Publication 128, the Agency, English Nature and the Countryside Council for Wales have considered whether the Stage 2 assessment in the current guidance is still appropriate, and have decided that it should be replaced with a screening stage which takes account of impacts to wildlife. Hence, the purpose of this report has been to develop 'wildlife screening levels' based on the findings in R&D Publication 128, in support of the Stage 2 process.

This report presents the results of radiological assessments performed to determine screening discharge levels 'wildlife screening levels' (TBq/y) for biota protected under the Habitats Regulations in designated Natura 2000 sites, for discharge of radioactivity to atmosphere, river and the coastal marine environment. The 'wildlife screening levels' were developed for inclusion in Appendix 8 of the Environment Agency guidance. Appendix 8 of the guidance is concerned with the 'Review of Consents' for authorisations of radioactive discharges which are issued by the Environment Agency under the Radioactive Substances Act 1993.

Because of uncertainties in the data for some biota, a precautionary approach has been taken as recommended in Agency R&D Publication 128, and a screening criterion has been adopted

which is based on 5 % of these dose rate levels. If discharge limits (TBq/y) are greater than 5 % of the assessed wildlife screening levels (TBq/y), then the authorisation should undergo a more detailed (Stage 3) assessment.

CONTENTS

INTRODUCTION

1. The UK Habitats Regulations 1994 implement the Habitats Directive (Council Directive 92/43/EEC on the conservation of natural habitats of wild flora and fauna), and provide mechanisms to protect sites designated under the Birds Directive. In practice the Habitats Regulations are intended to protect designated European sites, which are known as Natura 2000 sites. Natura 2000 sites are SACs (Special Areas of Conservation) which are designated under the Habitats Directive, and SPAs (Special Protection Areas), which are designated under the Birds Directive 1979. The regulations require measures to be taken to maintain or to restore to favourable conservation status in their natural range, habitats and species of wild flora and fauna in the Natura 2000 sites.

2. The Environment Agency authorises discharges of radioactive waste to the environment under the Radioactive Substances Act 1993 (RSA93) from a variety of premises, including hospitals, universities, pharmaceutical companies and nuclear sites. The Agency is required to undertake a 'Review of Consents' under the Habitats Regulations. This is a review of all permissions issued by the Agency which allow discharges into the environment which could affect biota protected by the Habitats Regulations in the designated Natura 2000 sites.

3. This report presents the results of radiological assessments performed to determine generalised screening discharge levels (TBq/y) for biota protected under the Habitats Regulations for discharge of radioactivity to atmosphere, river and the coastal marine environment. The purpose of these generalised 'wildlife screening levels' is to enable identification of those discharge authorisations which have the potential to lead to a significant adverse effect on populations of wildlife. For Natura 2000 sites which could be affected by these authorised discharges it is expected that a more detailed site specific radiological assessment for wildlife will be required.

BACKGROUND

4. The Agency has existing guidance, which was produced in association with English Nature, to facilitate the implementation of the Habitats Review of Consents for discharges of radioactive waste [Ref 1]. The guidance covers the following staged process:

   - Stage 1 Identify all relevant applications
   - Stage 2 Assessment of likely significant effect
   - Stage 3 Perform appropriate assessment
   - Stage 4 Determination of permissions

5. Stage 1 may be regarded as an initial screening process, and Stage 2 may be regarded as a final screening process. The Stage 2 screening assessment relies on the assumption, stated by the International Commission on Radiological Protection (ICRP), that: 'if man is adequately protected from ionising radiation, then so are other species'. This assumption has been increasingly challenged, mainly due to a lack of evidence to

support the ICRP position, and the inconsistency with situations where the precautionary approach has been adopted to protect the environment from non-radioactive discharges. In addition there has been increasing public and political pressure for the environment to be protected in its own right.

6. In anticipation of the Stage 3 process, the Agency and English Nature commissioned research and development work, whose findings were reported in a joint R&D Publication 128, entitled: "Impact Assessment of Ionising Radiation on Wildlife" [Ref 2] to provide up to date information on ionising radiation impacts on wildlife in England and Wales. This document may be regarded as having an interim status, as a European Commission funded project (Framework for ASSessment of Environmental impacT – FASSET) started in November 2000, and is expected to deliver a harmonised framework for consideration within the EU for future radiation assessments by October 2003.

7. As a result of the findings in R&D Publication 128 [Ref 2], the Agency, English Nature and the Countryside Council for Wales have considered whether the Stage 2 assessment in the current guidance is still appropriate and should be replaced with a screening stage which takes account of impacts to wildlife. Hence, the purpose of this report has been to develop 'wildlife screening levels' based on the results of Agency R&D.

BASIS FOR WILDLIFE SCREENING THRESHOLDS

8. The Stage 2 assessment is concerned with identifying those radioactive waste discharge authorisations which have the potential to give rise to significant impacts on species protected by the Habitats Regulations within Natura 2000 sites. Therefore, it is necessary to define screening thresholds which enable those authorisations to be identified.

9. R&D Publication 128 [Ref 2] reports guideline dose rate levels for generic biota derived from scientific reviews by the IAEA (International Atomic Energy Agency) and UNSCEAR (United Nations Scientific Committee of the Effects of Atomic Radiation). It is considered unlikely that there would be any significant effect on populations of organisms which are chronically exposed at these levels [Ref 2] which are summarised below:

- Terrestrial animal populations at chronic dose rates below 40 μGy/h.
- Terrestrial plant populations at chronic dose rates below 400 μGy/h.
- Populations of freshwater and coastal organisms at chronic dose rates below 400 μGy/h.

10. In practice, the guideline dose rate levels which were used as the basis for wildlife screening thresholds, were more clearly defined for individual groups of organisms, after consultation with the authors of R&D Publication 128 [Ref 2] and were as follows:

- 40 μGy/h for terrestrial animal populations
- 40 μGy/h for populations of freshwater organisms which could spend a significant proportion of their time in the terrestrial environment (amphibian, freshwater aquatic mammal and duck)
- 40 μGy/h for populations of marine organisms which could spend a significant proportion of their time in the terrestrial environment (seabird)
- 40 μGy/h for populations of marine mammals (seal, whale)
- 400μGy/h for terrestrial plant populations, including bacteria, fungi and lichen
- 400 μGy/h for populations of other coastal and freshwater organisms

11. It is stated in R&D Publication 128 [Ref 2] that where default concentration factors have been used in an assessment, it is appropriate to take the precautionary approach of adopting 5 % of the IAEA guideline dose rate values as the thresholds for the occurrence of a likely significant effect. As the screening levels have been calculated based on default concentration factors (or cautious estimates of concentration factors) then it is appropriate to use 5 % of the IAEA guideline dose rate values as thresholds for the occurrence of a likely significant effect. If discharges at the authorised limits exceed 5 % of the screening levels, then there could be a likely significant effect and it is proposed that a further detailed radiological assessment should be undertaken under the Stage 3 process.

12. In the approach described in this report, generic cautious assumptions have been made regarding the dispersion of radioactive substances discharged to the environment, and screening thresholds related to the dose rate guidelines have been set for the levels of activity discharged (ie TBq/y). Activity concentration per unit release factors and dose rate per unit activity concentrations have been used to calculate dose rate per unit release factors. This takes a similar approach to that used to determine Generalised Derived Constraints published by the NRPB [Ref 3].

DERIVATION OF WILDLIFE SCREENING THRESHOLDS

13. R&D Publication 128 [Ref 2] provides data and spreadsheet tools to enable calculation of dose rates to a variety of organisms, exposed to a limited number of radionuclides in various environmental media (see Table 1). The environmental media are broadly categorised as follows:

    - Terrestrial (air and soil)
    - Marine (coastal waters)
    - Freshwater

14. The methods are briefly described in the following sub-sections and in more detail in Appendices A, B and C. Where discharges are authorised for radionuclides other than

those considered in this report, cautious analogue radionuclides have been suggested as substitutes.

Terrestrial Environment

15. To derive the screening thresholds for the terrestrial environment, the concentration in air per unit release rate (Bq/m^3 per Bq/s) and in soil per unit release rate (Bq/kg per Bq/y) were determined for a cautious release scenario (ie ground-level release, exposure at a horizontal distance of 100 m from the release point). It was assumed that the atmospheric release occurred in category D weather conditions, which is cautious in terms of the radiological assessment. Further details are provided in Appendix A.

16. The dose rates to terrestrial organisms were calculated using the data and models provided in the R&D Publication 128 [Ref 2] for unit concentrations of radionuclides in air and soil (eg μGy/h per Bq/m^3 in air, and μGy/h per Bq/kg in soil). The R&D model calculates dose rates, using biota concentration factors, which describe the concentration of a given radionuclide in an organism compared with the concentration of the same radionuclide in the environment.

17. The two sets of data were combined together to derive the dose rate per unit release rate values (ie μGy/h per TBq/y) for particular organisms and radionuclides. For the purposes of calculation, the radionuclides discharged to atmosphere were divided into two groups: those which do not deposit on the ground to any significant extent (tritium, carbon-14 and sulphur-35) – the 'non-depositing radionuclides'; those which do deposit on the ground (strontium-90, iodine-129, caesium-137, radium-226, uranium-238 and plutonium-239) – the 'depositing radionuclides'. Screening thresholds were then calculated by dividing the guideline dose rates given above by the dose rate per unit release rate values.

Marine Environment

18. The marine environment screening thresholds were derived in a similar manner to those for the terrestrial environment, except in this case it was necessary to evaluate dispersion of radionuclides in coastal waters to derive the activity concentration in filtered seawater per unit discharge rate (Bq/m^3 per Bq/y). The following radionuclides were considered: tritium; carbon-14; strontium-90; technetium-99; iodine-129; caesium-137; polonium-210; uranium-238 and plutonium-239.

19. A marine dispersion module (called DORIS) within the radiological assessment code PC CREAM [Ref 4] was used to undertake the dispersion modelling. Modelling was undertaken for a representative variety of coastal locations, to enable a cautious scenario to be selected for each radionuclide (see Appendix B). The dispersion modelling takes account of the buildup of radionuclides in each coastal location after 50 years of continuous discharges. The coastal locations considered were the Ribble Estuary, the inner Thames Estuary, Plymouth Sound and the Irish Sea around BNFL Sellafield.

20. The R&D Publication 128 [Ref 2] model was used to calculate dose rates for unit concentrations of radionuclides in filtered seawater for the different organisms (ie μGy/h per Bq/m^3).

21. The two sets of data were combined together to derive the dose rate per unit release rate values (ie µGy/h per TBq/y) for particular organisms and radionuclides. Screening thresholds were then calculated by dividing the guideline dose rates given above by the calculated dose rate per unit release rate values.

Freshwater Environment

22. The following radionuclides were considered in the freshwater assessment: tritium; carbon-14; strontium-90; technetium-99; iodine-129; caesium-137; polonium-210; uranium-238 and plutonium-239 for discharge to river.

23. A river model within the PC CREAM code was used to undertake dispersion modelling in the freshwater environment and to enable activity concentrations in filtered river water per unit release rate to be derived (Bq/m^3 per Bq/y). The river was assumed to have physical characteristics which were cautious in terms of the radiological assessment, including a low flow rate of 1m^3/s (see Appendix C). As most rivers have flow-rates which exceed this value, a correction factor was used to account for this in the practical guidance for use of the screening levels (see Appendix D). Activity concentrations in filtered river water were those which would occur up to 500 m downstream of a discharge, after 50 years of continuous discharges. This is to account for the buildup of radionuclides in sediment over time.

24. The R&D Publication 128 [Ref 2] model was used to calculate dose rates for unit concentrations of radionuclides in filtered river water for a range of different organisms in the freshwater environment (ie µGy/h per Bq/m^3).

25. The two sets of data were combined together to derive the dose rate per unit release rate values (ie µGy/h per TBq/y) for particular organisms and radionuclides. Screening thresholds were then calculated by dividing the guideline dose rates given above by the calculated dose rate per unit release rate values.

DISCUSSION OF DERIVED WILDLIFE SCREENING THRESHOLDS

26. The derived wildlife screening thresholds are summarised in Table 2 for generic groups of organisms. The full range of results for individual organisms and radionuclides is provided in Appendices A, B and C.

27. For the range of release scenarios and organisms considered the highest screening levels (least restrictive) were for tritium, and the lowest (most restrictive) were for radium-226, uranium-238 and plutonium-239.

28. For releases to atmosphere, lower screening values were calculated for terrestrial animals than for terrestrial plants. Amongst the terrestrial animals, the vertebrates were generally shown to be more radiosensitive than the invertebrates for the range of radionuclides considered.

29. For releases to the coastal marine environment, lower screening values were calculated for the seabird, seal and whale than for the other marine organisms. The fish egg was also considered as part of the marine organisms group. Amongst the other marine organisms, the fish egg was found to be the most radiosensitive, as it has the lowest screening values for the largest range of radionuclides.

30. For releases to rivers, lower screening values were calculated for the amphibian, freshwater aquatic mammal and duck, than for the other freshwater organisms. The duck was found to be the most radiosensitive organism, as it has the lowest screening values for the largest range of radionuclides.

31. Guidance on the practical use of the screening levels is provided in Appendix D. As the discharge screening levels are based on calculations using cautious estimates of biota concentration factors where none were available, they must be regarded as indicative only, and there is flexibility in the guidance to enable alternative approaches to be used, where these can be justified. Data were not available to enable the calculation of screening levels for some radionuclides which are commonly discharged into the environment. Cautious analogues for these radionuclides have been suggested in Table 3. Further work resulting from FASSET will enable more realistic data to be provided eg concentration factors for a range of radionuclides for which data are currently unavailable.

CONCLUSIONS

32. There is a requirement to ensure that wildlife which is protected under the Habitats Regulations (1994) at Natura 2000 sites (Special Areas of Conservation and Special Protection Areas) is adequately protected from exposure to ionising radiation. The Environment Agency is implementing these regulations by means of a 'Review of Consents' process, where the potential impact of authorised discharges is being reviewed in four stages. Stage 2 of the process is designed to identify authorised discharges which could give rise to a 'likely significant effect' in populations of organisms protected under the Habitats Regulations.

33. In support of the Stage 2 process discharge screening levels (TBq/y) for discharges of radioactivity to the environment have been calculated for wildlife, based on cautious assumptions. Discharge screening levels have been calculated for discharges to the atmosphere, river and into the coastal environment. Discharges into lakes and into the deep ocean have not been included as part of this assessment, and should be considered on a site specific basis.

34. The discharge screening levels equate to chronic exposure of the biota at guideline dose rate levels recommended by the International Atomic Energy Agency (IAEA), as discussed in R&D Publication 128.

35. It is stated in R&D Publication 128 that where default concentration factors have been used in an assessment, it is appropriate to take the precautionary approach of adopting 5 % of the IAEA guideline dose rate values as the thresholds for the occurrence of a likely significant effect. As the screening levels have been calculated based on default

concentration factors (or cautious estimates of concentration factors) then it is appropriate to use 5 % of the IAEA guideline dose rate values as thresholds for the occurrence of a likely significant effect. If discharges at the authorised limits (TBq/y) exceed 5 % of the screening levels (TBq/y), then there could be a likely significant effect and it is proposed that further detailed radiological assessment should be undertaken under the Stage 3 process.

36. There is a lack of biota concentration factor data for some organisms and radionuclides which are used by the Agency R&D Publication 128 to derive dose rates. If further data becomes available (eg as a result of the FASSET work programme), the discharge screening levels for new permissions should be reviewed.

37. Guidance on the practical use of the screening levels in undertaking a Stage 2 assessment is provided in Appendix D. As the discharge screening levels are based on calculations using cautious estimates of biota concentration factors where none were available, they must be regarded as indicative only, and there is flexibility in the guidance to enable alternative approaches to be used as long as there is an clear audit trail through the data used in any assessment employing an alternative approach.

38. The guideline environmental dose rate levels which have been used as a basis for calculating the discharge screening levels are designed to protect biota against significant adverse deterministic (non-stochastic or 'threshold') effects. However there is a current concern that the induction of stochastic or 'non-threshold' effects such as cancer may be important for some organisms, especially long-lived marine mammals. If relevant data becomes available, the discharge screening levels for new permissions should be reviewed.

REFERENCES

1. Environment Agency (2001). Habitats Directive and Regulations Guidance Handbook.

2. Environment Agency & English Nature R&D Publication 128 (2001). Impact Assessment of Ionising Radiation on Wildlife.

3. National Radiological Protection Board Document Volume 11 No 2 (2000). Generalised Derived Constraints for Radioisotopes of Strontium, Ruthenium, Iodine, Caesium, Plutonium, Americium and Curium. Generalised Derived Limits for Radioisotopes of Polonium, Lead, Radium and Uranium.

4. Simmonds J R, Lawson G and Mayall A (1995). Methodology for assessing the radiological consequences of routine releases of radionuclides to the environment. European Commission, Luxembourg, EUR 15760 EN, Radiation Protection 72.

5. NCAS Technical Report: NCAS/TR/2001/003 (July 2001). Radiological Assessment: Authorised discharges of radioactive wastes from BNFL Sellafield (2000 review).

6. Titley, JGT et al, 2000. Investigation of the Sources and Fate of Radioactive Discharges to Public Sewers Environment Agency R&D Technical Report P288.

7. PCCREAM 98 EUR 17791 EN NRPB-SR296. Consequences of Releases to the Environment Assesssment Methodology.

8. NCAS Technical Report: NCAS/TR/2001/022 (January 2001). Radiological Assessment – Devonport Royal Dockyard Authorisation Variation Request 2000.

Table 1 Organisms and Radionuclides Used for Derivation of Screening Thresholds

Environment	Radionuclide	Organisms	Guideline Dose Rate Threshold for Significant Effects on Population
Terrestrial (discharge to air)	Tritium (not OBT) Carbon-14 Sulphur-35 Strontium-90 Caesium-137 Plutonium-239 Uranium-238 Iodine-129 Radium-226	bacteria[a] lichen tree shrub herb seed fungus	400 µGy/h
		caterpillar ant bee wood louse earthworm herbivorous mammal carnivorous mammal rodent bird bird egg reptile	40 µGy/h
Coastal marine	Tritium Carbon-14 Strontium-90 Technetium-99 Iodine-129 Caesium-137 Polonium-210 Uranium-238 Plutonium 239	bacteria[a] phytoplankton zooplankton macrophyte fish egg benthic mollusc small benthic crustacean large benthic crustacean pelagic fish benthic fish	400 µGy/h
		seabird[b] seal[c] whale[c]	40 µGy/h
Freshwater	Tritium Carbon-14 Strontium-90 Technetium-99 Iodine-129 Caesium-137 Polonium-210 Uranium-238 Plutonium 239	bacteria[a] phytoplankton zooplankton macrophyte benthic mollusc small benthic crustacean large benthic crustacean pelagic fish benthic fish	400 µGy/h
		amphibian[b] aquatic mammal[b] duck[b]	40 µGy/h

[a] ERC have advised that it is appropriate to use a guideline dose rate threshold of 400 µGy/h for bacteria.
[b] As these organisms could spend a significant proportion of their time in the terrestrial environment, it was considered appropriate to use a guideline dose rate threshold of 40µGy/h which applies to terrestrial animals.
[c] ERC have advised that it is appropriate to use a guideline dose rate threshold of 40 µGy/h for the marine mammals because of their relatively high radiosensitivity.

Table 2 Screening Thresholds (TBq/y)

Radionuclide	Release to Air		Release to Coastal Waters		Release to Freshwaters	
	Screening Threshold [a]	Limiting organism(s) [b]	Screening Threshold [a]	Limiting organism(s) [b]	Screening Threshold [a]	Limiting organism(s) [b]
Tritium (not OBT)	9E+03	ant	2E+07	seabird, seal, whale	1E+05	amphibian, aquatic mammal, duck
Carbon-14	7E+02	ant, herbivorous mammal, carnivorous mammal, rodent, bird, reptile	8E+01	seabird, seal, whale	5E-01	amphibian, aquatic mammal, duck
Sulphur-35	1E+04	caterpillar, ant, bee, wood louse, earthworm, herbivorous mammal, carnivorous mammal, rodent, bird, bird egg, reptile	-	-	-	-
Strontium-90	5E+00	herbivorous mammal, carnivorous mammal, bird, bird egg, reptile	3E+00	seabird, seal, whale	2E-02	amphibian, aquatic mammal, duck
Technetium-99	-	-	3E+01	seabird, seal, whale	2E-01	amphibian, aquatic mammal, duck
Iodine-129	3E-01	herbivorous mammal, carnivorous mammal, rodent, bird, bird egg, reptile	3E+01	seabird, seal, whale	2E-01	duck
Caesium-137	4E-01	earthworm, carnivorous mammal, bird egg, reptile	1E+01	seabird	8E-02	duck
Polonium-210	-	-	5E+01	seabird, seal, whale	2E-04	amphibian, aquatic mammal, duck
Radium-226	4E-04	carnivorous mammal, bird egg, reptile	-	-	-	-
Uranium-238	1E-03	carnivorous mammal, bird, bird egg, reptile	2E-02	seabird, seal, whale	1E-04	amphibian, aquatic mammal, duck
Plutonium-239	2E-03	carnivorous mammal, bird, bird egg, reptile	3E-01	seabird, seal, whale	1E-03	amphibian

[a] Screening levels for groups of organisms are based on the lowest values for any organism within the group.
[b] As screening levels are based on estimated biota concentration factors for some organisms and radionuclides, the limiting organisms for each radionuclide and type of release may change as more data becomes available in the future.

Table 3 Recommended analogues for radionuclides where no specific discharge screening level is set

Radionuclide [a]	Analogue radionuclide		
	Release to air	**Release to coastal waters**	**Release to freshwater (river)**
Tritium as OBT	Carbon-14	Carbon-14	Carbon-14
Phosphorus-32/33	Caesium-137	Caesium-137	Caesium-137
Sulphur-35	Data available	Carbon-14	Carbon-14
Argon-41[b]	Caesium-137	n/a	n/a
Cobalt-60 [c]	Caesium-137	Strontium-90	Caesium-137
Krypton-85 [b]	Caesium-137	n/a	n/a
Technetium-99m	Caesium-137	Caesium-137	Caesium-137
Ruthenium-106	Caesium-137	Caesium-137	Caesium-137
Iodine-125	Iodine-129	Iodine-129	Iodine-129
Iodine-131	Caesium-137	Caesium-137	Caesium-137
Uranium-234	Uranium-238	Uranium-238	Uranium-238
Uranium-235	Uranium-238	Uranium-238	Uranium-238
Other alpha-emitting nuclides e.g. Americium-241, Plutonium-241	Radium-226	Uranium-238	Uranium-238
Other beta/gamma-emitting nuclides	Caesium-137	Strontium-90	Strontium-90

[a] The analogue radionuclides represent cautious choices based on the best available data and should be regarded as indicative only. Alternative analogues or approaches may be used but there must be a clear audit trail through the assessment

[b] The analogue may be quite restrictive for argon-41 and krypton-85. Work is underway to provide data for these radionuclides. These radionuclides are not discharged to the aquatic environment.

[c] Cobalt-60 has higher concentration factors than caesium-137 for the marine environment. Therefore the more restrictive strontium-90 analogue has been selected.

APPENDIX A TERRESTRIAL ASSESSMENT METHODOLOGY AND RESULTS

A.1 The discharge screening levels for particular types of terrestrial organisms are shown in Table A1, and these have been calculated as detailed below. The dose rate thresholds which were used in the calculations are shown in Table 1.

A.2 Data which has been used in the terrestrial assessment has been taken from NRPB Document Vol 11 No 2 [Ref 3] for the ground level air activity concentration (Bq/m^3) and deposition rates (Bq/m^2/s) which would result at 100 m from the release point from a continuous release rate of 1 Bq/s to atmosphere, based on the same cautious assumptions which were used to calculate the NRPB Generalised Derived Constraints [Ref 3] ie 50 years' continuous discharges from a 1 m high stack for a release in 50 % Category D weather conditions. These data are shown in Table A2.

A.3 Radionuclides which were considered in the first part of the terrestrial assessment were those which do not deposit on the ground to a significant extent. These are tritium, carbon-14 and sulphur-35. The terrestrial model developed in Agency R&D Publication 128 [Ref 2] was used to calculate environmental dose rates to terrestrial biota per unit activity concentration in air (μGy/h per Bq/m^3), for relevant non-depositing radionuclides. The concentration factor data used in the Publication 128 model is shown in Table A3, and where these have been estimated, this is indicated, and the results are shown in Table A4. The data in Table A4 and air activity concentration per unit release rate values (Bq/m^3 per Bq/s) shown in Table A2 were used to calculate environmental dose rate values per unit release rate (μGy/h per Bq/y) as shown in Table A5. Screening discharge levels for non-depositing radionuclides discharged to atmosphere were calculated for the selected range of biota, by dividing the guideline dose rates given in Table 1 by the dose rate per unit release rate values in Table A5.

A.4 The soil activity concentrations per unit release rate after 50 years' continuous release to atmosphere (Bq/kg per Bq/y) have been calculated for radionuclides which deposit on the ground and are shown in Table A6. The calculations were based on cautious assumptions and used deposition rate per unit release rate data (Bqm^{-2}s^{-1} per Bq/s) and 50th year soil activity concentration data per unit deposition rate data (Bq/kg per Bqm^{-2}y^{-1}) from NRPB Document Vol 11 No 2 [Ref 3] which are shown in Table A6. In the absence of data, 50th year soil activity concentrations per unit deposit rate (Bq/kg per Bqm^{-2}y^{-1}) for radium-226 and for uranium-238 were cautiously estimated to be the same as for plutonium-239, which is the most restrictive of the radionuclides for which data are available.

A.5 The terrestrial model developed in Agency R&D Publication 128 [Ref 2] was used to calculate environmental dose rates for terrestrial biota per unit activity concentration in soil (μGy/h per Bq/kg), for depositing radionuclides as shown in Table A7. The concentration factor data used in the Agency R&D Publication 128 model are shown in Table A3, and where these have been estimated, this is indicated. Data from Tables A6 and A7 have been used to calculate environmental dose rate values per unit release (μGy/h per Bq/y), as shown in Table A8. Screening discharge levels for radionuclides discharged to atmosphere which deposit on the ground were calculated for the selected range of biota, by dividing the guideline dose rates in Table 1 by the dose rate per unit release values in Table A8.

Table A1 Terrestrial Discharge Screening Levels (TBq/y) [a]

Radionuclide/ organism	bacteria	lichen	tree	shrub	herb	seed
Tritium (not OBT)	3.E+05	9.E+04	1.E+05	1.E+05	1.E+05	2.E+06
Carbon-14	3.E+03	1.E+05	4.E+03	1.E+04	8.E+03	1.E+03
Sulphur-35	1.E+05	3.E+04	3.E+04	3.E+04	3.E+04	1.E+05
Strontium-90	5.E+01	6.E+01	1.E+02	7.E+01	5.E+01	5.E+01
Iodine-129	2.E+00	3.E+00	2.E+00	2.E+00	2.E+00	2.E+00
Caesium-137	3.E+00	8.E+00	4.E+00	4.E+00	4.E+00	3.E+00
Radium-226	4.E-03	3.E-01	2.E-01	1.E-01	2.E-01	4.E-03
Uranium-238	1.E-02	1.E-02	8.E-01	1.E-02	2.E-01	1.E-02
Plutonium-239	2.E-02	3.E-01	6.E-01	2.E-02	5.E+00	2.E-02

Radionuclide/ organism	fungus	caterpillar	ant	bee	wood louse	earthworm
Tritium (not OBT)	9.E+04	1.E+04	9.E+03	1.E+04	1.E+04	1.E+04
Carbon-14	5.E+04	1.E+03	2.E+03	1.E+03	9.E+02	1.E+03
Sulphur-35	1.E+05	1.E+04	1.E+04	1.E+04	1.E+04	1.E+04
Strontium-90	1.E+02	1.E+02	2.E+01	4.E+01	3.E+01	9.E+00
Iodine-129	3.E+00	7.E+00	2.E+00	5.E+00	2.E+00	1.E+00
Caesium-137	7.E+00	3.E+00	6.E-01	3.E+00	9.E-01	4.E-01
Radium-226	4.E-03	4.E-02	3.E-02	4.E-02	3.E-02	3.E-02
Uranium-238	1.E-02	1.E-01	1.E-01	1.E-01	1.E-01	1.E-01
Plutonium-239	2.E-02	2.E-01	2.E+00	1.E+01	5.E-01	9.E-01

Radionuclide/ organism	herbivorous mammal	carnivorous mammal	rodent	bird	bird egg	reptile
Tritium (not OBT)	1.E+04	1.E+04	1.E+04	1.E+04	1.E+04	1.E+04
Carbon-14	7.E+02	7.E+02	7.E+02	7.E+02	2.E+03	7.E+02
Sulphur-35	1.E+04	1.E+04	1.E+04	1.E+04	1.E+04	1.E+04
Strontium-90	5.E+00	5.E+00	9.E+00	5.E+00	5.E+00	5.E+00
Iodine-129	3.E-01	3.E-01	3.E-01	3.E-01	3.E-01	3.E-01
Caesium-137	5.E-01	4.E-01	7.E-01	1.E+00	4.E-01	4.E-01
Radium-226	4.E-03	4.E-04	7.E-02	5.E-02	4.E-04	4.E-04
Uranium-238	7.E-01	1.E-03	3.E+00	1.E-03	1.E-03	1.E-03
Plutonium-239	2.E+02	2.E-03	4.E+01	2.E-03	2.E-03	2.E-03

[a] Calculated using data in Tables 1, A5 and A8.

Table A2 Atmospheric parameters used in terrestrial assessment [a]

Atmospheric parameter	Value	Units
Air concentration per unit release rate [b]	8.8E-05	Bq/m^3 per Bq/s
Deposition rate per unit release rate (except	9.0E-08	$Bqm^{-2}s^{-1}$ per Bq/s
Deposition rate per unit release rate (iodine) [b]	8.1E-07	$Bqm^{-2}s^{-1}$ per Bq/s

[a] From NRPB Document Volume 11 No 2 [Ref 3].
[b] Air activity concentration and deposition rates at 100 m horizontal distance from 1m high release point, for release in 50 % Category D weather conditions and uniform windrose.

Table A3 Terrestrial Environment Concentration factors used in Environment Agency Publication 128 Model (Bq/kg per Bq/m^3)

Radionuclide/ organism	soil	bacteria	lichen	tree	shrub	herb	seed
Tritium (not OBT)	5.36E+01	5.36E+01	1.61E+02	1.07E+02	1.52E+02	1.18E+02	8.93E+00
Carbon-14	1.88E+03	1.88E+03[a]	3.75E+01	1.25E+03	4.22E+02	5.63E+02	4.75E+03
Sulphur-35	5.00E+01	5.00E+01	1.50E+02	1.50E+02	1.50E+02	1.50E+02	5.00E+01
Strontium-90	1.00E+01[a]	1.00E+01[a]	**1.00E+01**[b]	1.04E+00	1.70E-02	**1.00E+01**[b]	**1.00E+01**[b]
Iodine-129	1.00E+01[a]	1.00E+01[a]	**1.00E+01**[b]	**1.00E+01**[b]	**1.00E+01**[b]	**1.00E+01**[b]	**1.00E+01**[b]
Caesium-137	1.00E+01[a]	1.00E+01[a]	7.73E-01	4.00E-02	1.56E-01	1.43E-01	**1.00E+01**[b]
Radium-226	1.00E+01[a]	1.00E+01[a]	1.00E-01	1.10E-01	2.20E-01	1.93E-01	**1.00E+01**[b]
Uranium-238	1.00E+01[a]	1.00E+01[a]	**1.00E+01**[b]	1.40E-01	**1.00E+01**[b]	7.90E-01	**1.00E+01**[b]
Plutonium-239	1.00E+01[a]	1.00E+01[a]	6.60E-01	3.70E-01	**1.00E+01**[b]	4.70E-02	**1.00E+01**[b]

Radionuclide/ organism	fungus	caterpillar	ant	bee	wood louse	earthworm
Tritium (not OBT)	1.61E+02	1.52E+02	1.61E+02	1.52E+02	1.43E+02	1.54E+02
Carbon-14	3.75E+01	4.22E+02	2.81E+02	4.22E+02	5.63E+02	3.50E+02
Sulphur-35	5.00E+01	5.00E+01	5.00E+01	5.00E+01	5.00E+01	5.00E+01
Strontium-90	4.76E-03	**1.00E-01**[b]	**1.00E-01**[b]	**1.00E-01**[b]	**1.00E-01**[b]	**1.00E-01**[b]
Iodine-129	**1.00E+01**[b]	**1.00E-01**[b]	**1.00E-01**[b]	**1.00E-01**[b]	**1.00E-01**[b]	**1.00E-01**[b]
Caesium-137	1.13E+00	**1.00E-01**[b]	1.37E-02	1.60E-03	3.60E-02	1.30E-02
Radium-226	**1.00E+01**[b]	**1.00E-01**[b]	**1.00E-01**[b]	**1.00E-01**[b]	**1.00E-01**[b]	**1.00E-01**[b]
Uranium-238	**1.00E+01**[b]	**1.00E-01**[b]	**1.00E-01**[b]	**1.00E-01**[b]	**1.00E-01**[b]	**1.00E-01**[b]
Plutonium-239	**1.00E+01**[b]	**1.00E-01**[b]	1.37E-02	1.90E-03	4.50E-02	2.60E-02

Radionuclide/ organism	herbivorous mammal	carnivorous mammal	rodent	bird	bird egg	reptile
Tritium (not OBT)	1.34E+02	1.38E+02	1.38E+02	1.34E+02	1.52E+02	1.34E+02
Carbon-14	7.50E+02	6.90E+02	6.90E+02	7.03E+02	2.81E+02	7.03E+02
Sulphur-35	5.00E+01	5.00E+01	5.00E+01	5.00E+01	5.00E+01	5.00E+01
Strontium-90	**1.00E+01**[b]	**1.00E+01**[b]	5.00E+00	**1.00E+01**[b]	**1.00E+01**[b]	**1.00E+01**[b]
Iodine-129	**1.00E+01**[b]	**1.00E+01**[b]	**1.00E+01**[b]	**1.00E+01**[b]	**1.00E+01**[b]	**1.00E+01**[b]
Caesium-137	2.16E+00	9.03E+00	1.30E-02	1.60E+00	**1.00E+01**[b]	**1.00E+01**[b]
Radium-226	1.06E+00	**1.00E+01**[b]	2.32E-02	6.00E-02	**1.00E+01**[b]	**1.00E+01**[b]
Uranium-238	4.00E-03	**1.00E+01**[b]	2.00E-03	**1.00E+01**[b]	**1.00E+01**[b]	**1.00E+01**[b]
Plutonium-239	1.00E-04	**1.00E+01**[b]	5.00E-04	**1.00E+01**[b]	**1.00E+01**[b]	**1.00E+01**[b]

[a] Data infilled from Table 6.8 Environment Agency R&D Publication 128 [Ref 2].
[b] In the absence of data, these concentration factors were cautiously estimated by taking the highest known concentration factor for a given radionuclide and similar group of organisms and by rounding this up to the nearest order of magnitude. The estimated concentration factors are shown in bold type.
[c] Other concentration factor data used were the default values from Environment Agency R&D Publication 128 spreadsheets [Ref 2].

Table A4 Weighted absorbed dose rate per unit air activity concentration (µGy/h per Bq/m³) [a]

Radionuclide/ organism	bacteria	lichen	tree	shrub	herb	seed
Tritium (not OBT)	5.30E-04	1.60E-03	1.10E-03	1.50E-03	1.20E-03	8.80E-05
Carbon-14	5.30E-02	1.40E-03	3.60E-02	1.30E-02	1.70E-02	1.30E-01
Sulphur-35	1.40E-03	4.20E-03	4.20E-03	4.10E-03	4.10E-03	1.40E-03

Radionuclide/ organism	fungus	caterpillar	ant	bee	wood louse	earthworm
Tritium (not OBT)	1.60E-03	1.50E-03	1.60E-03	1.50E-03	1.40E-03	1.50E-03
Carbon-14	2.80E-03	1.20E-02	8.20E-03	1.20E-02	1.60E-02	1.10E-02
Sulphur-35	1.40E-03	1.40E-03	1.40E-03	1.40E-03	1.40E-03	1.40E-03

Radionuclide/ organism	herbivorous mammal	carnivorous mammal	rodent	bird	bird egg	reptile
Tritium (not OBT)	1.30E-03	1.40E-03	1.40E-03	1.30E-03	1.50E-03	1.30E-03
Carbon-14	2.20E-02	2.00E-02	2.00E-02	2.00E-02	8.00E-03	2.00E-02
Sulphur-35	1.40E-03	1.40E-03	1.40E-03	1.40E-03	1.40E-03	1.40E-03

[a] Calculated output from Environment Agency Publication 128 terrestrial model [Ref 2].

Table A5 Weighted absorbed dose rate per unit release rate (µGy/h per Bq/y) [a]

Radionuclide/ organism	bacteria	lichen	tree	shrub	herb	seed
Tritium (not OBT)	1.48E-15	4.46E-15	3.07E-15	4.18E-15	3.35E-15	2.45E-16
Carbon-14	1.48E-13	3.90E-15	1.00E-13	3.63E-14	4.74E-14	3.63E-13
Sulphur-35	3.90E-15	1.17E-14	1.17E-14	1.14E-14	1.14E-14	3.90E-15

Radionuclide/ organism	fungus	caterpillar	ant	bee	wood louse	earthworm
Tritium (not OBT)	4.46E-15	4.18E-15	4.46E-15	4.18E-15	3.90E-15	4.18E-15
Carbon-14	7.81E-15	3.35E-14	2.29E-14	3.35E-14	4.46E-14	3.07E-14
Sulphur-35	3.90E-15	3.90E-15	3.90E-15	3.90E-15	3.90E-15	3.90E-15

Radionuclide/ organism	herbivorous mammal	carnivorous mammal	rodent	bird	bird egg	reptile
Tritium (not OBT)	3.63E-15	3.90E-15	3.90E-15	3.63E-15	4.18E-15	3.63E-15
Carbon-14	6.13E-14	5.58E-14	5.58E-14	5.58E-14	2.23E-14	5.58E-14
Sulphur-35	3.90E-15	3.90E-15	3.90E-15	3.90E-15	3.90E-15	3.90E-15

[a] Calculated using data in Tables A2 and A4.

Table A6 Calculation of 50th year soil activity concentration for a unit release rate (Bq/kg per Bq/y)

Radionuclide/ organism	Deposition rate per unit release rate at 100 m from 1m high release point ($Bq m^{-2} s^{-1}$ per Bq/s) [a]	50th year soil activity concentration per unit deposition rate (Bq/kg per $Bq m^{-2} y^{-1}$)	50th year soil activity concentration for unit release rate (Bq/kg per Bq/y) [c]
Strontium-90	9.00E-08	1.50E-02	1.35E-09
Iodine-129	8.10E-07	3.30E-01	2.67E-07
Caesium-137	9.00E-08	3.00E-01	2.70E-08
Radium-226	9.00E-08	3.30E-01 [b]	2.97E-08
Uranium-238	9.00E-08	3.30E-01 [b]	2.97E-08
Plutonium-239	9.00E-08	3.30E-01	2.97E-08

[a] Data from Table A2.
[b] In the absence of data 50th year soil activity concentration per unit deposition rate (Bq/kg per ($Bq\ m^{-2} y^{-1}$) for uranium-238 and radium-226 has cautiously been assumed to be the same as for plutonium-239 which is the most restrictive nuclide which data is available [Ref 3].
[c] Calculated using data in previous columns.

Table A7 Weighted absorbed dose rate per unit soil activity concentration (µGy/h per Bq/kg) [a]

Radionuclide/ organism	bacteria	lichen	tree	shrub	herb	seed
Strontium-90	6.50E-03	5.00E-03	2.70E-03	4.50E-03	6.50E-03	6.50E-03
Iodine-129	6.00E-04	5.30E-04	6.00E-04	6.00E-04	6.00E-04	6.00E-04
Caesium-137	4.70E-03	1.80E-03	3.40E-03	3.70E-03	3.70E-03	4.70E-03
Radium-226	3.40E+00	4.30E-02	5.50E-02	9.50E-02	8.50E-02	3.40E+00
Uranium-238	1.00E+00	1.00E+00	1.60E-02	1.00E+00	8.50E-02	1.00E+00
Plutonium-239	5.90E-01	3.90E-02	2.20E-02	5.90E-01	2.80E-03	5.90E-01

Radionuclide/ organism	fungus	caterpillar	ant	bee	wood louse	earthworm
Strontium-90	2.70E-03	2.40E-04	1.70E-03	6.80E-04	8.60E-04	3.20E-03
Iodine-129	5.20E-04	2.10E-05	9.60E-05	2.80E-05	7.00E-05	1.50E-04
Caesium-137	2.10E-03	4.30E-04	2.30E-03	5.90E-04	1.70E-03	3.50E-03
Radium-226	3.40E+00	3.60E-02	4.60E-02	3.70E-02	4.20E-02	5.20E-02
Uranium-238	1.00E+00	1.10E-02	1.20E-02	1.10E-02	1.10E-02	1.30E-02
Plutonium-239	5.90E-01	5.90E-03	8.10E-04	1.10E-04	2.70E-03	1.50E-03

Radionuclide/ organism	herbivorous mammal	carnivorous mammal	rodent	bird	bird egg	reptile
Strontium-90	5.90E-03	6.50E-03	3.30E-03	5.80E-03	6.40E-03	6.30E-03
Iodine-129	5.70E-04	5.70E-04	5.80E-04	5.20E-04	5.60E-04	5.70E-04
Caesium-137	2.80E-03	3.70E-03	2.10E-03	1.20E-03	3.30E-03	3.80E-03
Radium-226	3.70E-01	3.40E+00	1.90E-02	2.50E-02	3.40E+00	3.40E+00
Uranium-238	1.90E-03	1.00E+00	4.00E-04	1.00E+00	1.00E+00	1.00E+00
Plutonium-239	8.40E-06	5.90E-01	3.20E-05	5.90E-01	5.90E-01	5.90E-01

[a] Calculated output from Environment Agency Publication 128 terrestrial model [Ref 2].

Table A8 Weighted absorbed dose rates per unit release rate (µGy/h per Bq/y) [a]

Radionuclide/ organism	bacteria	lichen	tree	shrub	herb	seed
Strontium-90	8.78E-12	6.75E-12	3.65E-12	6.08E-12	8.78E-12	8.78E-12
Iodine-129	1.60E-10	1.42E-10	1.60E-10	1.60E-10	1.60E-10	1.60E-10
Caesium-137	1.27E-10	4.86E-11	9.18E-11	9.99E-11	9.99E-11	1.27E-10
Radium-226	1.01E-07	1.28E-09	1.63E-09	2.82E-09	2.52E-09	1.01E-07
Uranium-238	2.97E-08	2.97E-08	4.75E-10	2.97E-08	2.52E-09	2.97E-08
Plutonium-239	1.75E-08	1.16E-09	6.53E-10	1.75E-08	8.32E-11	1.75E-08

Radionuclide/ organism	fungus	caterpillar	ant	bee	wood louse	earthworm
Strontium-90	3.65E-12	3.24E-13	2.30E-12	9.18E-13	1.16E-12	4.32E-12
Iodine-129	1.39E-10	5.61E-12	2.57E-11	7.48E-12	1.87E-11	4.01E-11
Caesium-137	5.67E-11	1.16E-11	6.21E-11	1.59E-11	4.59E-11	9.45E-11
Radium-226	1.01E-07	1.07E-09	1.37E-09	1.10E-09	1.25E-09	1.54E-09
Uranium-238	2.97E-08	3.27E-10	3.56E-10	3.27E-10	3.27E-10	3.86E-10
Plutonium-239	1.75E-08	1.75E-10	2.41E-11	3.27E-12	8.02E-11	4.46E-11

Radionuclide/ organism	herbivorous mammal	carnivorous mammal	rodent	bird	bird egg	reptile
Strontium-90	7.97E-12	8.78E-12	4.46E-12	7.83E-12	8.64E-12	8.51E-12
Iodine-129	1.52E-10	1.52E-10	1.55E-10	1.39E-10	1.50E-10	1.52E-10
Caesium-137	7.56E-11	9.99E-11	5.67E-11	3.24E-11	8.91E-11	1.03E-10
Radium-226	1.10E-08	1.01E-07	5.64E-10	7.43E-10	1.01E-07	1.01E-07
Uranium-238	5.64E-11	2.97E-08	1.19E-11	2.97E-08	2.97E-08	2.97E-08
Plutonium-239	2.49E-13	1.75E-08	9.50E-13	1.75E-08	1.75E-08	1.75E-08

[a] Calculated using data in Tables A6 and A7.

APPENDIX B MARINE ASSESSMENT METHODOLOGY AND RESULTS

B.1 The screening discharge levels for particular types of coastal organisms are shown in Table B1 and these have been calculated as detailed below. The dose rate thresholds which were used in the calculations are shown in Table 1.

B.2 The marine dispersion model, 'DORIS' (Dispersion of Radionuclides Released into the Sea) in the code PC Cream [Ref 4] was used to calculate the filtered seawater activity concentration which would result from 50 years' continuous discharges into the sea for a release rate of 1 TBq/y (Bq/l per TBq/y).

B.3 A representative range of discharge scenarios was chosen to ensure that the marine biota screening levels were based on the most restrictive case. For each discharge scenario, the volume of seawater into which the discharges were made was defined as a 'local compartment' and was characterised by some default DORIS input parameters, and by some user-defined parameters. In the DORIS model, the water in each local compartment is considered to exchange over time with seawater in an adjacent, larger 'regional compartment' which is characterised by DORIS default parameters. DORIS was used to calculate the filtered sea water activity concentrations in the following local compartments: Inner Thames Estuary; Ribble Estuary; Plymouth Sound; Sellafield. The local compartmental data used for the different discharge scenarios is shown in Table B2. Regional compartmental data was the regional data provided in DORIS [Ref 4].

B.4 The 'local compartmental model' approach has been used to calculate filtered seawater activity concentrations. This takes account of the effect of different tides and currents averaged over the local compartment. It is appropriate to use filtered seawater activity concentrations averaged over the local compartment, as this will be a better indicator of the activity levels to which organisms may be chronically exposed, when compared with filtered seawater activity concentrations which could be present at the end of a discharge pipeline. The dose rate levels in Table 1 are for chronic exposures. The assessment of a likely significant effect is concerned with the protection of populations of organisms, rather than the protection of individual organisms. It is unlikely that entire populations of protected organisms would inhabit an area close to the end of a discharge pipeline. Therefore it is considered that use of filtered sea water activity concentration values at the end of a discharge pipeline would not be appropriate.

B.5 The filtered seawater activity concentrations (Bq/l per TBq/y) for the local compartments were calculated using DORIS and the results are shown in Table B3. There are two sets of seawater activity concentration data for the Sellafield local compartment. One set is based on site specific sediment partition coefficient data used in the Sellafield Radiological Assessment [Ref 5], and the other set uses equivalent default DORIS data [Ref 4].

B.6 Calculated filtered seawater activity concentrations after 50 years' continuous discharges into the local compartments at a discharge rate of 1 TBq/y for all radionuclides and marine local compartments, varied between 0.00003 to 0.256 Bq/l.

Polonium-210 was the radionuclide which gave the lowest activity concentrations per unit discharge in each compartment, with plutonium-239 giving the next lowest values.

B.7 For the compartments representing the more restricted marine environments (Inner Thames and Ribble Estuary), tritium, technetium-99 and iodine-129 gave relatively high activity concentrations per unit discharge, with carbon-14, strontium-90, caesium-137 and uranium-238 giving intermediate values. For the compartments representing the less restricted marine environments (Devonport, Sellafield), activity concentrations for the following radionuclides gave similar, intermediate values: tritium, carbon-14, strontium-90, technetium-99, iodine-129, caesium-137 and uranium-238. There were no differences in the activity concentrations calculated for the Sellafield local compartment where site specific data were used instead of generic data for all radionuclides except for plutonium-239. For this radionuclide a higher activity concentration (by a factor of 2) was calculated using the site specific data when compared with that calculated using the generic data.

B.8 The Ribble Estuary local compartment is the most restrictive in terms of filtered seawater activity concentration, for all radionuclides except polonium-210 and plutonium-239, when compared with the other compartments. Consequently it was considered to be cautious to determine the screening values based on the filtered seawater activity concentrations in the Ribble Estuary for the following radionuclides: tritium; carbon-14; strontium-90; technetium-99; iodine-129; caesium-137; uranium-238. The Ribble Estuary is the most restrictive local marine compartment because its lower volume and turnover, when compared with the other local marine compartments. It has a similar volume to the Inner Thames Estuary, but its annual volumetric exchange of seawater with the regional compartment is a factor of 3 lower.

B.9 For the radionuclides polonium-210 and plutonium-239 the Inner Thames local compartment gave the highest filtered seawater activity concentrations which were 0.00014 and 0.024 Bq/l respectively, a factor of 5 and 2 higher than those calculated for the Ribble Estuary. Consequently it was considered to be cautious to determine the discharge screening levels for these radionuclides based on the filtered seawater activity concentrations in the Inner Thames local compartment. Polonium-210 and plutonium-239 have high sediment partition coefficients. This means that these radionuclides will adsorb strongly onto sediment in the water column or onto sea-bed sediment. The Ribble Estuary local compartment has a high suspended sediment load in seawater relative to the other local compartments. The adsorption of polonium-210 and plutonium-239 onto this suspended sediment, and the subsequent deposition of the sediment onto the sea-bed acted as a more effective removal mechanism for these radionuclides in the Ribble Estuary than in the other local compartments such as Inner Thames.

B.10 The model developed in Agency R&D Publication 128 [Ref 2] was used to calculate the environmental dose rates to marine biota per unit activity concentration in filtered seawater (μGy/h per Bq/m^3). The concentration factor data used in the Publication 128 model are shown in Table B4, and where these have been estimated, this is indicated. The results are shown in Table B5. Where these have been estimated, this is indicated. The data in Tables B3 and B5 were used to calculate environmental dose rate values per unit release (μGy/h per Bq/y), which are shown in Table B6-B10 for the different local marine compartments which were considered. Screening discharge levels for the selected range of biota for radionuclides discharged to the coastal marine environment were calculated by dividing the guideline dose rates in Table 1 by the highest dose rate per unit release values for each nuclide in any local compartment.

Table B1 Marine Discharge Screening Levels (TBq/y) [a]

Radionuclide/ organism	bacteria	phytoplankton	zooplankton	macrophyte	fish egg	benthic mollusc	small benthic crustacean
Tritium	2.E+08	2.E+08	2.E+08	2.E+08	2.E+08	2.E+08	2.E+08
Carbon-14	1.E+05	1.E+06	4.E+03	8.E+03	8.E+02	4.E+03	4.E+03
Strontium-90	7.E+03	3.E+06	1.E+06	1.E+04	1.E+02	4.E+04	2.E+04
Technetium-99	7.E+05	3.E+07	3.E+05	2.E+02	3.E+02	3.E+04	1.E+05
Iodine-129	3.E+06	3.E+05	1.E+04	3.E+04	3.E+02	1.E+07	3.E+06
Caesium-137	5.E+03	5.E+06	1.E+06	6.E+03	3.E+02	1.E+04	1.E+04
Polonium-210	6.E+02	2.E+03	2.E+03	5.E+04	5.E+02	5.E+03	9.E+02
Uranium-238	5.E+01	9.E+02	4.E+03	2.E+02	2.E-01	6.E+02	2.E+03
Plutonium-239	7.E+00	2.E+00	4.E+02	1.E+02	3.E+00	1.E+02	9.E+02

Radionuclide/ organism	large benthic crustacean	pelagic fish	benthic fish	seabird	seal	whale
Tritium	2.E+08	2.E+08	2.E+08	2.E+07	2.E+07	2.E+07
Carbon-14	4.E+03	4.E+03	4.E+03	8.E+01	8.E+01	8.E+01
Strontium-90	6.E+04	1.E+06	3.E+05	3.E+00	3.E+00	3.E+00
Technetium-99	3.E+03	1.E+06	1.E+06	3.E+01	3.E+01	3.E+01
Iodine-129	3.E+06	3.E+06	3.E+06	3.E+01	3.E+01	3.E+01
Caesium-137	1.E+04	8.E+04	2.E+04	1.E+01	1.E+03	4.E+03
Polonium-210	9.E+02	2.E+04	2.E+04	5.E+01	5.E+01	5.E+01
Uranium-238	2.E+03	2.E+04	2.E+04	2.E-02	2.E-02	2.E-02
Plutonium-239	1.E+03	7.E+03	7.E+03	3.E-01	3.E-01	3.E-01

[a] Calculated using data in Tables 1, B6, B7, B8, B9, B10.

Table B2 Local marine compartmental data

Compartmental parameter	Inner Thames ('Tidal Thames') Estuary Local Marine Compartment	Springfields Local Marine Compartment	Sellafield Local Marine Compartment	Plymouth Sound Local Marine Compartment
Description of compartment	Canalised tidal Thames between Teddington Lock and Shoeburyness [a]	as described in RP72 [c]	as described in RP72 [c]	as defined in NCAS Technical Report NCAS/TR/2000/022
Volume (m^3)	1.40E+08 [a]	2.00E+08 [c]	2.00E+09 [c]	2.90E+08 [g]
Depth (m)	7.50E+00 [a]	1.00E+01 [c]	2.00E+01 [e]	1.32E+01 [h]
Actual Coastline length (m)	1.92E+05 [a]	1.00E+04 [d]	2.00E+04 [d]	1.10E+05 [i]
Coastline length entered into DORIS (m)	1.00E+05 [b]	1.00E+04 [d]	2.00E+04 [d]	1.00E+05 [b]
Volumetric exchange ($m^3\ y^{-1}$)	1.20E+10 [a]	4.00E+09 [c]	8.00E+10 [c]	7.19E+10 [h]
Suspended sediment load ($t\ m^{-3}$)	2.50E-05 [a]	2.00E-04 [c]	5.00E-06 [c]	1.00E-05 [b]
Sedimentation rate ($t\ m^{-2}\ y^{-1}$)	1.00E-04 [a]	5.00E-03 [c]	1.00E-02 [e]	1.00E-04 [c]
Dry sediment density ($t\ m^{-3}$)	2.60E+00 [c]	2.60E+00 [c]	2.60E+00 [c]	2.60E+00 [c]
Bioturbation rate (lakes and coastal waters) ($m^2\ y^{-1}$)	3.60E-05 [c]	3.60E-05 [c]	3.60E-05 [c]	3.60E-05 [c]
Diffusion rate (sediment diffusion coefficient) ($m^2\ y^{-1}$)	3.15E-02 [c]	3.15E-02 [c]	3.15E-02 [c]	3.15E-02 [c]
Regional Compartment Used	North Sea South West Regional Marine Compartment [c]	Liverpool and Morecambe Bays Regional Marine Compartment [c]	Cumbrian Waters Regional Marine Compartment [c]	English Channel Waters Regional Marine Compartment [c]

[a] EA R&D report P288 [Ref 6].
[b] Maximum default value allowed for entry into DORIS (PCCREAM98 marine dispersion model) [Ref 7].
[c] Data from RP72 [Ref 4].
[d] Default data from DORIS (PCCREAM98 marine dispersion model) [Ref 7].
[e] Derived from data in Table 4.5 RP72, page 222 (sedimentation rate (5.0E-04 $tm^{-3}y^{-1}$) x depth (20 m)) [Ref 4].
[f] NCAS Technical Report NCAS/TR/2000/022 [Ref 8].
[g] Calculated by multiplying depth supplied by Plymouth Marine Lab (PML) by area of local compartment estimated by NCAS from map to be 2.2E7 m^2.
[h] Data estimated or calculated by PML.
[i] Measured from Ordnance Survey map.

Table B3 Filtered sea water activity concentration after 50 years continuous unit discharge (Bq/l per TBq/y) [a]

Local compartment/ Radionuclide	Inner Thames Estuary	Ribble Estuary	Devonport	Sellafield [b]	Sellafield [c]	Highest filtered seawater activity concentration in any local compartment [d]
Tritium	0.084	0.256	0.014	0.016	0.016	**0.256**
Carbon-14	0.080	0.178	0.014	0.016	0.015	**0.178**
Strontium-90	0.082	0.210	0.014	0.016	0.016	**0.210**
Technetium-99	0.084	0.252	0.014	0.016	0.016	**0.252**
Iodine-129	0.084	0.256	0.014	0.016	0.016	**0.256**
Caesium-137	0.079	0.154	0.014	0.015	0.016	**0.154**
Polonium-210	0.00014	0.00003	0.00006	0.00003	0.00003	**0.00014**
Uranium-238	0.082	0.211	0.014	0.016	0.016	**0.211**
Plutonium-239	0.024	0.011	0.007	0.005	0.011	**0.024**

[a] Calculated using DORIS (PCCREAM98 marine dispersion model) [Ref 7].
[b] Concentrations based on generic data.
[c] Concentrations based on site specific data.
[d] These values were used in the derivation of the screening levels.

Table B4 Marine Environment Concentration factors used in Environment Agency Publication 128 Model (Bq/kg per Bq/m^3) [c]

Radionuclide/ organism	sediment	bacteria	phytoplankton	zooplankton	macrophyte	fish egg	benthic mollusc	small benthic crustacean
Tritium	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	**1.00E-03**[b]	1.00E-03	1.00E-03
Carbon-14	2.00E+00	2.00E+00	9.00E+00	2.00E+01	1.00E+01	**1.00E+02**[a]	2.00E+01	2.00E+01
Strontium-90	1.00E+00	1.00E+00	3.00E-03	5.00E-03	1.00E-03	**1.00E+02**[a]	1.00E-02	1.50E-03
Technetium-99	1.00E-01	1.00E-01	5.00E-03	1.00E-01	1.40E+02	**1.00E+02**[a]	8.31E-01	2.43E-01
Iodine-129	2.00E-02	2.00E-02	1.00E+00	3.00E+00	1.00E+00	**1.00E+02**[a]	1.00E-03	1.00E-02
Caesium-137	3.00E+00	3.00E+00	2.00E-01	2.20E-02	5.00E-02	**1.00E+02**[a]	2.13E-02	1.00E-01
Polonium-210	2.00E+02	2.00E+02	3.00E+01	3.00E+01	1.00E+00	**1.00E+02**[a]	1.00E+01	5.00E+01
Uranium-238	1.00E+00	1.00E+00	2.00E-02	5.00E-03	1.00E-01	**1.00E+02**[a]	3.00E-02	1.00E-02
Plutonium-239	1.00E+02	1.00E+02	1.60E+02	8.00E-01	2.52E+00	**1.00E+02**[a]	2.43E+00	3.00E-01

Radionuclide/ organism	large benthic crustacean	pelagic fish	benthic fish	seabird	seal	whale
Tritium	1.00E-03	1.00E-03	1.00E-03	**1.00E-03**[b]	**1.00E-03**[b]	**1.00E-03**[b]
Carbon-14	2.00E+01	2.00E+01	2.00E+01	**1.00E+02**[a]	**1.00E+02**[a]	**1.00E+02**[a]
Strontium-90	1.50E-03	2.00E-03	2.00E-03	**1.00E+02**[a]	**1.00E+02**[a]	**1.00E+02**[a]
Technetium-99	8.00E+00	2.72E-02	2.72E-02	**1.00E+02**[a]	**1.00E+02**[a]	**1.00E+02**[a]
Iodine-129	1.00E-02	1.00E-02	1.00E-02	**1.00E+02**[a]	**1.00E+02**[a]	**1.00E+02**[a]
Caesium-137	3.00E-02	8.98E-02	8.98E-02	**1.00E+02**[a]	4.88E-01	1.88E-01
Polonium-210	5.00E+01	2.00E+00	2.00E+00	**1.00E+02**[a]	**1.00E+02**[a]	**1.00E+02**[a]
Uranium-238	1.00E-02	1.00E-03	1.00E-03	**1.00E+02**[a]	**1.00E+02**[a]	**1.00E+02**[a]
Plutonium-239	2.25E-01	4.00E-02	4.00E-02	**1.00E+02**[a]	**1.00E+02**[a]	**1.00E+02**[a]

[a] In the absence of data, these concentration factors were cautiously assumed to have the high value of 1.00E+02 (Bq/kg per Bq/m^3). Estimated concentration factors are shown in bold type.
[b] As concentration factors for tritium were the same for all the organisms for which data was available, it was assumed that the same concentration factors would apply for other organisms. Estimated concentration factors are shown in bold type.
[c] Other concentration factor data used were the default values from Environment Agency R&D Publication 128 spreadsheets [Ref 2].

Table B5 Weighted absorbed dose rate per unit activity concentration in filtered sea water (µGy/h per Bq/m³) [a]

Radionuclide/ organism	bacteria	phytoplankton	zooplankton	macrophyte	fish egg	benthic mollusc	small benthic crustacean
Tritium	9.80E-09	9.80E-09	9.80E-09	9.80E-09	9.80E-09	9.80E-09	9.80E-09
Carbon-14	2.30E-05	1.80E-06	5.50E-04	2.80E-04	2.70E-03	5.70E-04	5.50E-04
Strontium-90	2.60E-04	6.50E-07	1.50E-06	1.80E-04	1.70E-02	4.50E-05	8.70E-05
Technetium-99	2.40E-06	5.90E-08	5.30E-06	7.30E-03	5.20E-03	4.80E-05	1.30E-05
Iodine-129	5.20E-07	4.80E-06	1.40E-04	4.90E-05	4.90E-03	1.10E-07	5.50E-07
Caesium-137	5.60E-04	5.50E-07	2.50E-06	4.50E-04	8.80E-03	2.00E-04	2.30E-04
Polonium-210	4.90E+00	1.80E+00	1.80E+00	6.10E-02	6.10E+00	6.10E-01	3.10E+00
Uranium-238	4.20E-02	2.10E-03	5.20E-04	1.00E-02	1.00E+01	3.10E-03	1.10E-03
Plutonium-239	2.40E+00	9.50E+00	4.70E-02	1.50E-01	5.90E+00	1.40E-01	1.80E-02

Radionuclide/ organism	large benthic crustacean	pelagic fish	benthic fish	seabird	seal	whale
Tritium	9.80E-09	9.80E-09	9.80E-09	9.80E-09	9.80E-09	9.80E-09
Carbon-14	5.70E-04	5.70E-04	5.70E-04	2.90E-03	2.90E-03	2.90E-03
Strontium-90	3.40E-05	1.90E-06	6.60E-06	6.30E-02	6.40E-02	6.50E-02
Technetium-99	4.60E-04	1.60E-06	1.60E-06	5.80E-03	5.80E-03	5.80E-03
Iodine-129	5.60E-07	5.50E-07	5.80E-07	5.60E-03	5.40E-03	6.10E-03
Caesium-137	2.00E-04	3.40E-05	1.70E-04	1.80E-02	1.90E-04	6.10E-05
Polonium-210	3.10E+00	1.20E-01	1.20E-01	6.10E+00	6.10E+00	6.10E+00
Uranium-238	1.10E-03	1.00E-04	1.10E-04	1.00E+01	1.00E+01	1.00E+01
Plutonium-239	1.30E-02	2.40E-03	2.40E-03	5.90E+00	5.90E+00	5.90E+00

[a] Calculated output from Environment Agency Publication 128 marine model [Ref 2].

Table B6 Weighted absorbed dose rate per unit release rate for Inner Thames Local Compartment (µGy/h per Bq/y) [a]

Radionuclide/ organism	bacteria	phytoplankton	zooplankton	macrophyte	fish egg	benthic mollusc	small benthic crustacean
Tritium	8.26E-19	8.26E-19	8.26E-19	8.26E-19	8.26E-19	8.26E-19	8.26E-19
Carbon-14	1.85E-15	1.45E-16	4.42E-14	2.25E-14	2.17E-13	4.58E-14	4.42E-14
Strontium-90	2.14E-14	5.35E-17	1.23E-16	1.48E-14	1.40E-12	3.70E-15	7.16E-15
Technetium-99	2.02E-16	4.97E-18	4.46E-16	6.15E-13	4.38E-13	4.04E-15	1.09E-15
Iodine-129	4.39E-17	4.05E-16	1.18E-14	4.14E-15	4.14E-13	9.28E-18	4.64E-17
Caesium-137	4.40E-14	4.32E-17	1.96E-16	3.53E-14	6.91E-13	1.57E-14	1.81E-14
Polonium-210	6.66E-13	2.45E-13	2.45E-13	8.30E-15	8.30E-13	8.30E-14	4.22E-13
Uranium-238	3.46E-12	1.73E-13	4.28E-14	8.24E-13	8.24E-10	2.55E-13	9.06E-14
Plutonium-239	5.78E-11	2.29E-10	1.13E-12	3.62E-12	1.42E-10	3.37E-12	4.34E-13

Radionuclide/ organism	large benthic crustacean	pelagic fish	benthic fish	seabird	seal	whale
Tritium	8.26E-19	8.26E-19	8.26E-19	8.26E-19	8.26E-19	8.26E-19
Carbon-14	4.58E-14	4.58E-14	4.58E-14	2.33E-13	2.33E-13	2.33E-13
Strontium-90	2.80E-15	1.56E-16	5.43E-16	5.18E-12	5.27E-12	5.35E-12
Technetium-99	3.87E-14	1.35E-16	1.35E-16	4.88E-13	4.88E-13	4.88E-13
Iodine-129	4.73E-17	4.64E-17	4.90E-17	4.73E-13	4.56E-13	5.15E-13
Caesium-137	1.57E-14	2.67E-15	1.33E-14	1.41E-12	1.49E-14	4.79E-15
Polonium-210	4.22E-13	1.63E-14	1.63E-14	8.30E-13	8.30E-13	8.30E-13
Uranium-238	9.06E-14	8.24E-15	9.06E-15	8.24E-10	8.24E-10	8.24E-10
Plutonium-239	3.13E-13	5.78E-14	5.78E-14	1.42E-10	1.42E-10	1.42E-10

[a] Calculated using data in Tables B3 and B5.

Table B7 Weighted absorbed dose rate per unit release rate for Ribble Estuary Local Compartment (µGy/h per Bq/y) [a]

Radionuclide/ organism	bacteria	phytoplankton	zooplankton	macrophyte	fish egg	benthic mollusc	small benthic crustacean
Tritium	2.51E-18	2.51E-18	2.51E-18	2.51E-18	2.51E-18	2.51E-18	2.51E-18
Carbon-14	4.09E-15	3.20E-16	9.79E-14	4.98E-14	4.81E-13	1.01E-13	9.79E-14
Strontium-90	5.46E-14	1.37E-16	3.15E-16	3.78E-14	3.57E-12	9.45E-15	1.83E-14
Technetium-99	6.05E-16	1.49E-17	1.34E-15	1.84E-12	1.31E-12	1.21E-14	3.28E-15
Iodine-129	1.33E-16	1.23E-15	3.58E-14	1.25E-14	1.25E-12	2.82E-17	1.41E-16
Caesium-137	8.62E-14	8.47E-17	3.85E-16	6.93E-14	1.36E-12	3.08E-14	3.54E-14
Polonium-210	1.50E-13	5.51E-14	5.51E-14	1.87E-15	1.87E-13	1.87E-14	9.49E-14
Uranium-238	8.86E-12	4.43E-13	1.10E-13	2.11E-12	2.11E-09	6.54E-13	2.32E-13
Plutonium-239	2.64E-11	1.05E-10	5.17E-13	1.65E-12	6.49E-11	1.54E-12	1.98E-13

Radionuclide/ organism	large benthic crustacean	pelagic fish	benthic fish	seabird	seal	whale
Tritium	2.51E-18	2.51E-18	2.51E-18	2.51E-18	2.51E-18	2.51E-18
Carbon-14	1.01E-13	1.01E-13	1.01E-13	5.16E-13	5.16E-13	5.16E-13
Strontium-90	7.14E-15	3.99E-16	1.39E-15	1.32E-11	1.34E-11	1.37E-11
Technetium-99	1.16E-13	4.03E-16	4.03E-16	1.46E-12	1.46E-12	1.46E-12
Iodine-129	1.43E-16	1.41E-16	1.48E-16	1.43E-12	1.38E-12	1.56E-12
Caesium-137	3.08E-14	5.24E-15	2.62E-14	2.77E-12	2.93E-14	9.39E-15
Polonium-210	9.49E-14	3.67E-15	3.67E-15	1.87E-13	1.87E-13	1.87E-13
Uranium-238	2.32E-13	2.11E-14	2.32E-14	2.11E-09	2.11E-09	2.11E-09
Plutonium-239	1.43E-13	2.64E-14	2.64E-14	6.49E-11	6.49E-11	6.49E-11

[a] Calculated using data in Tables B3 and B5.

Table B8 Weighted absorbed dose rate per unit release rate for Sellafield Local Compartment (μGy/h per Bq/y) based on default data [a b]

Radionuclide/ organism	bacteria	phytoplankton	zooplankton	macrophyte	fish egg	benthic mollusc	small benthic crustacean
Tritium	1.60E-19	1.60E-19	1.60E-19	1.60E-19	1.60E-19	1.60E-19	1.60E-19
Carbon-14	3.59E-16	2.81E-17	8.58E-15	4.37E-15	4.21E-14	8.89E-15	8.58E-15
Strontium-90	4.13E-15	1.03E-17	2.39E-17	2.86E-15	2.70E-13	7.16E-16	1.38E-15
Technetium-99	3.94E-17	9.68E-19	8.69E-17	1.20E-13	8.53E-14	7.87E-16	2.13E-16
Iodine-129	8.53E-18	7.87E-17	2.30E-15	8.04E-16	8.04E-14	1.80E-18	9.02E-18
Caesium-137	8.46E-15	8.31E-18	3.78E-17	6.80E-15	1.33E-13	3.02E-15	3.47E-15
Polonium-210	1.55E-13	5.71E-14	5.71E-14	1.93E-15	1.93E-13	1.93E-14	9.83E-14
Uranium-238	6.72E-13	3.36E-14	8.32E-15	1.60E-13	1.60E-10	4.96E-14	1.76E-14
Plutonium-239	1.23E-11	4.87E-11	2.41E-13	7.70E-13	3.03E-11	7.18E-13	9.23E-14

Radionuclide/ organism	large benthic crustacean	pelagic fish	benthic fish	seabird	seal	whale
Tritium	1.60E-19	1.60E-19	1.60E-19	1.60E-19	1.60E-19	1.60E-19
Carbon-14	8.89E-15	8.89E-15	8.89E-15	4.52E-14	4.52E-14	4.52E-14
Strontium-90	5.41E-16	3.02E-17	1.05E-16	1.00E-12	1.02E-12	1.03E-12
Technetium-99	7.54E-15	2.62E-17	2.62E-17	9.51E-14	9.51E-14	9.51E-14
Iodine-129	9.18E-18	9.02E-18	9.51E-18	9.18E-14	8.86E-14	1.00E-13
Caesium-137	3.02E-15	5.13E-16	2.57E-15	2.72E-13	2.87E-15	9.21E-16
Polonium-210	9.83E-14	3.80E-15	3.80E-15	1.93E-13	1.93E-13	1.93E-13
Uranium-238	1.76E-14	1.60E-15	1.76E-15	1.60E-10	1.60E-10	1.60E-10
Plutonium-239	6.67E-14	1.23E-14	1.23E-14	3.03E-11	3.03E-11	3.03E-11

[a] Based on PCCREAM default data eg sediment partition coefficients [Ref 7].
[b] Calculated using data in Tables B3 and B5.

Table B9 Weighted absorbed dose rate per unit release rate for Sellafield Local Compartment (µGy/h per Bq/y) based on site specific data [a b]

Radionuclide/ organism	bacteria	phytoplankton	zooplankton	macrophyte	fish egg	benthic mollusc	small benthic crustacean
Tritium	1.60E-19	1.60E-19	1.60E-19	1.60E-19	1.60E-19	1.60E-19	1.60E-19
Carbon-14	3.47E-16	2.72E-17	8.31E-15	4.23E-15	4.08E-14	8.61E-15	8.31E-15
Strontium-90	4.08E-15	1.02E-17	2.36E-17	2.83E-15	2.67E-13	7.07E-16	1.37E-15
Technetium-99	3.91E-17	9.62E-19	8.64E-17	1.19E-13	8.48E-14	7.82E-16	2.12E-16
Iodine-129	8.53E-18	7.87E-17	2.30E-15	8.04E-16	8.04E-14	1.80E-18	9.02E-18
Caesium-137	9.13E-15	8.97E-18	4.08E-17	7.34E-15	1.43E-13	3.26E-15	3.75E-15
Polonium-210	1.55E-13	5.71E-14	5.71E-14	1.93E-15	1.93E-13	1.93E-14	9.83E-14
Uranium-238	6.72E-13	3.36E-14	8.32E-15	1.60E-13	1.60E-10	4.96E-14	1.76E-14
Plutonium-239	2.74E-11	1.08E-10	5.36E-13	1.71E-12	6.73E-11	1.60E-12	2.05E-13

Radionuclide/ organism	large benthic crustacean	pelagic fish	benthic fish	seabird	seal	whale
Tritium	1.60E-19	1.60E-19	1.60E-19	1.60E-19	1.60E-19	1.60E-19
Carbon-14	8.61E-15	8.61E-15	8.61E-15	4.38E-14	4.38E-14	4.38E-14
Strontium-90	5.34E-16	2.98E-17	1.04E-16	9.89E-13	1.00E-12	1.02E-12
Technetium-99	7.50E-15	2.61E-17	2.61E-17	9.45E-14	9.45E-14	9.45E-14
Iodine-129	9.18E-18	9.02E-18	9.51E-18	9.18E-14	8.86E-14	1.00E-13
Caesium-137	3.26E-15	5.54E-16	2.77E-15	2.93E-13	3.10E-15	9.94E-16
Polonium-210	9.83E-14	3.80E-15	3.80E-15	1.93E-13	1.93E-13	1.93E-13
Uranium-238	1.76E-14	1.60E-15	1.76E-15	1.60E-10	1.60E-10	1.60E-10
Plutonium-239	1.48E-13	2.74E-14	2.74E-14	6.73E-11	6.73E-11	6.73E-11

[a] Based on site specific data eg site specific sediment partition coefficients [Ref 5].
[b] Calculated using data in Tables B3 and B5.

Table B10 Weighted absorbed dose rate per unit release rate for Plymouth Sound Local Compartment (μGy/h per Bq/y) [a]

Radionuclide/ organism	bacteria	phytoplankton	zooplankton	macrophyte	fish egg	benthic mollusc	small benthic crustacean
Tritium	1.37E-19	1.37E-19	1.37E-19	1.37E-19	1.37E-19	1.37E-19	1.37E-19
Carbon-14	3.17E-16	2.48E-17	7.59E-15	3.86E-15	3.73E-14	7.87E-15	7.59E-15
Strontium-90	3.61E-15	9.04E-18	2.09E-17	2.50E-15	2.36E-13	6.26E-16	1.21E-15
Technetium-99	3.36E-17	8.26E-19	7.42E-17	1.02E-13	7.28E-14	6.72E-16	1.82E-16
Iodine-129	7.33E-18	6.77E-17	1.97E-15	6.91E-16	6.91E-14	1.55E-18	7.76E-18
Caesium-137	7.62E-15	7.48E-18	3.40E-17	6.12E-15	1.20E-13	2.72E-15	3.13E-15
Polonium-210	3.15E-13	1.16E-13	1.16E-13	3.92E-15	3.92E-13	3.92E-14	1.99E-13
Uranium-238	5.84E-13	2.92E-14	7.23E-15	1.39E-13	1.39E-10	4.31E-14	1.53E-14
Plutonium-239	1.68E-11	6.67E-11	3.30E-13	1.05E-12	4.14E-11	9.83E-13	1.26E-13

Radionuclide/ organism	large benthic crustacean	pelagic fish	benthic fish	seabird	seal	whale
Tritium	1.37E-19	1.37E-19	1.37E-19	1.37E-19	1.37E-19	1.37E-19
Carbon-14	7.87E-15	7.87E-15	7.87E-15	4.00E-14	4.00E-14	4.00E-14
Strontium-90	4.73E-16	2.64E-17	9.17E-17	8.76E-13	8.90E-13	9.04E-13
Technetium-99	6.44E-15	2.24E-17	2.24E-17	8.12E-14	8.12E-14	8.12E-14
Iodine-129	7.90E-18	7.76E-18	8.18E-18	7.90E-14	7.61E-14	8.60E-14
Caesium-137	2.72E-15	4.62E-16	2.31E-15	2.45E-13	2.58E-15	8.30E-16
Polonium-210	1.99E-13	7.72E-15	7.72E-15	3.92E-13	3.92E-13	3.92E-13
Uranium-238	1.53E-14	1.39E-15	1.53E-15	1.39E-10	1.39E-10	1.39E-10
Plutonium-239	9.13E-14	1.68E-14	1.68E-14	4.14E-11	4.14E-11	4.14E-11

[a] Calculated using data in Tables B3 and B5.

APPENDIX C FRESHWATER ASSESSMENT METHODOLOGY AND RESULTS

C.1 The guideline screening discharge levels for particular types of freshwater organisms are shown in Table C1, and these have been calculated as detailed below. The dose rate thresholds which were used in the calculations are shown in Table 1.

C.2 The 'dynamic model' of the Rivers Module of ASSESSOR in the code PC Cream [Ref 4] was used to calculate the filtered river water activity concentration per unit release rate after 50 years' continuous discharges for radionuclides for which appropriate data were available.

C.3 Generic assumptions were made about the data defining the characteristics of the river which were cautious in terms of the radiological assessment. It was assumed that the water in the river was untreated (ie no activity was removed from the river as a result of a water treatment process). The data defining the river characteristics was taken from NRPB Document Volume 11 No 2 [Ref 3], for input into ASSESSOR, and is shown in Table C2. The filtered river water activity concentrations per unit release (Bq/m^3 per Bq/y) which were calculated by ASSESSOR are shown in Table C3, and are those which would result from 50 years of continuous discharges into the river up to 500 m downstream of the discharge point, based on a mean flow rate of 1 m^3/s.

C.4 Filtered river water activity concentrations after 50 years' continuous discharges into a river at a continuous discharge rate of 1 TBq/y gave a range of activity concentrations ranging from 5.92 Bq/l for plutonium-239 to 31.7 Bq/l for tritium. In the absence of data for polonium-210, it was cautiously assumed that the filtered river water activity concentration per unit release for polonium-210 was the same as for tritium, as tritium is the most restrictive of the selected radionuclides in terms of activity concentration per unit release in filtered river water.

C.5 No model was available for the calculation of activity concentrations in filtered water arising from discharges to lakes, and this scenario has not been considered further as part of this assessment.

C.6 The model developed in Agency R&D Publication 128 [Ref 2] was used to calculate environmental dose rates to freshwater biota per unit activity concentration in filtered river water (μGy/h per Bq/m^3). The concentration factor data which were used are shown in Table C4, and where these have been estimated, this is indicated, and the results are shown in Table C5. The data in Tables C3 and C5 were used to calculate environmental dose rates per unit release (μGy/h per Bq/y), for the selected range of freshwater biota, as shown in Table C6. Screening discharge levels for discharges into the freshwater environment (rivers only, not lakes) for the selected range of biota were calculated by dividing the guideline dose rate levels in Table 1 by the dose rate per unit release values shown in Table C6.

Table C1 Freshwater Discharge Screening Levels (TBq/y) [a]

Radionuclide/ organism	bacteria	phytoplankton	zooplankton	macrophyte	benthic mollusc	small benthic crustacean
Tritium	1.E+06	1.E+06	1.E+06	1.E+06	1.E+06	1.E+06
Carbon-14	6.E+02	7.E+02	5.E+00	1.E+02	7.E+01	7.E+01
Strontium-90	5.E+01	1.E+03	6.E-01	3.E+01	9.E+01	9.E+01
Technetium-99	8.E+04	2.E+05	2.E+00	1.E+02	9.E+03	2.E+04
Iodine-129	5.E+04	3.E+01	3.E+00	7.E+02	2.E+03	2.E+03
Caesium-137	7.E+01	3.E+02	7.E+00	4.E+01	1.E+02	2.E+01
Polonium-210	2.E-01	2.E-03	2.E-03	1.E-01	2.E-03	2.E-01
Uranium-238	6.E+00	1.E-03	1.E-03	2.E-02	7.E-01	7.E-01
Plutonium-239	3.E-02	3.E-01	3.E-01	6.E-01	1.E+00	8.E+00

Radionuclide/ organism	large benthic crustacean	amphibian	pelagic fish	benthic fish	aquatic mammal	duck
Tritium	1.E+06	1.E+05	1.E+06	1.E+06	1.E+05	1.E+05
Carbon-14	7.E+01	5.E-01	1.E+02	1.E+02	5.E-01	5.E-01
Strontium-90	9.E+01	2.E-02	5.E+02	4.E+02	2.E-02	2.E-02
Technetium-99	2.E+04	2.E-01	5.E+03	5.E+03	2.E-01	2.E-01
Iodine-129	2.E+03	3.E-01	6.E+03	6.E+03	3.E-01	2.E-01
Caesium-137	9.E+01	9.E-02	7.E+00	7.E+00	9.E-02	8.E-02
Polonium-210	2.E-03	2.E-04	4.E+00	4.E+00	2.E-04	2.E-04
Uranium-238	7.E-01	1.E-04	1.E+01	1.E+01	1.E-04	1.E-04
Plutonium-239	8.E+00	1.E-03	2.E+01	2.E+01	5.E-01	6.E+01

[a] Calculated from data in Tables 1 and C6.

Table C2 River characteristics

Parameter	Parameter description/value	Units	Data input into Dynamic model	Units
Rivers module selected from ASSESSOR	PCCREAM ASSESSOR Dynamic Rivers model [Ref 7]	n/a	PCCREAM ASSESSOR Dynamic Rivers model [Ref 7]	n/a
No of river compartments	1.00E+00	n/a	1.00E+00	n/a
Velocity and sediment load				
Velocity of water	2.00E-01	m/s	6.31E+06	m/y
Velocity of bed sediment flow	3.17E-05	m/s	1.00E+03	m/y
Suspended sediment load	4.00E-02	kg/m^3	4.00E-05	t/m^3
River section dimensions				
River length	5.00E+02	m	5.00E+02	m
Width	5.00E+00	m	5.00E+00	m
Water depth	1.00E+00	m	1.00E+00	m
River bed sediments				
Bed sediment depth	3.00E-01	m	3.00E-01	m
Dry sediment density	1.50E+03	kg/m^3	1.50E+00	t/m^3
Other data				
Volumetric flow of water (m3/s)	1.00E+00	m^3/s	3.16E+07	m^3/y
Volumetric flow of bed sediment (m3/s)	4.76E-05	m^3/s	1.50E+03	m^3/y
Water volume	2.50E+03	m^3	2.50E+03	m^3

Nuclide selected in Dynamic rivers model of PCCREAM ASSESSOR [Ref 7]	Discharge rate entered in Dynamic rivers model of PCCREAM ASSESSOR [Ref 7] (Bq/y)	Default distribution coefficient Kd in Dynamic rivers model of PCCREAM ASSESSOR [Ref 7] (Bq/t)/(Bq/m3)
Tritium	1.00E+00	3.00E-02
Carbon-14	1.00E+00	2.00E+03
Technetium-99	1.00E+00	2.00E+02
Strontium-90	1.00E+00	2.00E+03
Caesium-137	1.00E+00	2.00E+03
Plutonium-239/240	1.00E+00	1.00E+05
Uranium-238	1.00E+00	5.00E+01
Iodine-129	1.00E+00	3.00E+02
Polonium-210 [a]	-	-

[a] In the absence of data for polonium-210 in ASSESSOR, it was cautiously assumed that the filtered river water activity concentration per unit release for polonium-210 was the same as for tritium, as tritium the most restrictive of the selected radionuclides in terms of activity concentration per unit release in filtered river water.

Table C3 Filtered river water activity concentrations per unit discharge after 50 years continuous discharges (Bq/m^3 per Bq/y) based on 1m^3/s flow rate [a]

Radionuclide	Filtered river water activity concentration (Bq/m^3 per Bq/y)
Tritium	3.17E-08
Carbon-14	2.93E-08
Strontium-90	2.93E-08
Technetium-99	3.14E-08
Iodine-129	3.13E-08
Caesium-137	2.93E-08
Polonium-210	3.17E-08
Uranium-238	3.16E-08
Plutonium-239	5.92E-09

[a] Output from PCCREAM98 Dynamic Rivers Model of Rivers module of ASSESSOR [Ref 7].

Table C4 Freshwater Environment Concentration factors used in Environment Agency Publication 128 Model (Bq/kg per Bq/m³) [b]

Radionuclide/ organism	sediment	bacteria	phytoplankton	zooplankton	macrophyte	benthic mollusc	small benthic crustacean
Tritium	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03
Carbon-14	2.00E+00	2.00E+00	**1.00E+02[a]**	**1.00E+02[a]**	4.55E+00	7.30E+00	7.28E+00
Strontium-90	1.00E+00	1.00E+00	**1.00E+02[a]**	**1.00E+02[a]**	1.20E+00	2.52E-01	2.67E-01
Technetium-99	5.00E-03	5.00E-03	9.00E-03	**1.00E+02[a]**	1.70E+00	2.40E-02	1.25E-02
Iodine-129	1.00E-02	1.00E-02	**1.00E+02[a]**	**1.00E+02[a]**	4.00E-01	1.70E-01	1.72E-01
Caesium-137	1.00E+00	1.00E+00	**1.00E+02[a]**	1.90E+01	2.33E+00	5.80E-01	5.23E+00
Polonium-210	2.70E+00	2.70E+00	**1.00E+02[a]**	**1.00E+02[a]**	1.40E+00	1.02E+02	1.02E+00
Uranium-238	5.00E-02	5.00E-02	**1.00E+02[a]**	**1.00E+02[a]**	6.50E+00	1.80E-01	1.80E-01
Plutonium-239	1.00E+02	1.00E+02	3.32E+00	3.32E+00	1.84E+00	8.17E-01	1.37E-01

Radionuclide/ organism	large benthic crustacean	amphibian	pelagic fish	benthic fish	aquatic mammal	duck
Tritium	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03
Carbon-14	7.28E+00	**1.00E+02[a]**	4.60E+00	4.60E+00	**1.00E+02[a]**	**1.00E+02[a]**
Strontium-90	2.67E-01	**1.00E+02[a]**	4.27E-02	4.27E-02	**1.00E+02[a]**	**1.00E+02[a]**
Technetium-99	1.25E-02	**1.00E+02[a]**	4.51E-02	4.51E-02	**1.00E+02[a]**	**1.00E+02[a]**
Iodine-129	1.72E-01	**1.00E+02[a]**	4.00E-02	4.00E-02	**1.00E+02[a]**	**1.00E+02[a]**
Caesium-137	6.33E-01	**1.00E+02[a]**	1.09E+01	1.09E+01	**1.00E+02[a]**	**1.00E+02[a]**
Polonium-210	1.02E+02	**1.00E+02[a]**	5.00E-02	5.00E-02	**1.00E+02[a]**	**1.00E+02[a]**
Uranium-238	1.80E-01	**1.00E+02[a]**	1.00E-02	1.00E-02	**1.00E+02[a]**	**1.00E+02[a]**
Plutonium-239	1.37E-01	**1.00E+02[a]**	6.93E-02	6.93E-02	2.26E-01	2.00E-03

[a] In the absence of data, these concentration factors were cautiously assumed to have the high value of 1E+02 (Bq/kg per Bq/m³). Estimated concentration factors are shown in bold type.
[b] Other concentration factor data used were the default values from Environment Agency R&D Publication 128 spreadsheets [Ref 2].

Table C5 Weighted absorbed dose rates per unit filtered river water activity concentration (µGy/h per Bq/m³) [a]

Radionuclide/ organism	bacteria	phytoplankton	zooplankton	macrophyte	benthic mollusc	small benthic crustacean
Tritium	9.80E-09	9.80E-09	9.80E-09	9.80E-09	9.80E-09	9.80E-09
Carbon-14	2.30E-05	1.90E-05	2.80E-03	1.30E-04	2.10E-04	2.00E-04
Strontium-90	2.60E-04	1.30E-05	2.20E-02	4.20E-04	1.50E-04	1.50E-04
Technetium-99	1.50E-07	5.90E-08	5.30E-03	8.90E-05	1.40E-06	6.70E-07
Iodine-129	2.80E-07	4.70E-04	4.50E-03	1.80E-05	8.00E-06	7.80E-06
Caesium-137	1.90E-04	4.30E-05	1.90E-03	3.70E-04	1.40E-04	5.90E-04
Polonium-210	6.60E-02	6.10E+00	6.10E+00	8.60E-02	6.20E+00	6.20E-02
Uranium-238	2.10E-03	1.00E+01	1.00E+01	6.70E-01	1.90E-02	1.90E-02
Plutonium-239	2.40E+00	2.00E-01	2.00E-01	1.10E-01	4.80E-02	8.10E-03

Radionuclide/ organism	large benthic crustacean	amphibian	pelagic fish	benthic fish	aquatic mammal	duck
Tritium	9.80E-09	9.80E-09	9.80E-09	9.80E-09	9.80E-09	9.80E-09
Carbon-14	2.10E-04	2.80E-03	1.30E-04	1.30E-04	2.80E-03	2.90E-03
Strontium-90	1.60E-04	6.20E-02	2.70E-05	3.20E-05	5.50E-02	6.30E-02
Technetium-99	7.20E-07	5.80E-03	2.60E-06	2.60E-06	5.80E-03	5.80E-03
Iodine-129	8.10E-06	5.00E-03	2.00E-06	2.00E-06	4.80E-03	5.20E-03
Caesium-137	1.50E-04	1.60E-02	1.90E-03	2.00E-03	1.50E-02	1.80E-02
Polonium-210	6.20E+00	6.10E+00	3.10E-03	3.10E-03	6.10E+00	6.10E+00
Uranium-238	1.90E-02	1.00E+01	1.00E-03	1.00E-03	1.00E+01	1.00E+01
Plutonium-239	8.10E-03	5.90E+00	4.10E-03	4.10E-03	1.30E-02	1.20E-04

[a] Calculated output from Environment Agency Publication 128 freshwater model [Ref 2].

Table C6 Weighted absorbed dose rates per unit release rate (μGy/h per Bq/y) based on 1m^3/s flow rate [a]

Radionuclide/ organism	bacteria	phytoplankton	zooplankton	macrophyte	benthic mollusc	small benthic crustacean
Tritium	3.11E-16	3.11E-16	3.11E-16	3.11E-16	3.11E-16	3.11E-16
Carbon-14	6.74E-13	5.57E-13	8.20E-11	3.81E-12	6.15E-12	5.86E-12
Strontium-90	7.62E-12	3.81E-13	6.45E-10	1.23E-11	4.40E-12	4.40E-12
Technetium-99	4.71E-15	1.85E-15	1.66E-10	2.79E-12	4.40E-14	2.10E-14
Iodine-129	8.76E-15	1.47E-11	1.41E-10	5.63E-13	2.50E-13	2.44E-13
Caesium-137	5.57E-12	1.26E-12	5.57E-11	1.08E-11	4.10E-12	1.73E-11
Polonium-210	2.09E-09	1.93E-07	1.93E-07	2.73E-09	1.97E-07	1.97E-09
Uranium-238	6.64E-11	3.16E-07	3.16E-07	2.12E-08	6.00E-10	6.00E-10
Plutonium-239	1.42E-08	1.18E-09	1.18E-09	6.51E-10	2.84E-10	4.80E-11

Radionuclide/ organism	large benthic crustacean	amphibian	pelagic fish	benthic fish	aquatic mammal	duck
Tritium	3.11E-16	3.11E-16	3.11E-16	3.11E-16	3.11E-16	3.11E-16
Carbon-14	6.15E-12	8.20E-11	3.81E-12	3.81E-12	8.20E-11	8.50E-11
Strontium-90	4.69E-12	1.82E-09	7.91E-13	9.38E-13	1.61E-09	1.85E-09
Technetium-99	2.26E-14	1.82E-10	8.16E-14	8.16E-14	1.82E-10	1.82E-10
Iodine-129	2.54E-13	1.57E-10	6.26E-14	6.26E-14	1.50E-10	1.63E-10
Caesium-137	4.40E-12	4.69E-10	5.57E-11	5.86E-11	4.40E-10	5.27E-10
Polonium-210	1.97E-07	1.93E-07	9.83E-11	9.83E-11	1.93E-07	1.93E-07
Uranium-238	6.00E-10	3.16E-07	3.16E-11	3.16E-11	3.16E-07	3.16E-07
Plutonium-239	4.80E-11	3.49E-08	2.43E-11	2.43E-11	7.70E-11	7.10E-13

[a] Calculated from data in Tables C3 and C5.

APPENDIX D STAGES IN THE ASSESSMENT OF LIKELY SIGNIFICANT EFFECT AND GUIDANCE ON USE OF DISCHARGE SCREENING LEVELS

The following process should be used to identify discharges requiring detailed impact assessments:

1. Identify the relevant Authorisations from the Stage 1 Assessment to be considered in the Stage 2 process.

2. Identify the RSA Authorisations (if more than one) which could impact on a European Natura 2000 site.

3. Add together the authorised discharge limits (TBq y^{-1}) from each relevant RSA93 Authorisation, for each radionuclide discharged to atmosphere, river and sea (coastal marine) and compare these with the appropriate screening level as indicated below.

4. Where data do not currently exist for radionuclides of potential interest, values based on analogues are presented in Table 3. These analogues are in all cases thought to be conservative. Alternative analogues or approaches may be used, but there must be a clear audit trail throughout the assessment.

(i) $X_{\text{freshwater organisms}}$ = **((Discharge limit** $_{\text{radionuclide1}}$**/Screening level** $_{\text{radionuclide1}}$**) + (Discharge limit**$_{\text{radionuclide 2}}$**/Screening level** $_{\text{radionuclide 2}}$**)......................+ (Discharge limit** $_{\text{radionuclide n}}$**/ Screening level** $_{\text{radionuclide n}}$**))/Minimum summer flow rate**

Note that for freshwater (river) systems, the flow rate of the water determines the extent of rapid dilution. This is site specific and must be entered by the user. As a precautionary approach the minimum summer flow rate is to be used (expressed m^3s^{-1}, subject to an upper flow rate of 100 m^3s^{-1}).

If $X_{\text{freshwater organisms}} > 0.05$ then a further detailed Stage 3 radiological assessment is indicated to determine the impact of freshwater (river) discharges on the European Natura 2000 site.

(ii) $X_{\text{marine organisms}}$ = **(Discharge limit** $_{\text{radionuclide1}}$**/Screening level** $_{\text{radionuclide1}}$**) + (Discharge limit**$_{\text{radionuclide 2}}$**/Screening level** $_{\text{radionuclide 2}}$**)......................+ (Discharge limit** $_{\text{radionuclide n}}$**/ Screening level** $_{\text{radionuclide n}}$**)**

If $X_{\text{marine organisms}} > 0.05$ then a further detailed Stage 3 radiological assessment is indicated to determine the impact of marine (coastal) discharges on the European Natura 2000 site.

(iii) $X_{\text{terrestrial organisms}}$ = **(Discharge limit** $_{\text{radionuclide1}}$**/Screening level** $_{\text{radionuclide1}}$**) + (Discharge limit**$_{\text{radionuclide 2}}$**/Screening level** $_{\text{radionuclide 2}}$**)......................+ (Discharge limit** $_{\text{radionuclide n}}$**/ Screening level** $_{\text{radionuclide n}}$**)**

If $X_{\text{terrestrial organisms}} > 0.05$ then a further detailed Stage 3 radiological assessment is indicated to determine the impact of atmospheric discharges on the European Natura 2000 site.

Appropriate screening levels (TBq per year) are shown in Table 2 and in Table 3 analogues are identified for those radionuclides for which adequate data to calculate specific discharge thresholds are unavailable.