BNFL

Discharges and Monitoring of the Environment in the UK
Annual Report 2002

monitoring our environment

SI Units

Quantity	SI unit and abbreviation
Absorbed dose	Gray (Gy)
Dose equivalent	Sievert (Sv)
Radioactivity	Becquerel (Bq)

Multiples and submultiples of SI units

Factor	Prefix and abbreviation	Factor	Prefix and abbreviation
10^{18}	exa (E)	10^{-3}	milli (m)
10^{15}	peta (P)	10^{-6}	micro (μ)
10^{12}	tera (T)	10^{-9}	nano (n)
10^{9}	giga (G)	10^{-12}	pico (p)
10^{6}	mega (M)	10^{-15}	femto (f)
10^{3}	kilo (k)	10^{-18}	atto (a)

The tonne (metric ton) has the official abbreviation 't'.
However, in this report 'te' has been used to avoid confusion with the British ton.

BNFL is mindful of the environmental impact of the production of this report and seeks to minimise the resources used wherever possible.

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Discharges and Monitoring of the Environment in the UK
Annual Report 2002

Issued by:
Director, Environment Health Safety and Quality

BNFL, Daresbury, Warrington, WA4 4GB

Foreword

This Annual Report on Discharges and Monitoring of the Environment in the United Kingdom supplements our Environment, Health and Safety Report by providing more detailed information for the UK on radioactive and non-radioactive discharges and disposals, monitoring of the environment, and critical group and collective doses.

We have published detailed Annual Reports on Radioactive Discharges and Monitoring of the Environment since 1977, and from1992 have published data on non-radioactive discharges (included in this report since 1997).

This year, for the first time, we have published a Corporate Social Responsibility Report, detailing our approach to this subject. It describes how we intend to measure our performance against the triple bottom line - environmental, economic and social - issues.

If you require additional information, please write to the Group Director, Environment Health Safety and Quality, BNFL, Daresbury, Warrington, WA4 4GB.

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Discharges and Monitoring of the Environment in the UK
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introduction

BNFL

1. BNFL is an international business with activities in 16 countries and employing around 23,000 people. In the United Kingdom, the focus of this report, it provides a range of products and services to the nuclear energy industry and other users of radioactive materials - from fuel manufacture, electricity generation, reprocessing of spent fuel through to the decommissioning and clean-up of redundant nuclear facilities and the disposal of solid low-level radioactive waste. The locations of the Company's UK sites are shown in figure 1 and their activities summarised in tables 1a and 1b.

Environmental reporting by BNFL

2 This 2002 report is BNFL's 26th consecutive annual report providing detailed information on radioactive discharges and disposals, monitoring of the environment and radiological impact. It also includes non-radioactive discharges and disposals, and is confined to operating and decommissioning sites in the UK (figure 1). With the exception of Magnox Electric, it does not include data relating to BNFL's subsidiary and associated companies but, where relevant, states where they may be obtained. It may be noted that the report provides a summary of the comprehensive data that are available for inspection by members of the public on the Public Registers maintained by the Environment Agency and Scottish Environment Protection Agency (SEPA). This report is also available on BNFL's website (www.bnfl.com).

3 Wherever practicable, this report continues to present annual discharge and disposal data over five years for all radionuclides specified in Radioactive Substances Act (RSA) authorisations (see paragraph 12); the results of

Table 1a. BNFL (including Magnox Electric) sites in the United Kingdom

Site	Principal activities	Comment	Chapter in this report
Administrative headquarters and support functions			
Daresbury	BNFL headquarters.	From 2003.	
Risley	Business Group support functions including Engineering Services and Research and Technology Group.		
Berkeley Centre	Group headquarters for Magnox generating stations. Various support functions including Central Radiochemical Laboratory (CRL).	Adjacent to Berkeley Magnox station (decommissioning). Owned by Magnox Electric. Operated by BNFL since December 2002.	Magnox
Geoffrey Schofield Laboratories	Provides analytical services to BNFL sites, particularly Sellafield and Drigg.	Situated on the Westlakes Science Park, Cumbria. Owned and operated by BNFL.	Sellafield
Littlebrook	Facility for reactor engineering and design.	Owned and operated by Magnox Electric.	Magnox
Reprocessing of spent nuclear fuel			
Sellafield	Reprocessing of spent nuclear fuel and associated waste management activities. Manufacture of mixed oxide fuel.	Owned and operated by BNFL.	Sellafield
Disposal of solid radioactive wastes			
Drigg	Disposing of low level solid radioactive waste arising in the UK from nuclear, industrial, academic and hospital sites.	Owned and operated by BNFL.	Drigg
Nuclear fuel manufacture and enrichment			
Springfields	Manufacture of nuclear fuel and intermediate fuel products.	The UK site of BNFL Westinghouse. Owned and operated by BNFL.	Springfields
Capenhurst	Decommissioning of redundant uranium enrichment plant.	Owned by BNFL. URENCO, which is part owned by BNFL, is located on the same site and operates uranium enrichment centrifuge plant.	Capenhurst

(continued in table 1b)

environmental monitoring for the report year; information on trends; and radiological impact in terms of critical group and collective doses. Any non-compliances with numerical limits are reported.

4 For non-radioactive discharges, it would be impracticable to report the discharges of all chemical species and performance against every condition in all authorisations and consents (see paragraphs 8 and 10), even more so for a five-year period. Accordingly, discharges and disposals are normally reported for just the year of the report and other quantitative conditions, such as temperature and pH, are usually only reported if non-compliant. Information relating to longer-term trends is included where it is of particular interest. Discharges are reported as annual 'loads', which are more practicable to report than effluent concentrations, the form in which limits are often defined, although any non-compliances with such limits are reported.

5 Environmental measurements required under the terms of non-radioactive consents and authorisations are reported, together with site-specific Environmental Quality Standard (EQS) information where available.

Table 1b. BNFL (including Magnox Electric) sites in the United Kingdom *(continued from table 1a)*

Site	Principal activities	Comment	Chapter in this report
Nuclear and hydroelectric power stations			
Chapelcross	Electricity generation and production of tritium.	Magnox station. Sister station to Calder Hall. Owned and operated by BNFL.	Magnox
Dungeness A	Electricity generation	Magnox station (adjacent to British Energy AGR station). Owned and operated by Magnox Electric.	Magnox
Oldbury	Electricity generation	Magnox station. Owned and operated by Magnox Electric.	Magnox
Sizewell A	Electricity generation	Magnox station (adjacent to British Energy PWR station). Owned and operated by Magnox Electric.	Magnox
Wylfa	Electricity generation	Magnox station. Owned and operated by Magnox Electric.	Magnox
Bradwell	Defuelling	Magnox station. Owned and operated by Magnox Electric.	Magnox
Calder Hall	Defuelling	Magnox station. Situated on Sellafield site. Ceased generation in March 2003. Owned and operated by BNFL.	Sellafield and Magnox
Hinkley Point A	Defuelling	Magnox station (adjacent to British Energy AGR station). Owned and operated by Magnox Electric.	Magnox
Berkeley	Decommissioning	Magnox station adjacent to Berkeley Centre. Owned by Magnox Electric. Operated by BNFL since December 2002.	Magnox
Hunterston A	Decommissioning	Magnox station (adjacent to British Energy AGR station). Owned by Magnox Electric. Operated by BNFL since August 2000.	Magnox
Trawsfynydd	Decommissioning	Magnox station. Owned by Magnox Electric. Operated by BNFL since December 2002.	Magnox
Maentwrog	Electricity generation	Hydroelectric power station. Owned and operated by Magnox Electric.	Magnox

Figure 1. BNFL (including Magnox Electric) site locations

6 All current authorisations and consents, as well as Waste Disposal and Waste Management Licences issued specifically to each site, are listed in the Annex to each site chapter and are available for inspection on the Public Registers referred to in paragraph 2. General authorisations issued under RSA 1960, which originally applied to all of the Company's licensed sites, are not included in the Annex to a particular site chapter if, for relevant discharges and disposals from that site, they have been superseded by site specific authorisations.

Regulation of non-radioactive discharges and disposals

7 The regulation of non-radioactive discharges and disposals is, with the exception of discharges regulated by consents issued by the relevant sewage undertaker (see paragraph 10), the responsibility of the Environment Agency, SEPA and local authorities who regulate discharges in accordance with the provisions of the Environmental Protection Act 1990 (EPA 1990), the Control of Pollution Act 1974, and the Water Resources Act 1991 as amended by the Environment Act 1995.

8 The control of discharges from 'Prescribed Processes' (EPA 1990) are made under Integrated Pollution Control (IPC) authorisations (issued by the Environment Agency or SEPA) or by air pollution control authorisations issued by local authorities or SEPA. These ensure compliance with quality objectives and standards by specifying discharge limits (i.e. to air and water) and other conditions. There is also a 'residual duty' in these authorisations that Best Available Techniques Not Entailing Excessive Costs (BATNEEC) will be used to prevent or minimise releases of the most polluting substances and render them harmless. Where releases of a substance may affect more than one environmental medium, the authorisation must have regard to the Best Practicable Environmental Option (BPEO).

9 Prescribed Process authorisations will be progressively replaced over the next few years by permits issued under the Pollution Prevention and Control Regulations 2000 (PPC). These regulations implement the requirements of the EC Integrated Pollution Prevention and Control Directive (IPPC). They require detailed assessments of all environmental discharges from primary and directly associated activities on industrial sites. They also regulate matters such as energy usage, noise, odour and vibrations.

10 Discharges to controlled waters of sewage or trade effluent, from processes not subject to EPA 1990 authorisation, are regulated through a system of consents under the Water Resources Act in England and Wales and the Control of Pollution Act in Scotland. Where discharges of trade effluent are made to public sewers, they must be subject to a consent issued by the relevant sewage undertaker as required by the Water Industry Act 1991 in England and Wales and the Sewerage Scotland Act 1968. In granting consents, the regulatory agencies or sewage undertakers take account of Statutory Water Quality Objectives. Consents place limits on either total quantities discharged (loads) or on instantaneous concentrations.

11 Disposals of non-radioactive wastes are regulated through EPA 1990 and the Environment Act 1995 which amended the Waste Management Licensing Regulations 1994. These in turn replaced sections of the Control of Pollution Act. Where wastes are transferred to another organisation for disposal, there is a legal Duty of Care on producers, carriers and disposers to ensure that waste is only disposed of under the terms of a licence. Where waste is transferred, it is accompanied by a transfer note and a full written description of the waste. The Special Waste Regulations 1996 (as amended) place extra controls on wastes deemed hazardous under UK and EC regulations. Landfill disposals are now subject to the Landfill Regulations which implement the requirements of the Landfill Directive and will place additional requirements on both landfill site operators and waste consignors.

Regulation of radioactive discharges and disposals

12 The control of radioactive wastes is subject to the provisions of RSA 1993. Under this Act, operators are permitted to discharge and dispose of radioactive waste only in accordance with Certificates of Authorisation issued by the Environment Agency in England and Wales, and SEPA in Scotland.

13 It is the policy of these agencies to review authorisations regularly. In establishing discharge limits for authorisations, they take into account the radiation protection principles presented in the latest relevant Government White Paper (table 2)[1]. These principles are based on Government policy and the advice of the National Radiological Protection Board (NRPB) as discussed below in the context of critical group dose limits and constraints (paragraphs 23-25) and collective doses (paragraphs 29-30). They were incorporated into UK law in the Radioactive Substances (Basic Safety Standards) Direction 2000 issued by the appropriate ministers to the Environment Agency and SEPA so as to implement those parts of the Euratom Basic Safety Standards Directive (BSS) 1996 relating to dose limits (paragraph 26). Other provisions of the BSS Directive were implemented through the Ionising Radiation Regulations 1999.

14 All discharges of radioactivity are subject to the requirement to use best practicable means (BPM) to limit the amount of radioactivity discharged. To enable the Environment Agency to monitor the application of best practicable means, Quarterly Notification Levels (QNLs) apply at some sites to discharges of certain radionuclides. Exceeding a QNL requires the operator to submit a written justification of the BPM used to limit discharges.

15 The Food Standards Agency, which reports to health ministers, was formed on 1 April 2000. Its responsibilities include food safety implications of discharges of radioactive waste, in support of which it undertakes a substantial radiological surveillance programme both for aquatic and terrestrial samples. It has taken on the role, formerly

Table 2. Summary of radiation protection principles in the Government's review of radioactive waste management policy (1995)[1]

Annual dose	Applicability	Comments
1000 μSv	Limits the overall exposure to the general public from man-made sources of radiation (excluding medical uses), including the effects of past and current discharges and summing across all relevant exposure pathways.	The previous flexibility to average exposure over more than one year is no longer considered necessary, and this limit is now a cap on annual exposure.
500 μSv	A 'site constraint' to limit the aggregate exposure from a number of sources with contiguous boundaries at a single location.	Applies irrespective of whether different sources on the site are owned or operated by the same or different organisations.
300 μSv	A 'dose constraint' used as the principal criterion in determining applications for discharge authorisations from new facilities. It applies to the sum of all relevant exposures resulting from the operation of a single new source only.	Existing facilities may seek a higher dose constraint in certain circumstances. In most cases this should not be necessary and, in any case, the dose limit and the ALARA principle continue to apply.
20 μSv	Threshold for optimisation below which the regulators will not seek further reduction in public exposures, provided they are satisfied that 'Best Practicable Means' are being applied to safeguard the public.	The introduction of this concept is consistent with the current practice of the Health and Safety Executive.

exercised by the Ministry of Agriculture Fisheries and Foods (MAFF), as statutory consultee to the Environment Agency and SEPA in matters relating to radioactive discharge authorisations. The Nuclear Installations Inspectorate (NII) has a similar role as statutory consultee because it regulates the accumulation of radioactive waste on licensed sites and the exposure of the general public to direct radiation from those sites.

16 The nuclear regulators employed by the Environment Agency and SEPA regularly pay inspection visits to nuclear sites to critically review operations against radiological protection criteria. Thus the authorisation process is one of continual review (see also paragraph 13). This process not only reviews operations, effluent control and treatment arrangements, on-site sampling and analytical methods, but also the results of environmental monitoring, habits surveys and advances in radiological methodologies, to ensure that radiological impacts are assessed with the most up-to-date information.

17 Thus the authorisation and inspection process embraces important aspects of radiation protection by:

- controlling, monitoring and recording discharges to the environment;
- monitoring of the environment to establish resultant radionuclide concentrations;
- carrying out appropriate research, investigations and assessments to determine pathways for the transport of radioactivity through the environment;
- assessing radiation doses to the public;
- predictive assessment of radiation doses to the public arising from future discharges to the environment.

18 The company is involved in all these activities with respect to discharges from its sites. Under the terms of the discharge authorisations, there is a statutory obligation to carry out defined monitoring programmes, both for discharges and for environmental radioactivity, the latter being known as Statutory Environmental Monitoring Programmes. In addition, the NII requires the assessment of doses to members of the public from direct radiation. The company also carries out monitoring additional to statutory requirements.

19 At the Ministerial meeting of the OSPAR Commission at Sintra in Portugal in July 1998 (see Glossary), the UK Government agreed to a commitment to reduce concentrations of radioactive and hazardous substances in the marine environment so that, by 2020, discharges will be reduced to levels where the resulting concentrations additional to historic levels are close to zero. Following consultation last year on a proposed national discharge policy to meet these requirements, defra (see Glossary) in July 2002 published its 'UK Strategy for Radioactive Discharges 2001-2020'. The Company is working with Government and regulators to achieve the objectives agreed at Sintra.

Critical group and collective doses

Critical group doses

20 A key concept for assessment of dose to the public is the 'critical group'. This represents those members of the public who are most exposed to radiation due to operations at a given site[2,3]. The dose to members of a critical group is assessed as the mean of the sums of their committed effective doses from intakes of radionuclides during the year and their effective doses from external irradiation (see paragraph 35). These sums are for convenience termed 'effective doses' (see Glossary). Committed effective doses

are calculated from dose per unit intake data (see Appendix) and from estimates of annual radionuclide intake by inhalation and ingestion, taking into account all relevant intake pathways, such as consumption of specific foods at high rates and inhalation doses from occupancy of certain areas[4,5]. From this, it follows that the mean dose to the critical group provides a stringent assessment of radiation dose against limits or constraints.

21 In determining the critical group appropriate to a particular site, it is recognised that the relative doses from different pathways will depend on the habits of particular groups of individuals. Such doses should be summed as required to obtain the critical group dose. Thus a high rate consumer of seafoods may receive only a minor exposure via pathways such as milk consumption or proximity to the site perimeter. For another group, consumption of locally produced meat and milk may combine to result in an elevated exposure. Accordingly, it is common practice to define exposure groups in terms of a dominant pathway or habit (e.g. seafood consumers, boat dwellers, anglers, inhalation pathways etc). For simplicity, these may at times be referred to in this report as 'critical groups', although strictly speaking the National Radiological Protection Board (NRPB)[3] defines only the most exposed group at any given time as the critical group.

22 This report focuses mainly on doses to members of critical groups; the small groups of people that are most exposed to radiation from nuclear facilities. The doses received by the rest of the population from operations at BNFL sites will be very much less than those received by critical groups.

Critical group dose limits and constraints

23 The current position on dose limits and constraints, which are applicable to controlled releases of radioactivity, is based on the '1990 Recommendations' of the International Commission on Radiological Protection (ICRP)[2] in which it reviewed the quantities used in radiological protection, the biological effects of radiation relevant to radiological protection, the conceptual framework of radiological protection and recommendations on dose limitation. Under these recommendations, the primary dose quantity was redefined as effective dose (see paragraph 20 and the Glossary), taking into account 'weighting factors' which reflect the sensitivity of different body organs to induction of cancer following exposure to radiation. For members of the public, the ICRP recommended an annual limit on effective dose of 1000 μSv.

24 The '1990 Recommendations' also placed emphasis on the optimisation of radiation protection (see paragraph 30) and on the concept of source-related restrictions on individual dose, relating to the optimisation process, termed 'dose constraints'. A dose constraint is an upper bound on the annual dose to the overall critical group, summed over all exposure pathways, from the planned operation of a controlled source[3]. Dose constraints may introduce additional restrictions within the overall dose limit.

25 In 1993, the NRPB published guidance based on ICRP's '1990 Recommendations' and recommended that for proposed new controlled sources, the maximum dose constraint should be 300 μSv per year[3]. Constraints lower than this could be set where such doses are readily achievable. Existing facilities are expected to operate within the appropriate constraints but where it is not possible to comply with the recommended dose constraint, the NRPB advise that the operating regime be reviewed with the regulatory body to ensure that doses are 'as low as reasonably achievable'. Exposures arising from past controlled releases should be included in any comparison with the 1000 μSv dose limit but not in comparison with the dose constraint of 300 μSv. NRPB's advice included the caveat that doses should in any case be below the 1000 μSv limit on annual dose.

26 The 1000 μSv dose limit was incorporated into the Euratom Basic Standards Directive 1996 and implemented in UK law through Direction 2000 (paragraph 13). Ministers have directed the Environment Agency and SEPA, when discharging their duties under RSA 1993, to ensure that the Directive limit on annual dose to the public is not exceeded, and that a maximum source constraint of 300 μSv and a site constraint of 500 μSv are applied for authorising radioactive discharges. The annual dose limit of 1000 μSv should be compared with the sum of doses from external exposure and internal exposure from intakes of radionuclides.

Collective doses

27 In addition to estimating doses to critical groups, doses to populations as a whole can be estimated[6]. This involves the concept of 'collective dose': the summation of all individual radiation doses received by a population over some defined period of time. Since radionuclides persist in the environment, subject to processes of dilution, dispersion, radioactive decay, and ingrowth of daughter products, the public will continue to receive radiation doses (generally at a decreasing rate) for some time after a discharge is made. Calculating the collective dose therefore involves predicting the behaviour of radionuclides over extended periods following the discharge.

28 In practice, collective doses are often dominated by the summation of a large number of exceedingly small doses received by individuals who are remote, in both space and time, from the point of discharge. Consequently, the calculation of collective dose relies heavily on the use of theoretical models that predict the dispersion of radionuclides over large geographical areas and long timescales. The unit for collective dose is the man sievert (man Sv) which emphasises that the value quoted is the sum of doses received by a number of individuals.

29 The time and geographical area over which a collective dose is integrated is necessarily stated with the estimated value. Current NRPB advice emphasises a 500 year integration period[7] and this is used throughout this report. Doses are generally calculated to the populations of UK, Europe (including the UK) and the world. Detailed information is given in the Appendix.

30 Collective doses play an important role in the optimisation of radiological protection using the ALARA (As Low As Reasonably Achievable) principle. This is recognised by the NRPB[3] as being a useful technique for aiding decisions between different options for radiological protection. Its advice gives monetary values for unit collective doses, which allows the cost of collective doses to be compared with the capital and operating costs of preventing those doses from arising.

Monitoring of environmental radioactivity and dose assessment

31 The structure of the Statutory Environmental Monitoring Programmes (paragraph 18) reflects the emphasis placed on assessing radiation doses to the public in the areas local to BNFL's sites. The essential considerations are to:

- take account of the most important pathways by which radiation exposure of the public may occur;
- conduct appropriate sampling and analysis to determine radionuclide concentrations or radiation levels relevant to those pathways;
- combine the monitoring results with data on foodstuff consumption and other habits, and with data on the biokinetic behaviour of radionuclides, to yield estimates of radiation dose to the public.

32 It should be noted that these dose estimates, being based on environmental concentrations, will include contributions from radionuclides discharged in earlier years. They will therefore differ from those dose estimates in technical submissions to authorisation reviews which relate to projected doses at expected future levels of discharge and at proposed discharge limits.

33 Data identifying critical groups and their habits by pathway have been provided by the Food Standards Agency, Environment Agency, SEPA and CEFAS (or their predecessors) based on published survey work[8,9]. Site-specific habits data used in dose assessments may relate to single years or to five-year averages as appropriate. Generalised food consumption rates for use in radiological dose assessments (particularly for terrestrial pathways) were reviewed by MAFF and NRPB and revised guidelines issued in 1995[10]. Where appropriate, such generalised advice may be supplemented by other NRPB advice[11], or by information from local habits surveys, such as those occasionally undertaken by BNFL.

34 In assessing doses, the company takes account of research studies carried out both nationally and internationally, and also sponsors extensive programmes of environmental research focusing specifically on the behaviour of radionuclides released from its sites. Nonetheless, throughout this report the guidance of NRPB[3] and the most recent dose coefficients in ICRP Publication 72[12] are adopted where available and appropriate. For the specific calculation of doses from argon-41 and krypton-85, where the NRPB does not provide advice, a cloud immersion dose is calculated from the recommendations of the ICRP[2,13]. In general, default values recommended by the ICRP for each radionuclide are assumed for the purpose of dose calculations unless specific studies indicate that an alternative is appropriate, as discussed in the Appendix.

35 In accordance with regulatory guidance[14], radiation dose rates in air ('air kerma') are generally measured in primary units of μGy h^{-1}, the absorbed dose rate. In order to express this as a dose rate equivalent, μSv h^{-1}, a conversion factor of 0.86 μSv per μGy is appropriate in most cases[14]. This reflects the differing energy deposition of ionising radiation in differing media: in this case air and tissue. By expressing the radiation dose rate in μSv h^{-1} and making allowance for background dose rates[8,9,15,16], a direct estimate of the dose to man can be obtained.

36 Independent environmental monitoring programmes and dose assessments in areas both local to BNFL's sites and further afield are carried out and reported by government agencies and other groups[8,9,17-20].

37 Collective doses have been calculated, using a 500 year integration period (paragraph 29), based on the most recent EU methodology[21-23]. This approach is consistent with the dosimetric basis used to calculate critical group doses, as assessed by both BNFL and independently by the Food Standards Agency[8]. A summary of collective dose per unit release factors is included in the Appendix.

Analytical measurements, limits of detection and rounding of data

38 All measurements of radioactive discharges, concentrations of radionuclides in the environment and radiation dose rates are subject, as with any other type of measurement, to uncertainties arising from the measurement process itself. These may become important when the quantities involved are very small compared with the measurement uncertainty, and the result is then quoted as a 'limit of detection' (i.e. with a '<' sign). This value is chosen to give a high degree of confidence that the actual result is less than that value.

39 For clarity of presentation (and after calculations have been completed) discharges, concentration and dose rate data are normally rounded to two significant figures, or just one where the numbers are very small.

40 Results from the Company's environmental monitoring programmes are reported here as the arithmetic means of measurements taken throughout the year. The concentrations of many radionuclides in the environment are now consistently below the level at which it is practicable to make positive determinations. They continue to be included in the monitoring and analysis programmes for reassurance that new pathways involving, for example, remobilised historical materials, have not arisen. Dose calculations either conservatively use such 'limit of detection' values, or use more realistic concentrations derived using environmental models.

Figure 2. Sources of annual average radiation dose to the UK population[15]

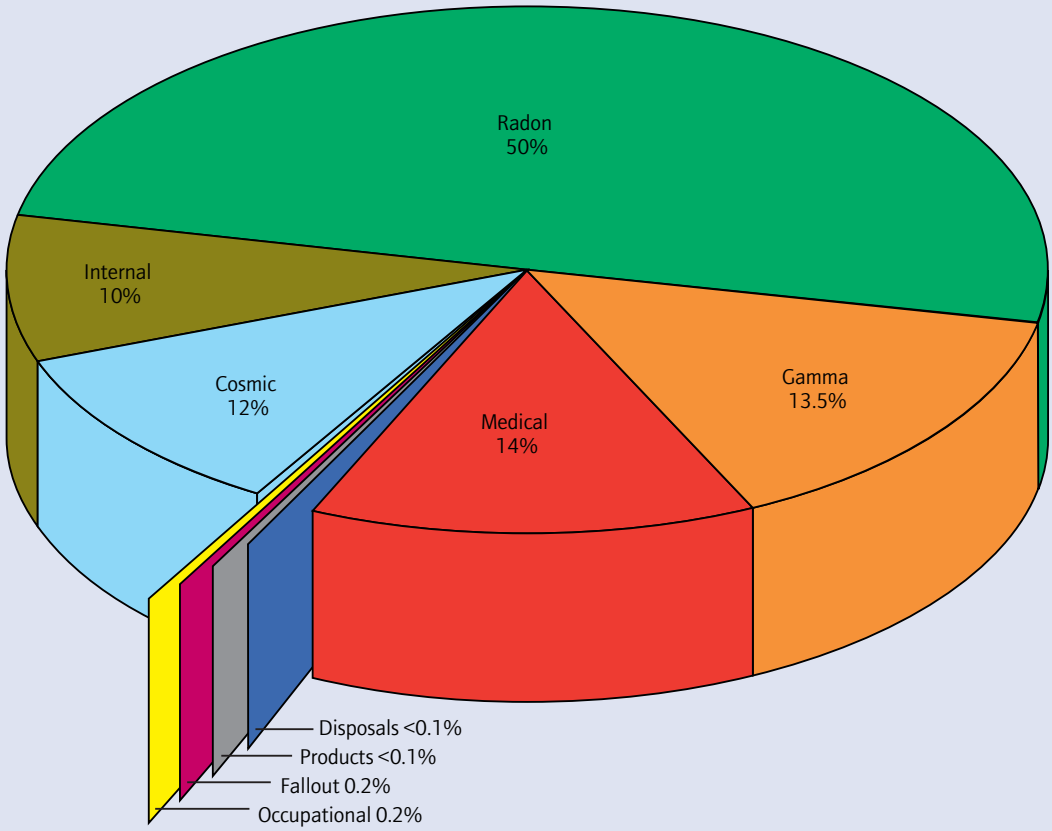

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Table 3. Summary of doses to the UK population from natural sources[15]

Source	Annual dose (μSv)	
	Average	Range
Cosmic radiation	320	200 - 400
Terrestrial gamma radiation	350	100 - 1000
Irradiation from internal radionuclides	270	100 - 1000
Exposure to radon and progeny	1200	300 - 100,000
Exposure to thoron and progeny	100	50 - 500
Total	2240	1000 - 100,000

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41 It should also be noted that measurements of 'total alpha' and 'total beta' activity do not necessarily equate to the sum of individually measured radionuclides. This is because of differing counting efficiencies and the presence of naturally occurring radioactive isotopes.

Protection of the environment

42 The ICRP[2] considered that 'the standard of environmental control needed to protect man to the degree presently thought desirable will ensure that other species are not put at risk'. This view is defensible in most situations, particularly where critical groups are exposed in the areas of highest environmental concentrations, close to the point of discharge, through a variety of pathways. However, ICRP acknowledges that the protection of the environment needs to be considered in the wider sense, and has work underway which is addressing this matter. It was recognised in the Ministerial Statement of the OSPAR Convention at Sintra (1998), that the protection of biota for the preservation of biodiversity and bioresources is necessary in its own right. BNFL is contributing to a number of initiatives intended to develop criteria for the protection of the environment. In addition, BNFL is carrying out assessments of exposure against the guidelines given in national and international publications[24,25].

Natural radioactivity

43 To put into context the data presented in this report, it is important to recognise that natural radioactivity is the dominant source of radiation exposure to the population as a whole, including individuals living close to nuclear establishments. The widespread radioactive fallout from the testing of nuclear weapons and from Chernobyl also contributes to doses. The subject has been reviewed comprehensively by the NRPB[15,16] and others[26].

44 Individual doses from natural radioactivity in the UK range broadly from 1000 μSv to 100,000 μSv per year[15]. The upper end of the range stems from homes with particularly high indoor levels of radon and its decay products. Dose limits set for the industry do not apply to natural background radiation, such as that from radon. Nevertheless, it may be noted for comparative purposes only, that these upper figures substantially exceed the dose limits to the public (and indeed the workforce) applicable to the operation of nuclear establishments (see paragraphs 13, 26, and table 2). The NRPB recommends that measures be taken to reduce radon in levels in homes if the average annual indoor activity concentrations exceed 200 Bq m^{-3} and suggests that a radon-222 concentration of 20 Bq m^{-3} corresponds to an annual dose of 1000 μSv from the solid short-lived decay products of the gas[15].

45 The measurements in this report relate to environmental radioactivity which is mainly attributable to discharges from Company sites. However, natural radioactivity makes an appreciable contribution to the reported values in some instances. Where it is practicable to do so, the appropriate correction is made and noted. Thus, gamma dose rates quoted in this report are total dose rates including natural terrestrial background and cosmic ray contributions. For dose assessment purposes, the natural contributions are deducted.

46 A comparison of annually averaged doses to individuals in the UK population from all sources of radioactivity is presented in table 3 and figure 2. Typically, natural background accounts for some 85% of the total dose and medical uses of radiation for a further 14%. On this basis, the annual average dose is around 2600 μSv; of which 2240 μSv is derived from natural sources (mainly cosmic rays, rocks and soils, radon gas and foodstuffs – see table 3), 370 μSv from medical exposures, 6 μSv from occupational exposure, 4 μSv from nuclear weapons fallout, 0.3 μSv from discharges and disposals, including those from the nuclear industry, and 0.1 μSv from consumer products[15]. In areas of higher natural background radiation (e.g. Cornwall), the average dose may exceed 7000 μSv per year[16].

Acknowledgements

This report was compiled, edited and its production organised by Ralph Atherton of Ralph Atherton Associates Ltd on contract to BNFL Group Environment Health Safety and Quality. The contributions of staff at BNFL's operating sites are acknowledged at the end of each chapter, and those of staff at Westlakes Scientific Consulting (WSC) at the end of the Appendix. Alan Kite of BNFL Group Environment Health Safety and Quality, Professor Steve Jones of WSC and staff of the the National Radiological Protection Board, the Environment Agency, the Scottish Environment Protection Agency and the Food Standards Agency are all thanked for their many constructive comments on drafts of this report.

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Discharges and Monitoring of the Environment in the UK Annual Report 2002

sellafield

Summary

1 There were no instances in 2002 of non-compliance with numerical limits in authorisations regulating discharges and disposals of radioactive wastes at Sellafield or accumulation and disposal of radioactive wastes at the Geoffrey Schofield Laboratories.

2 Some radioactive discharges were higher than in 2001 as a result of improved reprocessing throughputs and other reasons (paragraphs 18 and 19).

3 The estimated dose in 2002 from discharges to sea from Sellafield to members of the critical group who consume fish and shellfish from the local area was about 170 µSv. Taking into account doses from beach occupancy and aerial pathways, the total dose to this group was about 210 µSv. Doses from direct radiation from plant on site were estimated as being up to 19 µSv to the most exposed members of the public who live nearby. They may, in addition, have received up to 25 µSv from other pathways. These doses are summarised in table 1. Some people in Lancashire, Scotland and Wales receive doses arising from the much higher discharges of caesium-137 to the Irish Sea from Sellafield in the 1970s. These doses are discussed in the Springfields and Magnox chapters.

4 There were no instances in 2002 of non-compliance with numerical limits in IPC authorisations. On one occasion the temperature limit in the consent covering discharges from Calder Hall to the Calder Interceptor Sewer was exceeded.

Operations at Sellafield

5 BNFL's main activities at Sellafield in 2002 were the reprocessing of used nuclear fuel, waste management and decommissioning; and the operation of Calder Hall where only one of the four Magnox nuclear reactors which supply the National Grid was in operation during the year. (Discharge, environmental monitoring and dose data for the Calder Hall reactors are included in this chapter rather than in the Magnox chapter, because the data relating to them cannot be practically separated from those relating to the rest of the site.) The Windscale laboratories of the UKAEA are also situated on the site. In addition, Fellside Heat and Power Ltd, a subsidiary company of BNFL, operates a combined heat and power plant on a site adjacent to Sellafield.

6 During reprocessing operations, some effluents containing a small fraction of the radioactivity originally present in the used fuel are discharged to sea and atmosphere, or disposed of as solid wastes to Drigg. Discharges of radioactivity to sea have declined significantly since the 1970s (figure 1a) as a result of the considerable investments and improvements in effluent treatment plants which have been described in previous reports.

7 Since 1990, a number of plants that encapsulate solid intermediate-level radioactive waste in stainless steel drums have been constructed and brought on line.

8 Also in operation at Sellafield is the Waste Vitrification Plant (WVP) which converts both historic and current arisings of liquid high-level waste into a form of glass. The molten glass is allowed to solidify inside stainless steel containers, which are then placed in a specially designed, self-cooling storage facility. Originally designed with two separate vitrification lines, the WVP has been modified to incorporate a third line to increase plant throughput. This is now fully operational.

9 The Solvent Treatment Plant, which was commissioned in 2002 and is now fully operational, treats arisings of solvent as well as historic solvent wastes currently stored at Sellafield.

Table 1. Summary of critical group doses from operations at Sellafield (µSv)

Pathway	2001	2002	Position in text (paragraph no.)
Marine critical group			
seafood consumption	120	170	48
aerial pathways	10	10	48
external radiation from beach occupancy	21	28	49
Total dose to marine critical group	150	210	48,49
Terrestrial critical group			
inhalation (adults)	0.4	0.5	52
immersion (adults)	32	7	55
external radiation from beach occupancy (all ages)	2	2	54
terrestrial foodstuff consumption (infants)	24	17	51,52
(of which milk)	(12)	(14)	51
marine foodstuff consumption (adults)	3	2.5	54
All discharge pathways (adults 2001, infants 2002)	58	25	56
direct radiation	110	19	57
Total dose to terrestrial critical group (adults 2001, infants 2002)	170	44	56,57

10 The Sellafield MOX (Mixed Oxide) Fuel Plant (SMP) manufactures reactor fuel. The plant received final authorisation from the Government in 2001 for plutonium commissioning and operations have now commenced.

11 Magnox and Thorp reprocessing throughputs during 2002 were slightly higher than in 2001 and this is reflected in discharge levels. Decommissioning work on older plants continued throughout the year.

Radioactive discharges and disposals

12 Sellafield holds a number of authorisations covering discharges and disposals of radioactive wastes to sea, to atmosphere and by burial in the ground, either on-site or at the Drigg disposal site. BNFL's Geoffrey Schofield Laboratory, situated on the Westlakes Science Park on the outskirts of Whitehaven, is also authorised to handle, store and dispose of waste containing low levels of radioactivity arising from the analysis of environmental samples. In addition, a number of inter-site transfer authorisations cover the transfer of radioactive waste between Sellafield and Drigg and between the Geoffrey Schofield Laboratory and Drigg. All current authorisations are listed in the Annex to this chapter.

13 The authorisations are currently under review. Having considered the comments made to it in the public consultation in 2001, the Environment Agency has made proposals for authorised limits to the Secretary of State for the Environment whose decision is awaited.

Liquid discharges via the pipeline

14 Radioactive liquid effluents arise from fuel reprocessing and storage operations, Calder Hall, on-site decommissioning operations, and the laboratories of the UKAEA. Liquors from the reprocessing plant which contain the highest levels of activity are routed directly to storage pending incorporation into solid glass form in the Waste Vitrification Plant; they are not therefore discharged from the site.

15 Where practicable, the medium active waste streams are routed via the Medium Active Evaporator, or the Salt Evaporator, to interim decay storage pending treatment in the Enhanced Actinide Removal Plant (EARP) prior to discharge. Where this is not possible, the effluents are routed directly to EARP or other plants for treatment prior to discharge.

16 The remaining low-level liquid effluents are discharged to sea via the Sellafield pipeline. The main sources of such effluents are:

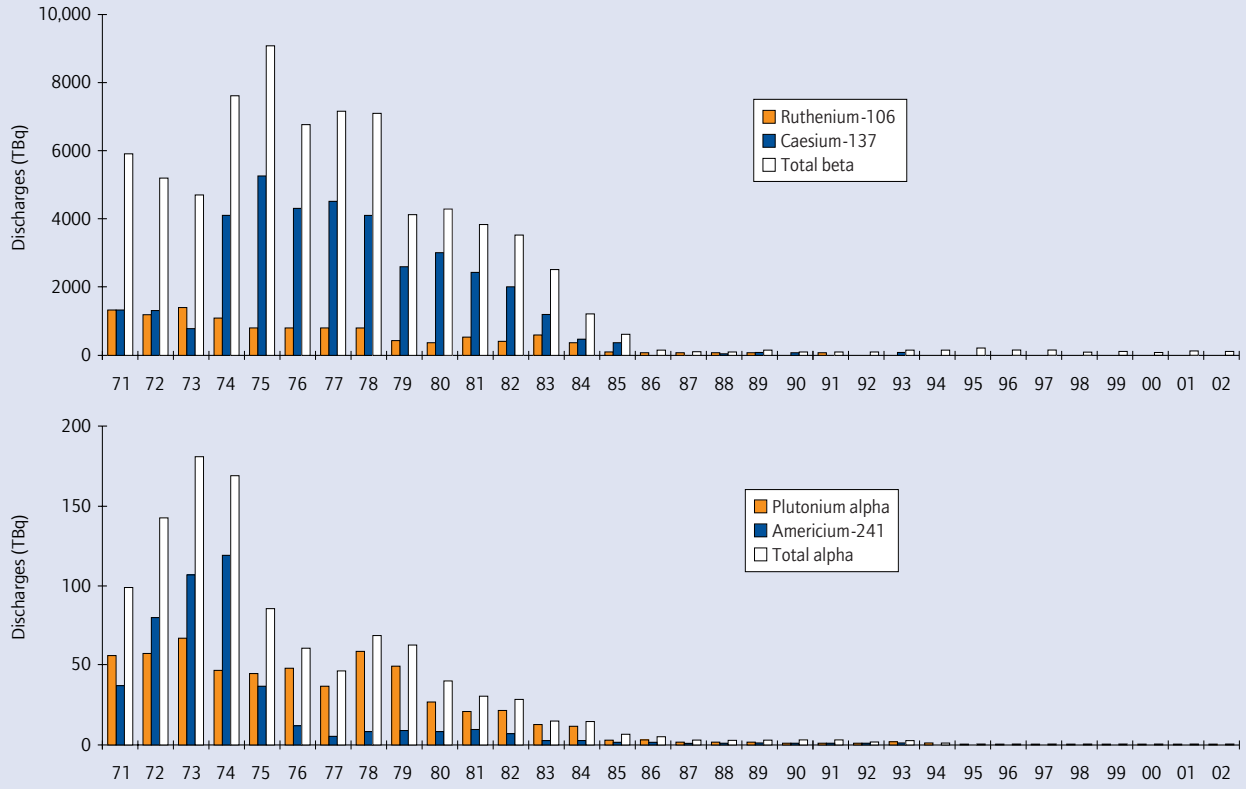
- Storage pond water from the old Magnox decanning plants and the new Fuel Handling Plant (FHP). This water is treated in the Site Ion Exchange Effluent Plant (SIXEP) to remove radioactive contaminants, principally caesium-137 and strontium-90, before being discharged to sea.
- Storage pond water from the oxide fuel reprocessing plant (Thorp). This water is monitored and discharged directly to sea.
- EARP Bulks discharges, consisting of treated Magnox effluents and some effluents from Thorp; and EARP Concentrates discharges, consisting of treated batches of effluent from interim storage and other concentrates. These effluents are monitored before being discharged directly to sea.
- Dissolver off-gas scrubber liquors from Thorp. These are treated to remove carbon-14 before being monitored and discharged directly to sea.
- Remaining process liquors are routed to the Segregated Effluent Treatment Plant (SETP) where effluent is adjusted for pH and held for confirmation of its composition prior to discharge. Three discharge tanks are in operation, permitting flexible effluent management and the extended retention of effluent if required.
- Minor waste streams, such as surface drainage water and laundry effluent, are discharged directly to sea after monitoring to determine the concentration of radioactivity.

17 The current liquid effluent authorisation includes Annual Limits and Quarterly Notification Levels for 'total alpha' and 'total beta' activity as well as for individual radionuclides. To comply with the authorisation, samples from each waste stream are analysed daily (i.e. Thorp Receipt and Storage, SIXEP, laundry, surface drainage water) or prior to discharge (i.e. SETP, EARP Bulks and Concentrates, Thorp carbon-14 removal facility) for 'total alpha', 'total beta' and tributylphosphate (SETP and EARP only). More detailed analyses for a wide range of radionuclides, including all those listed in the schedule to the authorisation, are carried out on fortnightly, monthly or quarterly bulks of daily samples.

18 Table 2 presents data on discharges over the last five years and provides a basis for comparison with current authorised limits. Trends in liquid effluent discharges via the pipeline are illustrated in figures 1a and 1b. All discharges during 2002 were within those limits. Discharges of technetium-99 increased again because of the processing of larger quantities of medium active concentrates. Discharges of carbon-14 continued their upward trend, partly due to increased reprocessing throughput and partly to diversion (by introduction of a gas scrubber) of activity previously discharged to air. This diversion was made to reduce the overall radiological impact of the site's discharges. Increased discharges of tritium also reflect the increased throughput.

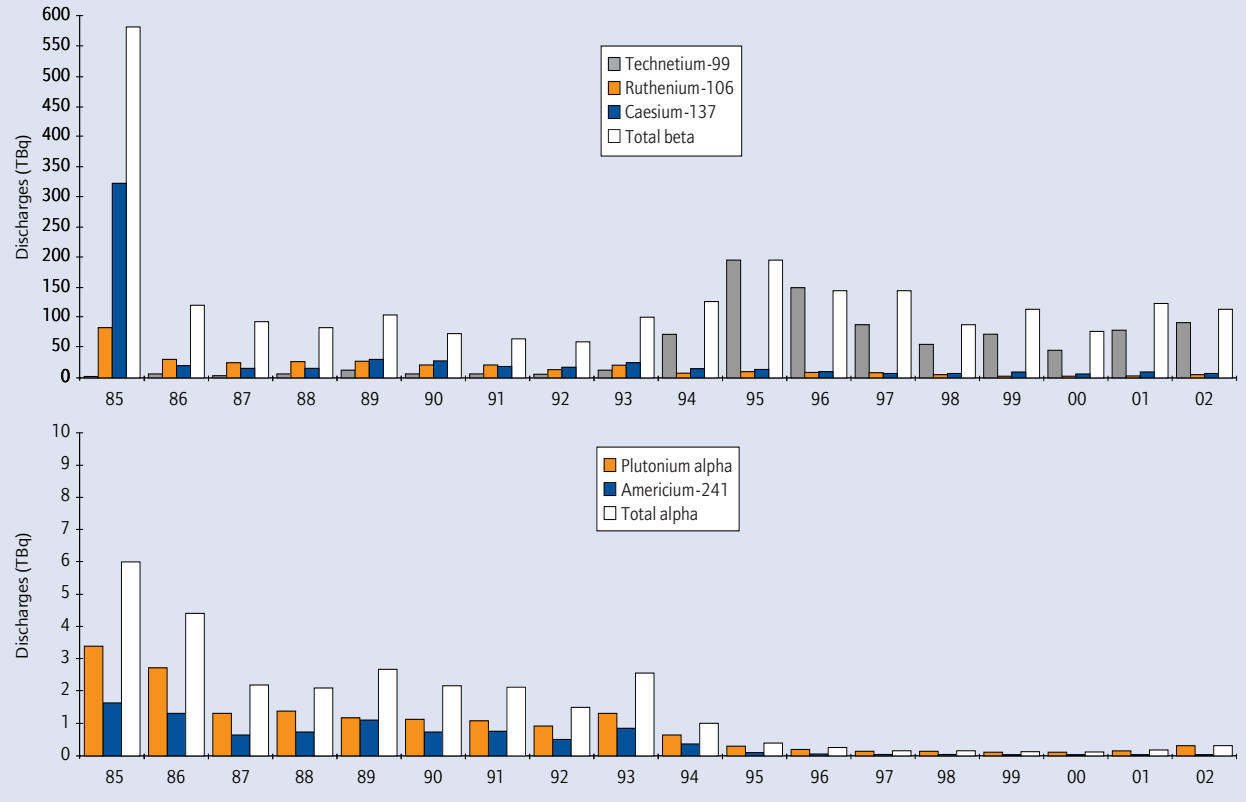
19 Increased discharges of antimony-125 and the actinides (and hence of 'total alpha') arose not only from increased reprocessing throughputs but also from increased pond water activity concentrations in the FHP. The increase in concentrations was due to a combination of increased fuel cladding problems (on receipt and during storage) and, for

Figure 1a. Marine pipeline discharges from Sellafield, 1971-2002



'Total alpha' and 'total beta' are overall control measures which do not reproduce precisely the contributions of individual radionuclides.

Figure 1b. Marine pipeline discharges from Sellafield, 1985-2002



'Total alpha' and 'total beta' are overall control measures which do not reproduce precisely the contributions of individual radionuclides.

Table 2. Radioactive discharges to the Irish Sea via the pipeline

Radionuclide	Annual discharge (TBq)					Authorised Limit (TBq)
	1998	1999	2000	2001	2002	
Tritium	2300	2500	2300	2600	3320	25,000[b]
Carbon-14	3.7	5.8	4.6	9.5	13	20.8
Sulphur-35	0.43	0.32	0.36	0.16	0.17	
Manganese-54	0.07	0.04	0.01	0.03	0.02	
Iron-55	0.01	0.02	0.04	0.02	0.03	
Cobalt-60	2.4	0.89	1.2	1.2	0.89	13
Nickel-63	0.40	0.58	0.43	0.27	0.46	
Zinc-65	0.14	0.07	0.03	0.05	0.03	
Strontium-89	0.88	0.60	0.64	0.76	0.52	
Strontium-90	18	31	20	26	20	48
Zirconium-95	0.30	0.10	0.10	0.13	0.17	9
Niobium-95	0.35	0.08	0.09	0.14	0.25	
Technetium-99	53	69	44	79	85	90
Ruthenium-103	0.15	0.13	0.11	0.15	0.18	
Ruthenium-106	5.6	2.7	2.7	3.9	6.0	63
Silver-110m	0.12	0.09	0.08	0.10	0.11	
Antimony-125	4.8	7.9	7.8	13	17	
Iodine-129	0.55	0.48	0.47	0.63	0.73	1.6[b]
Caesium-134	0.32	0.34	0.23	0.48	0.49	6.6
Caesium-137	7.5	9.1	6.9	9.6	7.7	75
Cerium-144	0.76	0.60	0.55	0.79	0.97	8
Promethium-147	0.39	0.41	0.35	0.42	0.79	
Europium-152	0.16	0.11	0.07	0.11	0.13	
Europium-154	0.10	0.05	0.06	0.08	0.13	
Europium-155	0.09	0.04	0.05	0.07	0.10	
Neptunium-237	0.04	0.04	0.03	0.04	0.06	
Plutonium alpha	0.14	0.12	0.11	0.16	0.34	0.7
Plutonium-241	3.5	2.9	3.2	4.6	10	27
Americium-241	0.05	0.03	0.03	0.04	0.04	0.3
Curium-242	0.006	0.003	0.003	0.006	0.02	
Curium-243+244	0.003	0.002	0.003	0.003	0.005	
Total alpha[a]	0.17	0.13	0.12	0.20	0.35	1.0
Total beta[a]	86	110	77	120	110	400
Uranium (kg)	550	540	610	390	440	2040

a. 'Total alpha' and 'total beta' are control measures relating to specified analytical determinations. They do not reproduce precisely the contributions from all individual isotopes.

b. Discharge limits applicable to a Thorp plant uranium throughput in the range 400-800 te per annum. This was achieved in every year of the period 1997-2002.

some containers, loss of the gas seal between the water in the fuel containers and the bulk pond water. A recovery programme is underway in FHP to either reprocess the Magnox fuel and remove it from the system promptly, or to re-establish the containment of the Magnox fuel stored in containers within the FHP pond until it can be reprocessed. The aim is to minimise the lifetime discharges to sea for this programme whilst maintaining discharges within authorised limits. The elevated discharges are predicted to continue at least during 2003. All liquors arising from this programme are treated in SIXEP prior to sea discharge.

Liquid discharges via the Seaburn sewer

20 The Seaburn sewer discharges into the confluence of the Rivers Calder and Ehen. The primary source of the effluent is surface water drainage from non-radioactive areas of the Sellafield site to the north of the River Calder. This water may contain trace amounts of radioactivity and therefore discharges are included in the authorisation for the Sellafield site. Total quantities of radioactivity discharged over the last five years and current authorised limits are shown in table 3.

Table 3. Radioactive discharges to the Irish Sea via the Seaburn sewer

Radionuclide	Annual discharge (GBq)					Authorised Limit (GBq)
	1998	1999	2000	2001	2002	
Total alpha	0.032	0.040	0.035	0.032	0.055	3.3
Total beta	0.47	0.47	0.49	0.38	0.44	13.5
Tritium	17	15	11	25	26	132

Aerial discharges

21 Aerial effluents are discharged from a number of stacks on the Sellafield site. They mainly consist of ventilation air

Table 4. Airborne radioactive discharges

Radionuclide	Source of discharge													
	High Stacks		Intermediate Stacks		Low Stacks		Calder Hall		Thorp		Oil Burner		Approved Places	
	Discharge	Limit	Discharge	Limit	Discharge	Limit	Discharge	Limit	Discharge	Limit[a]	Discharge	Limit[b]	Discharge	Limit
	Annual discharge (TBq)													
Tritium	240	1400	-	-	-	-	1.5	11	13.3	33	-	-	-	-
Carbon-14	0.40	5	0.22	1.5	-	-	0.05	0.47	0.14	0.65	-	-	-	-
Argon-41	-	-	-	-	-	-	325	3700	-	-	-	-	-	-
Krypton-85	24,000	120,000	-	-	-	-	-	-	77,000	350,000	-	-	-	-
	Annual discharge (GBq)													
Sulphur-35/Carbon-14	-	-	-	-	-	-	-	-	-	-	4.2	7.2	-	-
Sulphur-35	-	-	-	-	-	-	12	210	-	-	-	-	-	-
Cobalt-60	-	-	-	-	-	-	0.006	0.92	-	-	-	-	-	-
Strontium-90	0.009	0.10	0.02	1.0	0.007	0.50	-	-	0.02	7.8	-	-	-	-
Ruthenium-106	0.04	1.5	0.83	20	-	-	-	-	0.44	37	-	-	-	-
Antimony-125	-	-	-	-	0.38	5.0	-	-	-	-	-	-	-	-
Iodine-129	5.6	32	0.35	4	-	-	-	-	15	33	-	-	-	-
Iodine-131	0.30	45	0.16	10	-	-	-	-	-	-	-	-	-	-
Caesium-137	0.06	0.23	0.17	5.1	0.19	2.0	-	-	0.02	11	-	-	-	-
Plutonium alpha	0.02	0.66	0.001	0.025	0.001	0.03	-	-	0.001	0.5	-	-	-	-
Plutonium-241	0.09	4.0	0.001	0.2	0.005	0.15	-	-	0.002	13	-	-	-	-
Americium-241 + Curium-242	0.01	0.2	0.002	0.09	0.002	0.06	-	-	0.003	0.39	-	-	-	-
Total alpha	0.03	0.7	0.002	0.2	0.001	0.06	-	-	0.003	1.0	0.0001	0.0108	0.01	0.50
Total beta	0.14	5.2	0.14	17	0.17	6.0	0.007[c]	20	0.02	280	0.0001	3.0	0.45[d]	13

a. Discharge limits applicable for a plant uranium throughput in the range 400 to 800 te per year. b. These limits are based on 12 x monthly limits of 600, 0.90 and 250 MBq of sulphur-35/carbon-14, total alpha and total beta respectively.
c. The total beta figure in 2002 was 0.06 GBq (omitted last year). d. In the 2001 report, the total beta figure should have been 0.41 not 0.041 GBq.

from the process plants and Calder Hall. Their radioactive constituents comprise noble gases (e.g. argon and krypton), other gases and vapours (e.g. hydrogen, iodine and carbon dioxide) and suspended particulates. Major release points are monitored continuously and fitted with appropriate abatement equipment, such as high efficiency particulate filters or scrubbers.

22 Discharges of radioactivity to the atmosphere also take place from non-scheduled 'approved places'. They are largely associated with the resuspension of small amounts of radioactivity from open fuel storage ponds and other places. As in previous years, releases in 2002 were calculated by a methodology agreed with the Environment Agency using data on activity concentrations in air at the site perimeter.

23 For reporting purposes, the various stacks and other outlets are grouped into High, Intermediate and Low Stacks, Calder Hall, Thorp, Approved Places and the Waste Oil Burner. Discharges in 2002 from all of these are presented in table 4, and total site discharges for the years 1998 to 2002 in table 5. Reduced discharges of carbon-14 and iodine-131 reflect the introduction of the gas

Table 5. Total airborne radioactive discharges, 1998 - 2002

Radionuclide	1998	1999	2000	2001	2002
	Annual discharge (TBq)				
Tritium	250	250	220	240	250
Carbon-14	2.9	2.9	2.9	0.95	0.81
Argon-41	2500	2600	2500	1900	330
Krypton-85	99,000	100,000	74,000	100,000	100,000
	Annual discharge (GBq)				
Sulphur-35	150	100	120	120	16
Cobalt-60	0.053	0.040	0.033	0.03	0.006
Strontium-90	0.06	0.06	0.05	0.05	0.05
Ruthenium-106	1.1	0.95	1.1	1.1	1.3
Antimony-125	0.18	0.25	0.18	0.54	0.38
Iodine-129	27	25	25	20	21
Iodine-131	3.2	4.0	2.7	2.3	0.45
Caesium-137	0.44	0.57	0.57	0.33	0.43
Plutonium alpha	0.03	0.10	0.04	0.03	0.02
Plutonium-241	0.27	0.83	0.26	0.18	0.10
Americium-241 + Curium-242	0.05	0.07	0.04	0.04	0.02
Total alpha	0.08	0.17	0.08	0.07	0.05
Total beta	1.6	2.2	0.82	0.97	0.92

Table 6. Disposals of solid radioactive waste to Drigg from Sellafield

Radionuclide	Radioactivity disposed (GBq)					Authorised Limit (GBq)
	1998	1999	2000	2001	2002	
Tritium	120	77	74	5.7	4.7	10,000
Carbon-14	3.4	3.5	2.1	0.8	0.9	50
Cobalt-60[a]	78	47	62	21	21	2000
Iodine-129	0.007	0.009	0.013	0.03	0.04	50
Others[b]	3700	1700	1300	980	650	15,000
Radium-226 + Thorium-232	0.24	0.28	1.4	0.20	0.05	30
Uranium	23	25	45	14	9.7	300
Other alpha emitters[c]	86	40	24	18	11	300
Volume (m^3 a^{-1})[d,e]	6900	5200	5000	3500	5100	38,000

a. The cobalt-60 figure is included in 'others' as well as shown separately.
b. Defined in the current authorisation as:
i. iron-55 and beta emitting radionuclides with half lives greater than three months (excluding carbon-14, iodine-129 and tritium).
ii. not more than 2 TBq may be cobalt-60.
c. Alpha emitting radionuclides with half-lives greater than three months (excluding uranium, radium-226 and thorium-232).
d. These volumes represent the volume of the waste and its primary containment.
e. Includes waste consigned by other customers for treatment at Sellafield and that generated at Sellafield by AEA Windscale.

scrubber on the ventilation system serving highly active waste storage plants. Argon-41 and sulphur-35 discharges significantly decreased in 2002 due to the shutdown of three of the four Calder Hall reactors. Most of the remaining radionuclides are associated with particulate material and their annual discharges are not directly related to annual reprocessing rates. Although lower than in 2001, antimony-125 discharges continued to reflect the pond water concentrations in the Fuel Handling Plant (paragraph 19).

Solid wastes

24 Solid low level radioactive wastes arise on the Sellafield site from process operations and decommissioning. Arisings of process wastes have been reduced in recent years to a fairly constant level, so that fluctuations in total arisings now mainly reflect decommissioning operations. The wastes are sent to the Drigg disposal site under the terms of an inter-site transfer authorisation which also covers use of the Waste Monitoring and Compaction (WAMAC) facility at Sellafield. This facility reduces the volume of waste being

sent for disposal at Drigg. It also offers a compaction service to other generators of low level radioactive wastes in the UK. In consequence, the inter-site transfer authorisation also includes allowances for non-BNFL Sellafield waste. Annual radionuclide disposals from Sellafield to Drigg under the terms of the inter-site transfer authorisation are presented in table 6.

25 Contaminated soil arising at Sellafield from construction and excavation is disposed of on-site at the South Landfill Site and the Calder Floodplain Landfill Extension (164 te and 3 te respectively in 2002) under the terms of an RSA authorisation (see paragraph 67). The terms include an activity limit of 3.7×10^4 Bq kg^{-1} (dry weight) for total alpha + total beta, above which soil has to be disposed of at Drigg as low level radioactive waste.

Monitoring of the environment for radioactivity

26 The main pathways identified by BNFL, the Environment Agency and Food Standards Agency as relevant to calculating critical group doses attributable to radioactive discharges from Sellafield are:

- internal exposure from the high rate consumption of seafoods (particularly fish and shellfish) and of local agricultural produce (particularly milk).
- external gamma radiation from exposed intertidal sediments, particularly the fine silts and muds of estuaries and harbours.
- inhalation of, and exposure to, airborne radioactivity.

The habits and consumption rates relating to each pathway are kept under regular review[1]. The Statutory Environmental Monitoring Programme reflects these pathways and also includes the analysis of 'indicators'. These materials accumulate radioactivity and are therefore more likely to produce positive analytical results and provide information on trends in environmental concentrations; examples are grass and seaweed. Doses from direct radiation, as distinct from discharges, are discussed under a separate heading.

27 The Environment Agency reviewed the Statutory Environmental Monitoring Programme in 1999 with a revised programme coming into effect in 2000. The principal changes were:

- Rationalisation of coastal gamma and beta-gamma monitoring to place greater emphasis on monitoring in the areas of highest dose rate and public occupancy and where contaminated flotsam and jetsam may be found.
- Standardisation on quarterly sampling of marine biota, except for winkles and lobsters which continue to be sampled monthly.
- Inclusion of annual samples of fish species which figure to only a small extent in people's diets.
- Inclusion of new indicators for aerial discharges (grass, total deposition and ground level beta-gamma monitoring).
- Extension of the catchment area for milk sampling to within a 4 km radius of the Sellafield site, in order to account for farms whose cattle graze substantially within the 3 km zone used for critical group dose assessment purposes.

An interim review with the Environment Agency in 2002 added strontium-90 to the monitoring programme, as a useful indicator in seawater, and reduced the tritium, carbon-14 and iodine-129 analyses in some of the seafoods.

28 Concentrations of radioactivity in the marine environment reflect discharges through the Sellafield pipeline, whereas those in the terrestrial environment generally reflect discharges to atmosphere. Some overlap does occur, however, with sea to land transfer processes[2,3] and on tidally inundated pastures[4]. Concentrations of caesium-137, plutonium and americium-241 in most environmental materials are dominated by historic discharges.

29 The outbreak of foot and mouth disease in 2001 led to the suspension of much of the monitoring programme. The full monitoring schedule resumed in 2002.

Marine pathways

30 The extent of the marine environmental monitoring programme is illustrated in figure 2. Samples are regularly collected from the Cumbrian coast with more limited sampling from the Solway area, including south-west Scotland, and the Isle of Man. The precise locations are reviewed periodically. In certain cases, additional samples are obtained through commercial suppliers, representing foodstuffs available for general consumption.

Foodstuffs

31 The concentrations of radionuclides in the edible parts of fish, molluscs and crustaceans from the Sellafield area and further afield are presented in tables 7 and 8. Temporal trends are shown in figures 3a – 3c. Data for carbon-14 are corrected for the levels which are present naturally[5]. For marine foodstuffs and seaweeds, a carbon-14 background of 24 Bq kg^{-1} (wet weight) has been assumed, based on an oceanic carbon-14 background of 240 Bq kg^{-1} carbon. Concentrations of radioactivity in seafood in 2002 were generally similar to recent years. The average concentration of technetium-99 in crustaceans, which had been in decline from the peak levels observed in 1997, increased in 2002 due to the increased technetium discharge in 2002 compared to those in the period 1998-2001.

Figure 2. Marine environmental monitoring around Sellafield

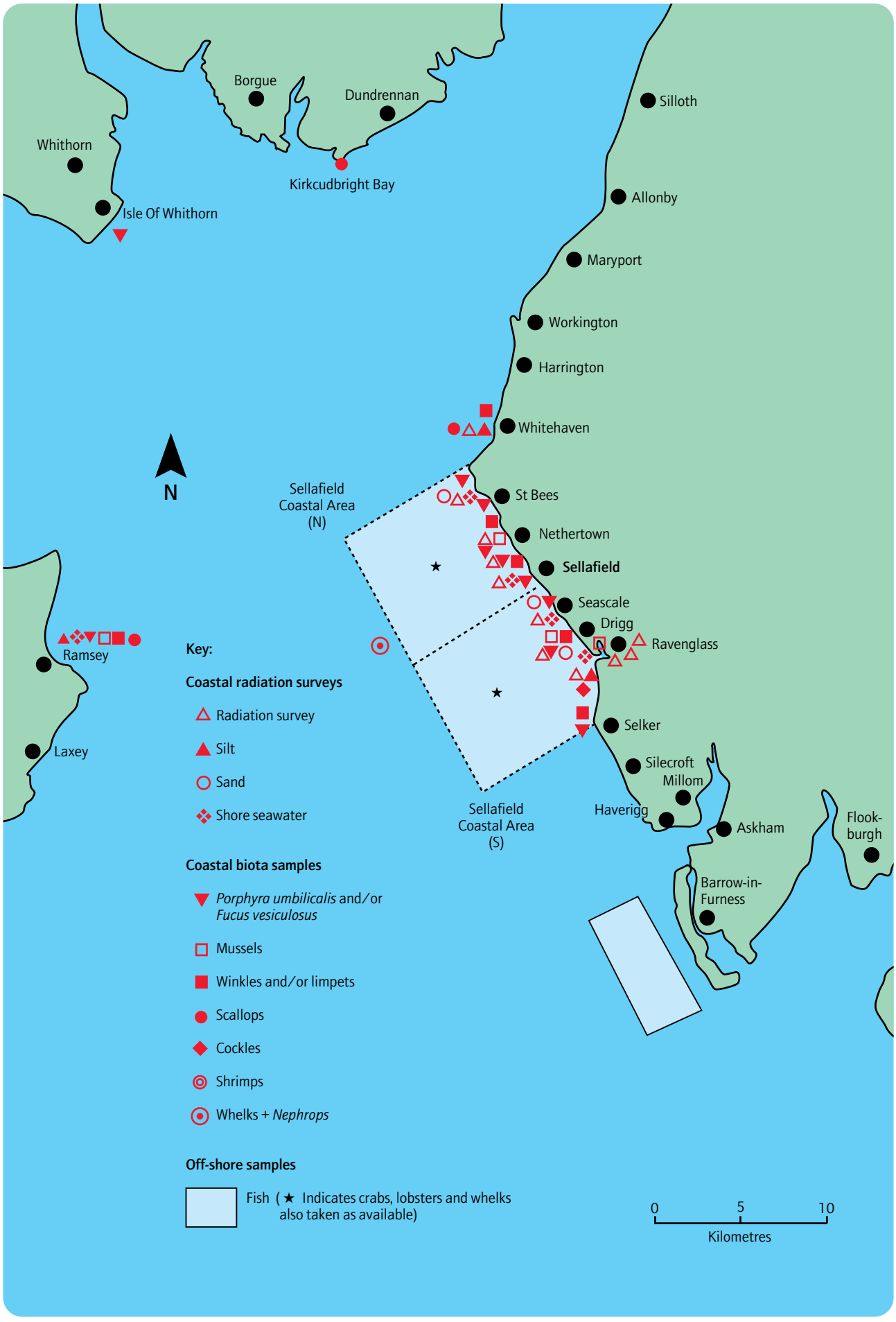


Figure 3a. Radioactivity in seafoods and indicators (St Bees to Selker), 1972 -2002

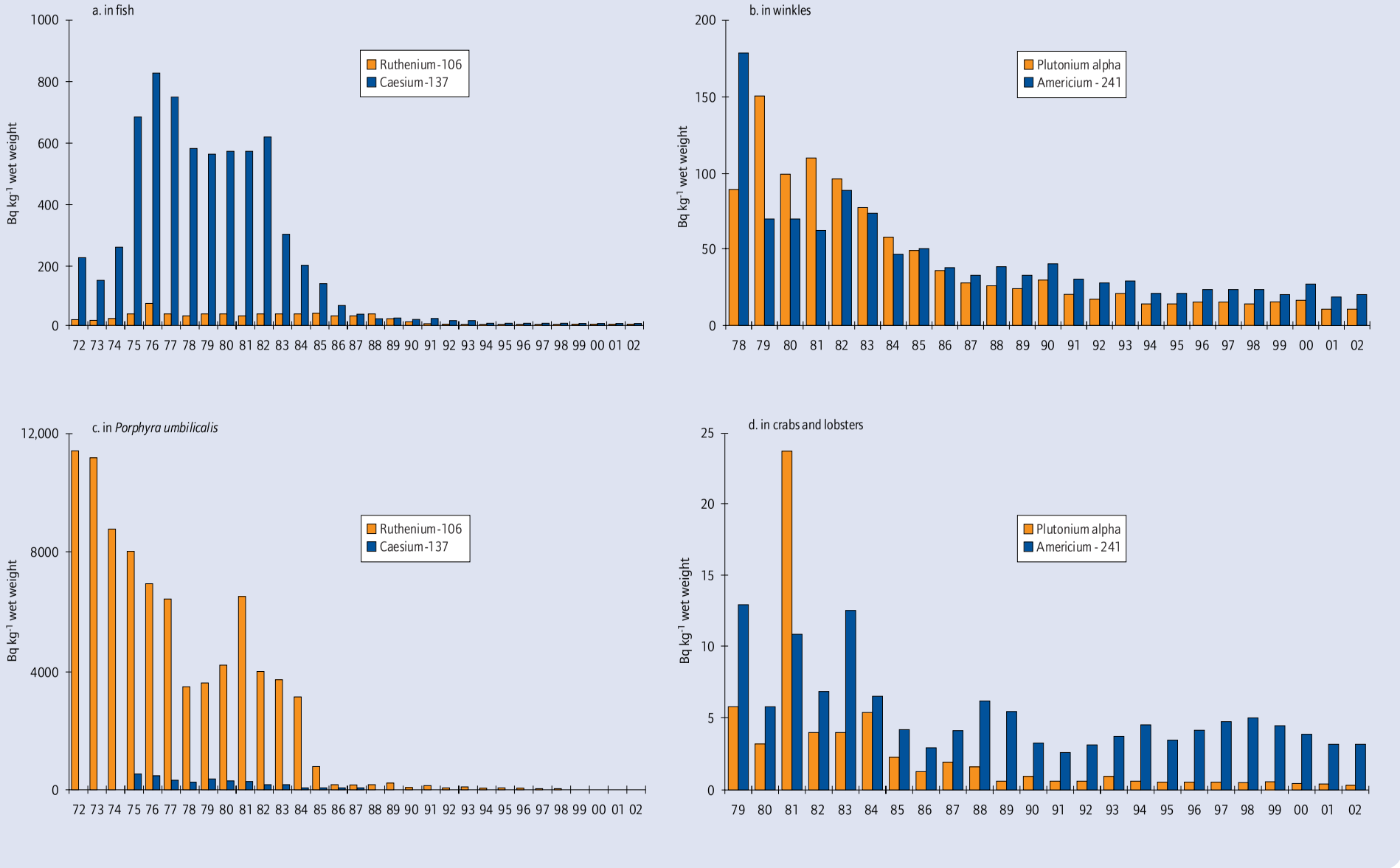


Figure 3b. Radioactivity in seafoods and indicators (St Bees to Selker), 1985 -2002

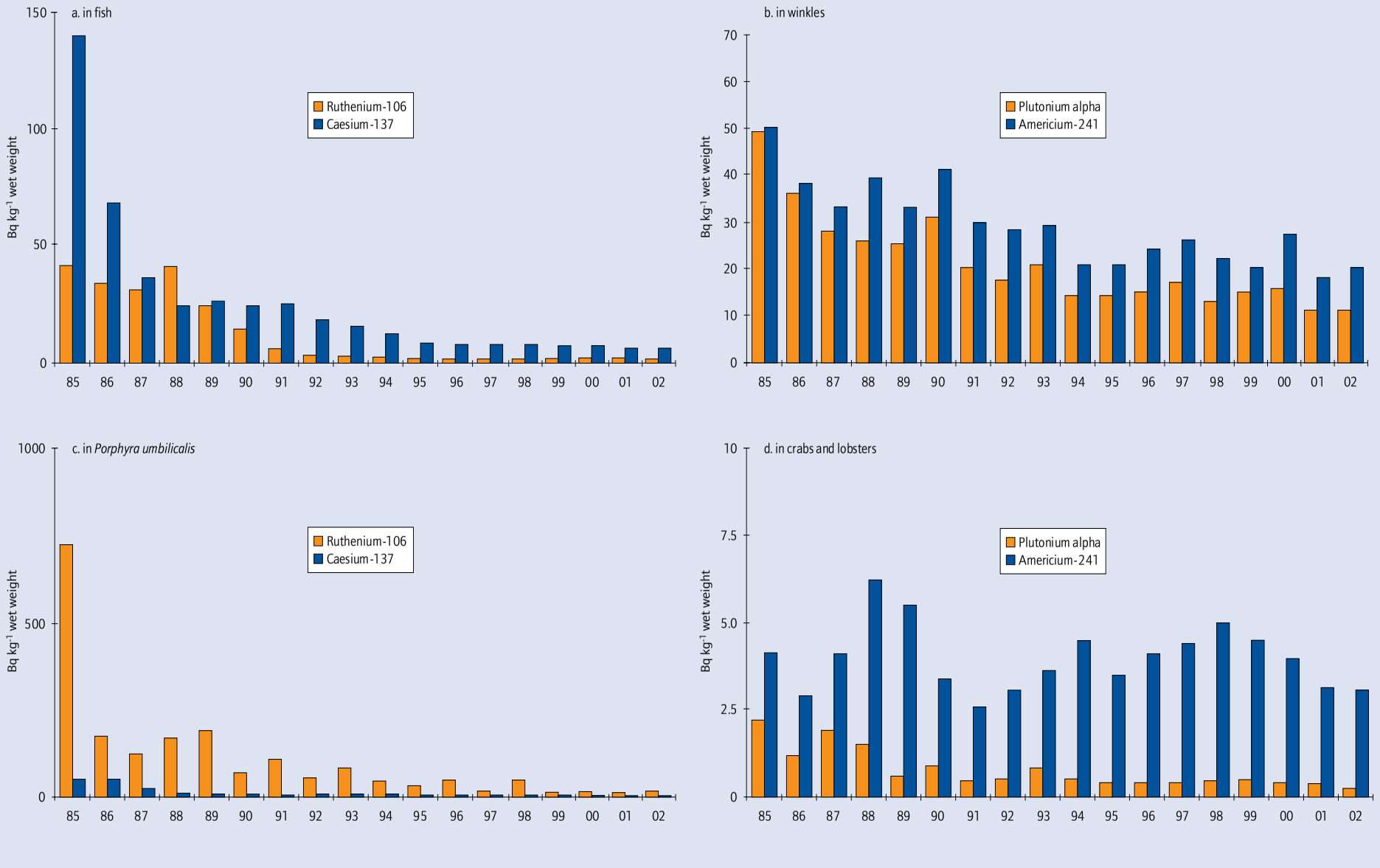
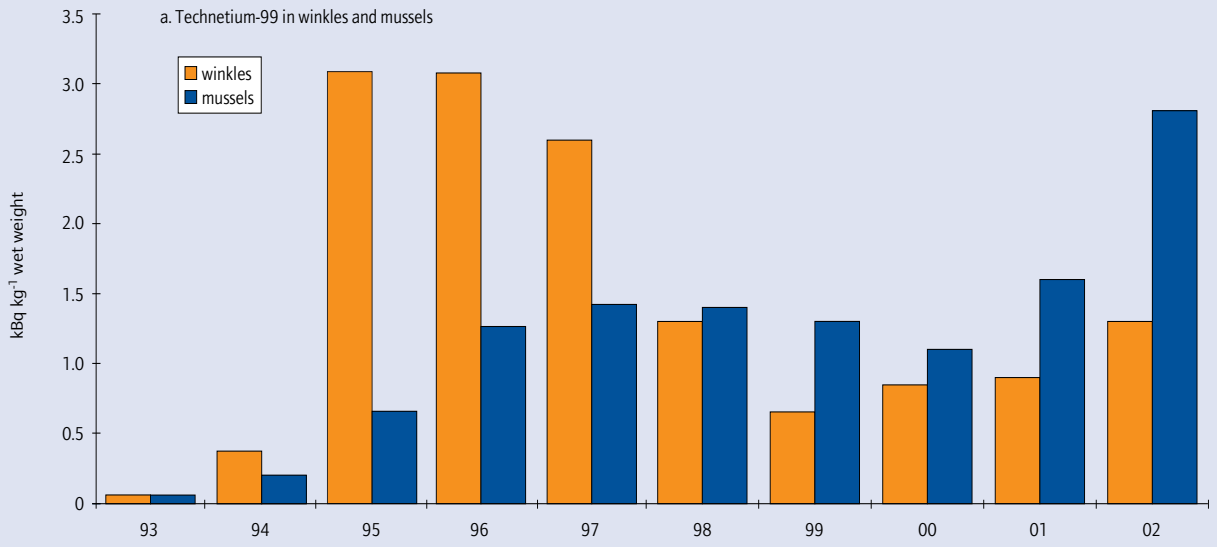
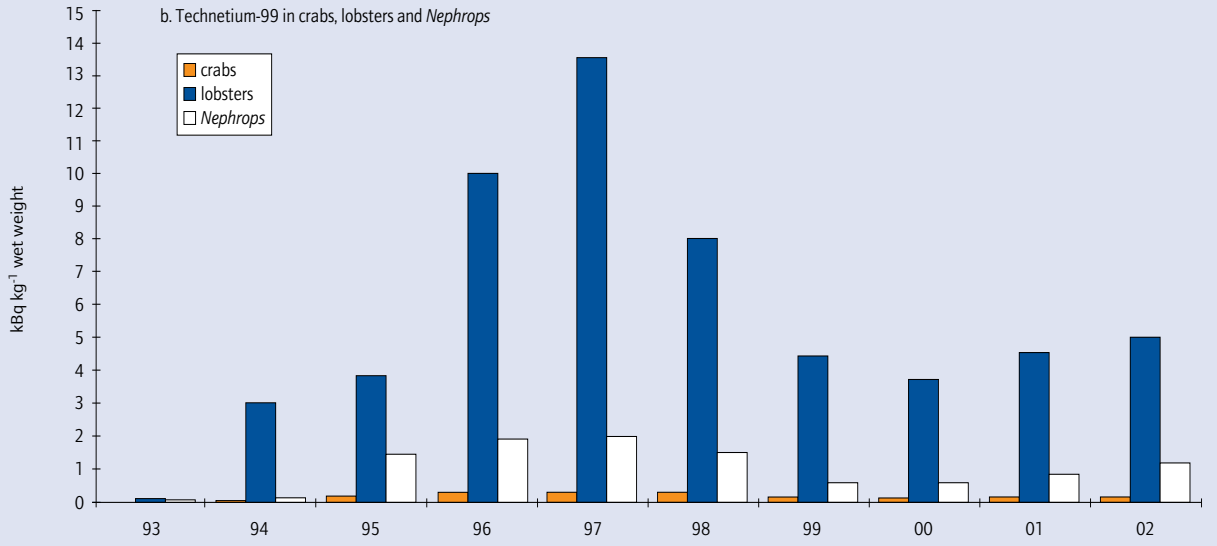
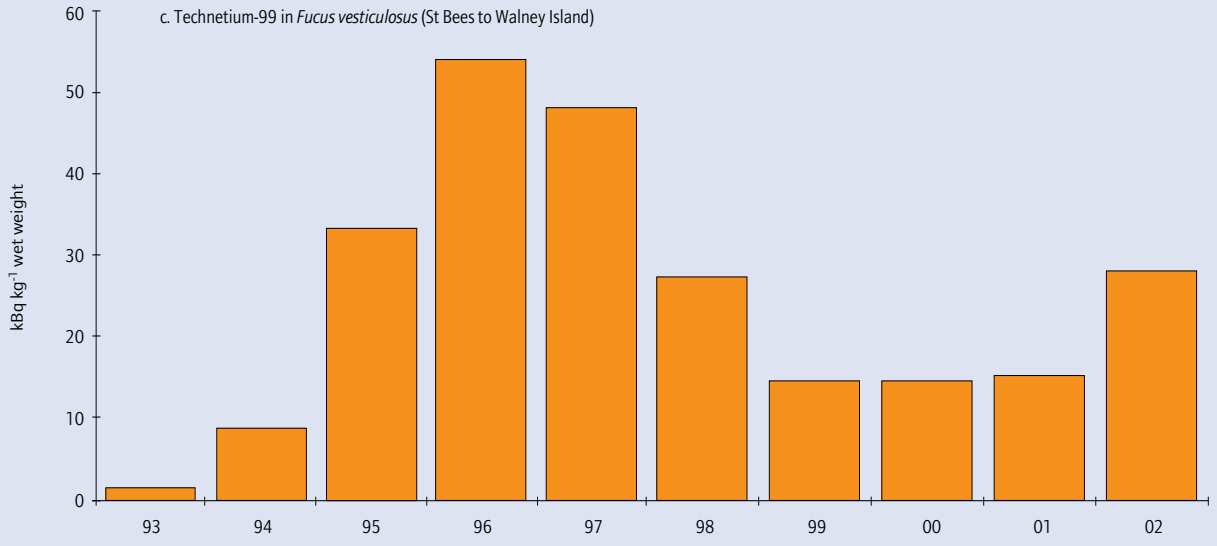


Figure 3c. Radioactivity in seafoods and indicators (St Bees to Selker), 1993-2002







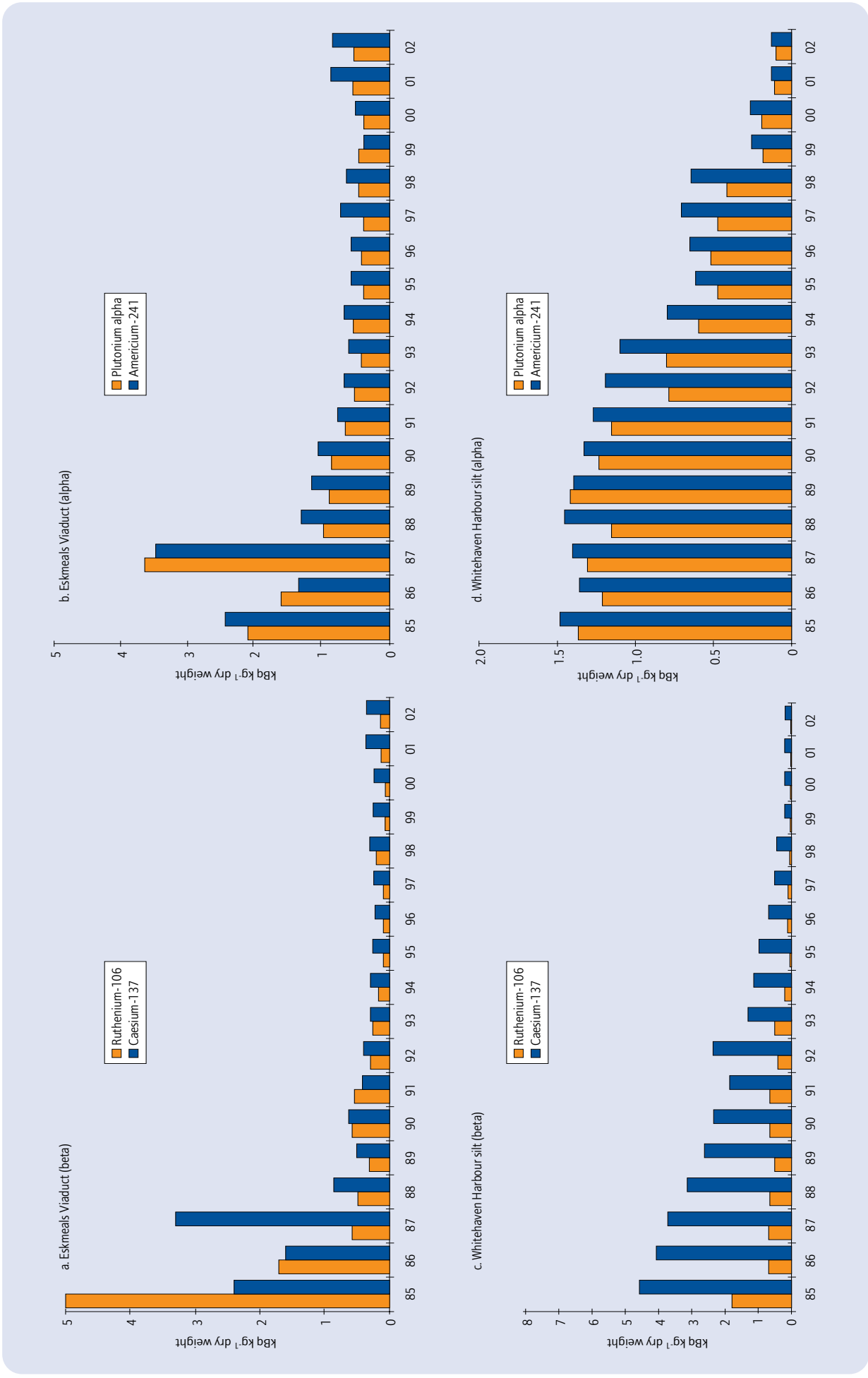
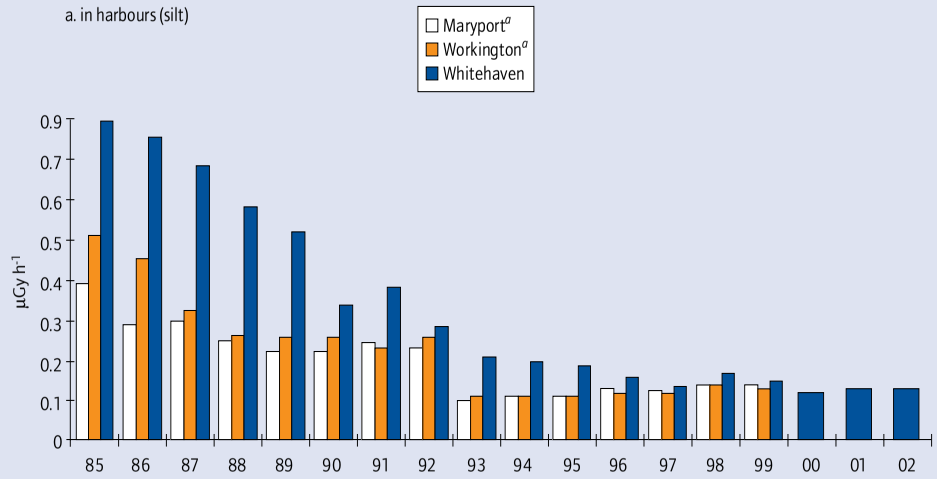
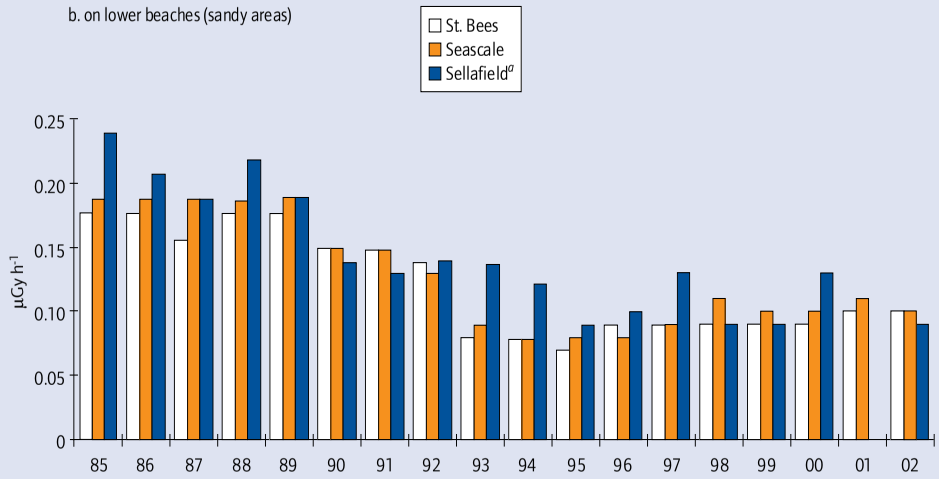


Figure 4. Radioactivity in silts, 1985-2002

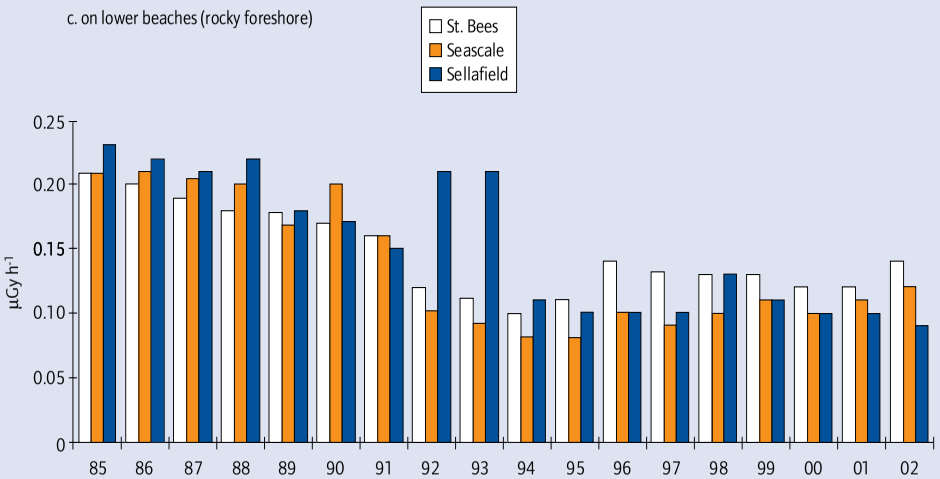
Figure 5. Gamma dose rates in coastal areas, 1985-2002

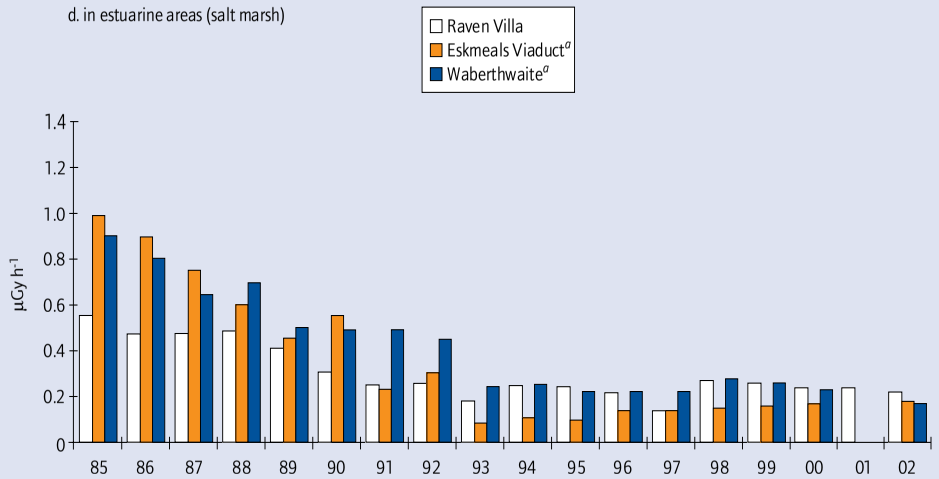


a. Not monitored from 2000 (see paragraph 27).



a. Not monitored in 2001 because of foot and mouth disease access restrictions.





a. Not monitored in 2001 because of foot and mouth disease access restrictions.

Table 7. Radioactivity in fish

Species	Location	Mean radionuclide concentration (Bq kg^{-1} wet weight)												
		Total ^{3}H	^{14}C[a]	^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru	^{129}I	^{134}Cs	^{137}Cs	Pu(α)	^{241}Am
plaice	St Bees-Selker	63	95	<0.25	<0.13	<0.30	<0.12	11	<1.5	0.02	<0.19	4.5	0.05	0.08
	Whitehaven	55	79	<0.21	<0.14	<0.30	<0.12	13	<1.4	<0.05	<0.18	4.0	0.04	0.04
	Barrow	33	80	<0.25	<0.14	<0.35	<0.13	8.7	<1.7	0.02	<0.24	3.5	<0.01	<0.01
cod	St Bees-Selker	51	100	<0.21	<0.14	<0.27	<0.11	<1.5	<1.4	0.36	<0.22	6.3	<0.03	<0.04
	Whitehaven	68	51	<0.31	<0.17	<0.35	<0.11	<1.7	<1.7	0.13	<0.32	7.9	<0.01	<0.01
	Barrow	330	29	<0.24	<0.13	<0.38	<0.14	1.9	<1.8	0.06	<0.24	3.4	<0.01	<0.01
wrasse	Sellafield Coastal Area	-	-	<0.25	0.21	<0.39	<0.15	<1.2	<1.8	-	<0.28	4.7	<0.01	<0.02
whiting		-	-	<0.19	<0.11	<0.33	<0.11	<1.5	<1.5	-	<0.22	3.0	0.09	0.11
dab		-	-	<0.18	<0.13	<0.24	<0.06	1.7	<1.3	-	<0.16	5.3	<0.02	0.05
flounder		-	-	<0.25	<0.13	<0.43	<0.13	<1.2	<2.0	-	<0.32	8.5	<0.01	0.03
rays		-	-	<0.45	<0.16	<0.66	<0.19	<1.4	<3.0	-	<0.48	5.1	0.02	<0.02
gurnard		-	-	<0.31	<0.10	<0.55	<0.11	<1.7	<2.3	-	<0.36	4.3	0.08	0.11
pollack		-	-	<0.21	<0.14	<0.35	<0.14	<0.96	<1.7	-	<0.28	11	<0.01	<0.01
nurse		-	-	<0.17	<0.08	<0.27	<0.13	<1.2	<1.3	-	<0.22	8.8	0.02	0.04
turbot		-	-	<0.17	<0.11	<0.20	<0.07	<1.1	<0.94	-	<0.10	5.2	0.02	0.03
sea bass		-	-	<0.14	<0.13	<0.19	<0.08	<1.3	<1.0	-	0.15	13	0.02	0.02
spurdog		-	-	<0.15	<0.07	<0.22	<0.09	<1.2	<1.0	-	<0.17	1.2	<0.006	<0.007
mullet		-	-	<0.18	0.36	<0.40	-	3.0	<1.5	-	<0.22	6.4	0.02	0.03

a. Net of background (see paragraph 31).

Indicators

32 The seaweed *Fucus vesiculosus* accumulates technetium-99 and is particularly sensitive to fluctuations in its concentration in seawater. Concentrations in 2002 (table 9) at some locations were somewhat higher than in 2001.

Seawater and sediments

33 Concentrations of radioactivity in samples of seawater from the Sellafield area (table 10) were generally similar to those of recent years except for tritium, which reflected the increased discharge.

34 Concentrations of radioactivity in sediments (table 11) were also similar to those of recent years (figure 4). The effects of Sellafield's discharges can also be measured at more distant locations. Thus, caesium-137 levels in silt in the Ribble Estuary are similar to those in West Cumbria (see table 9 in the Springfields chapter).

External pathways

35 Gamma dose rate surveys are carried out in the areas most often frequented by the public, especially in harbours and estuaries where silt or mud accumulates and where dose rates tend to be higher. Several measurements are made in each area (table 12) allowing temporal and geographical trends to be observed.

36 Dose rates fell steadily until 1993/1994 (figure 5) and have subsequently stayed fairly constant. This maintenance of the gamma dose rates is partially due to higher activity concentrations of cobalt-60 in the sediments, arising from increased discharges since 1995.

37 Beta-gamma ground level monitoring is undertaken just above the surface on local beaches to ascertain the general levels of contamination and to remove items of higher than normal activity. In addition to the routine monitoring programme, extra monitoring is carried out in the event of exceptionally high tides or severe storms. During 2002, 1609 man-hours of effort were spent monitoring 489 km of coastline. Monitoring was concentrated on recent tidelines and wind-blown debris in near-shore areas. Since the installation of fine

Table 8. Radioactivity in molluscs and crustaceans

Species	Location	Mean radionuclide concentration (Bq kg^{-1} wet weight)													
		$^{14}C^{a}$	^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru	^{110m}Ag	^{137}Cs	^{237}Np	Pu(α)	^{241}Pu	^{241}Am	U(α)
Molluscs															
winkles	St Bees-Selker	220	11	1.4	<1.3	0.50	1300	33	4.0	6.8	0.02	13	95	20	1.5
	Parton	130	3.3	1.0	<1.2	<0.40	330	<9.5	1.0	5.9	0.02	6.3	44	13	1.9
mussels	St Bees-Selker	260	7.6	1.6	<0.75	<0.30	2800	21	<0.60	2.4	0.05	10	81	18	2.2
limpets	St Bees-Selker	120	5.5	5.6	<1.3	-	3800	20	2.9	7.8	0.03	13	100	22	2.7
cockles	Ravenglass	200	17	1.9	<1.3	<0.40	96	10	<1.2	5.5	0.16	15	110	34	2.6
whelks	off-shore	130	2.1	<0.22	<0.55	<0.22	160	3.5	0.95	1.0	0.01	1.3	9.4	2.9	0.49
queens	off-shore	-	<0.23	<0.12	<0.55	-	7.5	<1.8	<0.3	0.31	0.02	<0.17	1.6	0.11	-
Crustaceans															
crabs	St Bees-Selker	130	3.5	1.0	<0.51	<0.18	110	<2.9	-	1.6	0.005	<0.38	3.2	1.6	0.28
lobsters	St Bees-Selker	200	2.5	0.43	<0.48	-	5000	<1.9	-	1.6	0.02	<0.31	2.6	4.6	0.07
Nephrops	Irish Sea Area	110	<0.26	<0.17	<0.47	<0.10	1200	<2.1	-	3.8	0.002	0.49	2.9	1.8	0.08

a. Net of background (see paragraph 31).

Table 9. Radioactivity in seaweed and samphire

Species	Location	Mean radionuclide concentration (Bq kg^{-1} wet weight)													
		Total ^{3}H	$^{14}C^{a}$	^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru	^{129}I	^{134}Cs	^{137}Cs	Pu(α)	^{241}Am	U(α)
Porphyra umbilicalis	St Bees-Selker	7.3	97	1.6	<8.7	<0.68	<0.27	200	18	1.3	<0.46	3.6	7.2	12	0.44
Fucus vesiculosus	Fleswick Bay	7.5	67	6.5	<10	<0.79	<0.31	34,500	<3.5	23	<0.50	2.9	11	3.3	3.0
	Seamill	3.4	35	5.7	<7.3	<0.64	<0.59	8380	<4.3	14	<0.42	3.0	8.6	7.6	1.8
	Nethertown	5.1	61	19	<9.4	<0.77	0.63	19,400	7.3	16	<0.47	5.7	18	6.3	4.1
	Seascale	9.9	45	14	<8.9	<0.79	<0.29	38,200	<4.0	15	<0.48	4.8	14	7.4	2.0
	Drigg	6.9	130	28	<9.0	<1.3	0.53	48,300	8.6	8.1	<0.80	6.4	32	9.2	6.2
	Tarn Bay	4.1	79	8.8	<8.1	<0.75	<0.26	30,300	3.1	13	<0.40	4.3	13	3.5	2.9
	Walney Island	5.4	43	2.5	<8.6	<0.68	<0.22	18,500	<3.2	<10	<0.43	3.8	6.4	<2.7	3.7
	Ramsey, IOM	3.4	18	<0.45	<7.4	<0.68	<0.19	2110	<3.1	0.85	<0.42	0.54	0.32	<2.0	1.1
	Isle of Whithorn	4.1	22	0.60	<7.7	<0.76	<0.25	2320	<3.5	<4.1	<0.56	1.8	1.6	<2.1	1.6
Samphire	Ravenglass	-	-	0.68	<5.2	<0.70	<0.18	9.7	-	-	<0.42	3.8	7.7	10	0.40

a. Net of background (see paragraph 31).

Table 10. Radioactivity in coastal samples of seawater from the Irish Sea

Location		Mean radionuclide concentration (Bq in one litre of seawater)								
		Total alpha	Total beta	^{3}H	^{14}C	^{90}Sr	^{99}Tc	^{137}Cs	Pu(α)	^{241}Am
St Bees:	filtrate	<7.9	8.6	6.8	<0.47	<0.22	0.31	<0.30	0.005	0.002
	solid	0.37	<1.3	-	-	<0.18	-	0.05	0.09	0.15
Sellafield:	filtrate	<8.1	8.7	34	<0.55	<0.23	1.5	0.23	0.006	<0.005
	solid	0.49	1.0	-	-	<0.18	-	0.05	0.19	0.19
Seascale:	filtrate	<8.4	8.8	26	<0.55	<0.25	1.6	0.23	0.006	<0.003
	solid	0.72	<1.1	-	-	<0.15	-	0.07	0.15	0.22
Drigg:	filtrate	<7.7	9.5	24	<0.45	<0.23	0.97	0.24	0.006	<0.002
	solid	0.40	<0.70	-	-	<0.17	-	0.05	0.08	0.13
Whitehaven:	filtrate	-	-	12	-	<0.23	-	<0.20	<0.002	<0.001
	solid	-	-	-	-	-	-	<0.02	0.01	<0.06

Table 11. Radioactivity in silts and sands from the West Cumbrian Coast

Location	Mean radionuclide concentration (Bq kg^{-1} dry weight)											
	^{3}H	^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru	^{134}Cs	^{137}Cs	Pu(α)	^{241}Am	U(α)
Silt												
Whitehaven:												
Outer 1, north	<2.3	2.8	<210	<4.4	<2.1	13	<24	<2.7	150	120	170	33
Outer 2, south	<3.9	<3.2	<210	<4.6	<1.7	25	<25	<3.1	180	79	110	40
Ravenglass:												
Raven Villa	25	37	<210	<6.8	1.2	120	77	<3.5	210	410	610	41
Salmon Garth	10	7.6	<210	<3.8	<1.6	22	<17	<2.8	68	160	210	21
Boat area	16	28	<200	<5.7	<1.7	83	47	<3.9	150	330	490	34
Eskmeals Viaduct	<4.6	59	<220	<9.2	6.1	120	150	<5.0	360	520	830	57
Waberthwaite	<10	41	<230	<8.7	<2.7	160	91	<5.0	340	560	760	52
Newbiggin	<4.1	50	<220	<6.3	<5.0	170	150	<4.6	430	730	1000	70
Muncaster Bridge	<4.6	35	<240	<9.4	3.1	120	120	<5.6	580	870	1200	59
Sand												
St Bees	-	3.6	<210	<1.4	<0.62	6.0	<8.0	<0.97	67	170	210	21
Seascale	-	2.6	<210	<1.5	<0.62	8.4	<7.6	<0.97	46	130	170	27
Drigg beach	-	4.5	<210	<2.0	<1.1	13	<12	<1.4	39	150	190	15

mesh strainers on the Sellafield pipeline in 1984, followed by the introduction of SETP with strainers and hydrocyclones, finds of contaminated debris have been rare and there were none in 2002.

Airborne and terrestrial pathways

38 The extent of the terrestrial environmental monitoring programme is illustrated in figure 6.

Airborne radioactivity

39 High flow rate air sampling equipment is located close to the site perimeter and in nearby centres of population to sample airborne particles. The concentrations of particulate radioactivity measured in air in 2002 are presented in table 13. Levels off-site were generally below the limit of detection, with most positive values due to historic marine discharges (see paragraph 28).

Foodstuffs and water

40 Milk consumption remains the main contributor to the critical group dose from terrestrial foodstuffs and represents one of the more rapid food transfer pathways. For this reason, an extensive milk monitoring programme is operated. Locations sampled include local farms (seven in the range 0 to 4 km from the Sellafield site) and a farm situated on the Ravenglass Estuary. The average concentrations of radioactivity in milk are summarised in table 14. The figures include natural background levels (except for carbon-14), and the residual effects of weapons testing and the 1986 Chernobyl reactor accident. Data for carbon-14 are corrected for natural background levels which are expressed relative to the total carbon content of the sample. For all terrestrial foodstuffs and vegetation, a background level of 254 Bq kg^{-1} carbon is used based on the results of a survey in 1992[6]. The results for 2002 are generally similar to those observed for previous years. The effect of deposition on the tide-washed pastures is evident

Table 12. Mean gamma dose rates measured in air in intertidal and other coastal areas of Cumbria

Area of survey	Description	Nature of ground	Number of observations[a]	Mean dose rate ($\mu Gy\ h^{-1}$)[b]
Whitehaven Harbour, north	outer harbour	mud/sand	12	0.13
Whitehaven Harbour, south	outer harbour	soft mud	12	0.14
Whitehaven Marina	pontoons	pontoons	12	0.06
St Bees beach	groynes	pebbles/rocks	12	0.14
St Bees beach	beach	sand	12	0.10
St Bees beach	swimming pool area	shingle	12	0.14
St Bees	promenade & play area	concrete/grass	1	0.07
St Bees	Seamill Lane	car park	1	0.07
Coulderton	beach bungalows	grass banks	1	0.07
Nethertown	beach bungalows	grass banks	1	0.07
Nethertown	car park	tarmac	1	0.07
Nethertown	beach	pebbles/shingle	4	0.15
Braystones	beach	pebbles/shingle	4	0.14
Braystones	beach bungalows	grass banks	1	0.08
Sellafield	dunes and grass banks	dunes/grass banks	1	0.09
Sellafield	pipeline 1	gabions	12	0.09
Sellafield	pipeline 2	gabions	12	0.09
Sellafield	pipeline 3	sand	12	0.08
Sellafield	pipeline 4	sand	12	0.08
Seascale	dunes and car park	dunes/car park	1	0.07
Seascale beach	north of pipeline	sand	12	0.10
Seascale beach	south of pipeline	rocks/sand	12	0.12
Drigg beach	beach	sand	4	0.13
Drigg beach	Barn Scar	mussel beds/silt/rocks	4	0.12
Ravenglass	Main Street	tarmac/pavements	1	0.09
Raven Villa, Ravenglass	ford	mud/silt	12	0.16
Raven Villa, Ravenglass	saltmarsh	saltmarsh	12	0.22
Raven Villa, Ravenglass	basin	soft mud	12	0.14
Boating Area, Ravenglass	boating area	firm silt/pebbles	4	0.13
Salmon Garth, Ravenglass	salmon garth	mussel beds	4	0.13
Salmon Garth, Ravenglass	near saltmarsh	sand/firm silt	4	0.14
Salmon Garth, Ravenglass	track	firm silt/pebbles	4	0.13
Factory Sewer	north of outfall	rocks/boulders	12	0.13
Factory Sewer	south of outfall	sand/shingle	12	0.14
Eskmeals Viaduct	saltmarsh	soft/firm silt	1	0.18
Newbiggin	saltmarsh	saltmarsh	12	0.25
Muncaster road bridge	riverbank	grass	1	0.16
Hall Waberthwaite	saltmarsh	saltmarsh turf	1	0.17

a. Each observation consists of the mean of a number of individual readings at a given location.
b. Figures include contributions from natural background, typically 0.05 $\mu Gy\ h^{-1}$ over sandy areas and 0.07 $\mu Gy\ h^{-1}$ over silt[1].

from the positive plutonium and americium analytical results on Ravenglass samples compared to the limit of detection results on samples from other areas.

41 An extensive programme of sampling animal produce and wild and cultivated fruit and vegetables was undertaken in 2002 (tables 15 and 16). Samples were collected from within 4 km of the Sellafield site as they became available throughout the year. Direct comparison with the results of earlier years is difficult due to the relatively small numbers of samples and their locations. Data for carbon-14 are corrected for the levels which are present naturally (see paragraph 40).

42 Water samples from the River Calder are collected monthly and samples from other local rivers, lakes and domestic supplies collected quarterly. All samples are analysed quarterly. The results (table17) are all very low and rarely above the limits of detection except for strontium-90 which is generally present in rain water and surface water at levels typical of those throughout the UK[7,8].

Indicators

43 Grass and soil sampling is included in the monitoring programme since it is a useful indicator material and is often used to provide time trend data on environmental concentrations of radioactivity. Samples are normally collected quarterly from six locations close to Sellafield and from one in the Ravenglass Estuary (table 18).

Figure 6. Terrestrial environmental monitoring around Sellafield

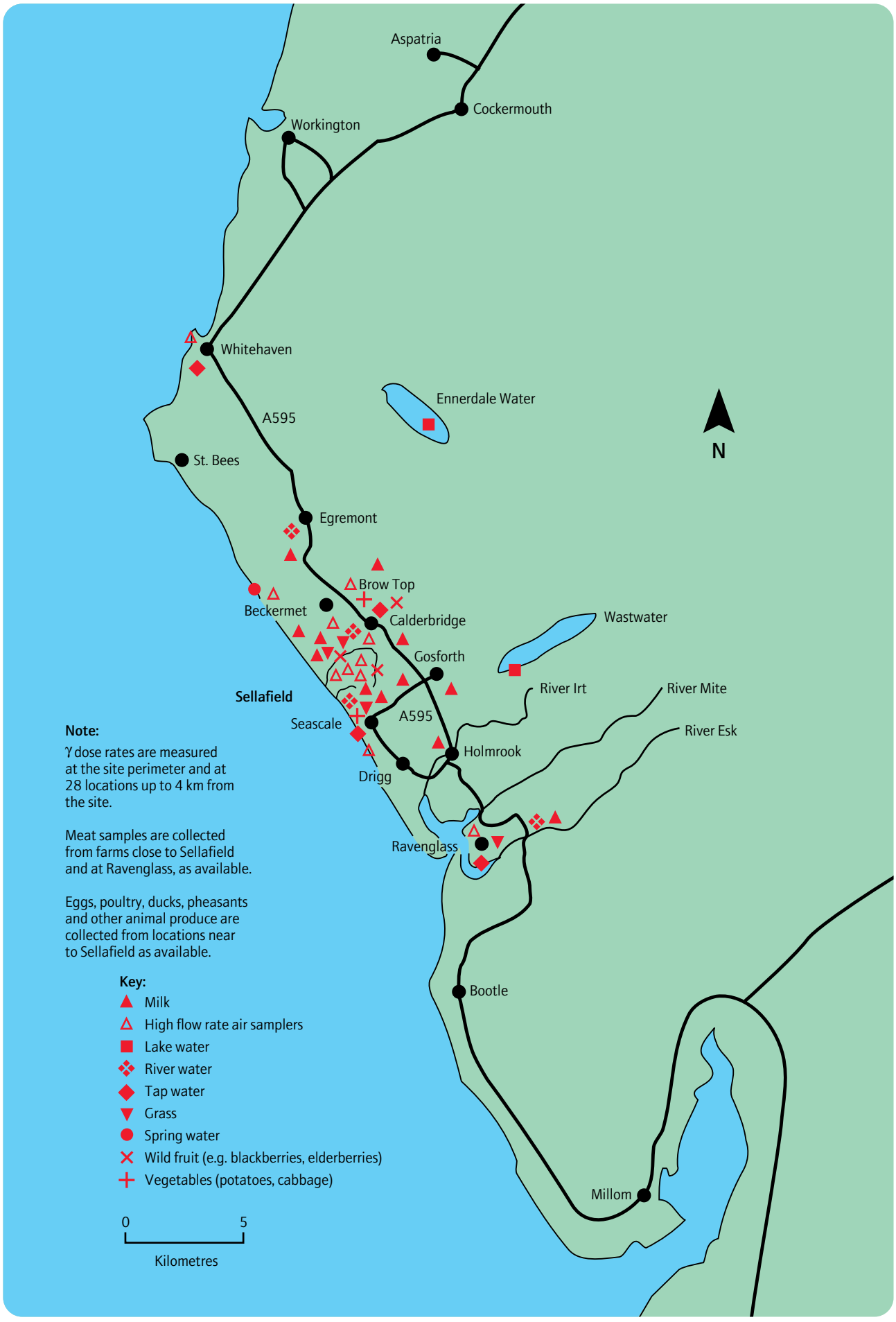


Table 13. Radioactivity in air at locations in the vicinity of Sellafield

Radionuclide	Mean radionuclide concentration (mBq m^{-3})							
	Site perimeter							
	Calder Gate	Met Station	North Gate	West Ring Road	Beckermet	Calderbridge	Ravenglass	Seascale
Strontium-90	0.004	0.005	0.008	0.002	<0.001	<0.0009	<0.0007	<0.0008
Zirconium-95	<0.007	<0.01	<0.01	<0.01	<0.001	<0.009	<0.01	<0.01
Niobium-95	<0.002	<0.002	<0.003	<0.002	<0.002	<0.002	<0.003	<0.002
Ruthenium-103	<0.005	<0.006	<0.007	<0.006	<0.007	<0.005	<0.007	<0.006
Ruthenium-106	<0.04	<0.05	<0.05	<0.05	<0.06	<0.04	<0.05	<0.04
Caesium-134	<0.006	<0.007	<0.007	<0.006	<0.007	<0.005	<0.006	<0.006
Caesium-137	0.03	0.05	0.05	0.01	0.01	0.007	<0.006	<0.006
Plutonium alpha	<0.0004	<0.0005	<0.001	<0.0004	<0.0002	<0.0001	<0.0001	0.0002
Plutonium-241	<0.01	<0.01	<0.01	<0.01	<0.02	<0.01	<0.01	<0.01
Americium-241	0.0004	0.0007	0.0008	0.0005	0.0004	0.0006	0.0004	0.0007

No samples taken from Braystones and Brow Top in 2002 as there was no access to these sites.

Table 14. Radioactivity in milk from farms near Sellafield

Location	Mean radionuclide concentration (Bq l^{-1})										
	^{3}H	$^{14}C^{a}$	^{35}S	^{90}Sr	^{99}Tc	^{106}Ru	^{129}I	^{131}I	^{137}Cs	Pu(α)	^{241}Am
0 to 4 km zone	7.3	1.0	<0.92	0.15	<0.014	<0.36	<0.020	<0.12	0.38	<0.0001	<0.0002
Ravenglass Estuary	5.3	0.50	<0.87	0.17	<0.012	<0.35	<0.015	<0.12	0.43	0.0003	0.0005

a. Net of background (see paragraph 40).

Table 15. Radioactivity in animal produce

Species (location)	Mean radionuclide concentration (Bq kg^{-1} wet weight)								
	^{3}H	$^{14}C^{a}$	^{90}Sr	^{99}Tc	^{106}Ru	^{129}I	^{137}Cs	Pu(α)	^{241}Am
beef (Seascale)	<5.0	-	<0.11	1.7	<0.74	<0.005	0.78	<0.001	0.002
beef liver (Seascale)	<14	-	<0.12	0.88	<0.69	<0.003	<0.07	<0.002	0.002
mutton (Ravenglass)	<5.0	1.5	<0.11	<0.41	<0.72	0.007	1.6	<0.001	0.002
mutton liver (Ravenglass)	-	-	<0.16	<0.55	<4.5	<0.006	<0.43	<0.002	0.002
deer (Gosforth)	14	1.0	<0.11	<0.35	<3.4	0.011	11	<0.001	0.002
hare (Seascale)	<7.6	1.4	<0.13	0.34	<0.85	<0.004	1.1	<0.001	<0.001
honey (Gosforth)	17	5.7	0.03	-	<2.3	-	1.9	0.001	-
wood pigeon (Ponsonby)	<5.0	1.0	<0.11	<0.42	<3.7	-	0.98	<0.0009	<0.001
pheasant (Gosforth)	32	1.8	<0.07	0.58	<3.3	0.006	1.2	<0.002	0.002
woodcock (Saltcoats)	<5.0	-	<0.11	6.0	<4.0	-	1.9	<0.002	0.002
ducks (Seascale)	<5.0	0.70	<0.11	3.2	<2.2	0.001	0.46	<0.002	<0.001
duck eggs (Seascale)	-	2.9	0.23	<0.42	<0.64	0.098	0.25	0.002	<0.0009
geese (Seascale)	<5.0	2.3	<0.08	0.41	<0.77	0.002	0.49	<0.001	0.002
hens (Seascale)	13	1.1	<0.11	11	<3.2	0.003	0.48	<0.002	0.002
hens' eggs (Seascale)	-	2.1	<0.10	<0.34	<0.64	0.044	0.14	<0.001	0.001
mallard (Saltcoats)	<5.0	2.5	0.15	0.70	<3.5	0.006	2.6	<0.001	<0.002

a. Net of background (see paragraph 40).

Table 16. Radioactivity in fruit and vegetable produce

Species (location)	Mean radionuclide concentration (Bq kg^{-1} wet weight)									
	^{3}H	^{14}C[a]	^{35}S	^{90}Sr	^{99}Tc	^{106}Ru	^{129}I	^{137}Cs	Pu(α)	^{241}Am
potatoes (North of Sellafield)	5.4	0	<0.69	<0.05	<1.6	<0.87	<0.004	0.08	<0.001	<0.0009
potatoes (East of Sellafield)	8.3	0.60	<0.88	<0.08	<1.2	<0.83	<0.004	<0.11	0.001	<0.0008
elderberries (North of Sellafield)	14	2.5	<2.5	0.63	<0.22	<3.5	0.15	3.0	0.007	0.007
pears (Sellafield site)	40	3.5	<2.1	5.1	0.35	<1.3	0.031	73	0.025	0.013
blackberries (Calder Valley)	18	3.4	<2.3	4.4	0.23	<3.2	0.017	8.4	0.004	0.004

a. Net of background (see paragraph 40).

Table 17. Radioactivity in local waters

Location	Mean radionuclide concentration (Bq l^{-1})			
	^{3}H	^{90}Sr	^{137}Cs	Pu(α
River water: Calder, downstream of site	<8.5	0.008	<0.019	<0.002
Calder, upstream of site	<7.9	0.008	<0.020	<0.001
Esk	<8.2	0.007	<0.024	<0.002
Ehen at Egremont	<7.4	0.005	<0.020	<0.002
Lake water: Wastwater	<5.5	0.005	<0.020	<0.0007
Ennerdale	<6.1	0.004	<0.021	<0.0007
Tap water: Calderbridge	<9.9	0.004	<0.023	<0.0008
Ravenglass	<7.1	0.004	<0.023	<0.0007
Seascale	<9.1	0.004	<0.021	<0.0007
Whitehaven	<6.3	0.004	<0.024	<0.0008
Sellafield beach seepage[a]	940	<2.7	<1.8	-

a. Results corrected for seawater content.

Table 18. Radioactivity in grass

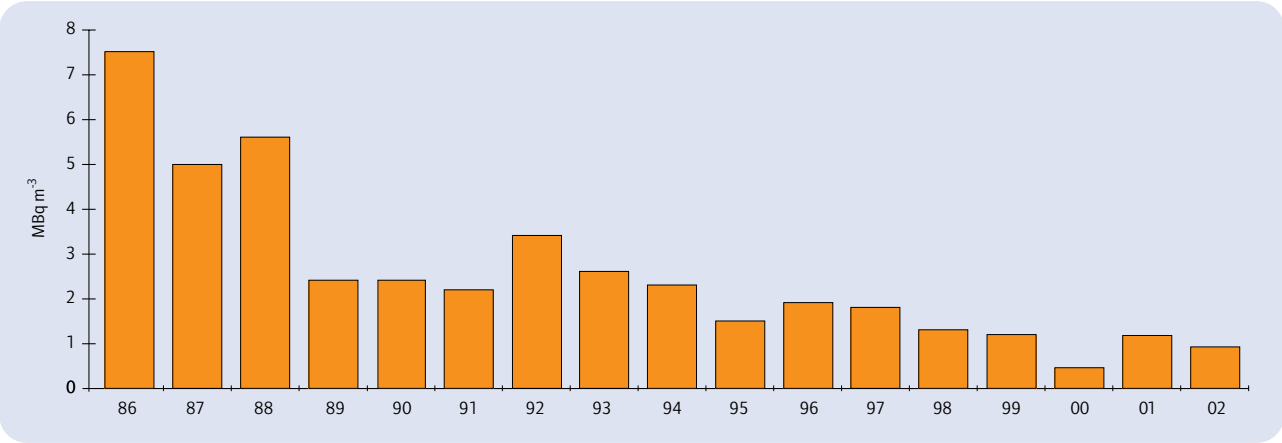
Location	Mean radionuclide concentration (Bq kg^{-1} wet weight)									
	^{3}H	^{14}C[a]	^{35}S	^{90}Sr	^{99}Tc	^{106}Ru	^{129}I	^{137}Cs	Pu(α)	^{241}Am
North of site	17	2.4	1.5	17	<1.6	1.7	0.25	24	0.75	0.28
South of site	15	4.4	2.8	2.2	<1.3	<1.9	0.21	3.4	0.24	0.20
Ravenglass	3.1	1.6	-	0.36	57	<1.7	0.11	2.4	0.72	0.97

a. Net of background (see paragraph 40).

Table 19. Radioactivity in groundwater

Borehole number	Mean radionuclide concentration (Bq m^{-3})						
	Alpha	Beta	^{3}H	^{90}Sr	^{106}Ru	^{137}Cs	^{99}Tc
103	<200	<240	500,000	<200	<1800	<180	1300
108	<200	<240	180,000	<200	<1700	<170	330
138	<200	<230	250,000	<210	<1700	<170	24,000
139	<200	<820	21,000,000	<300	<1800	<210	41,000
140	<230	<240	120,000	<200	<1700	<180	320
33	<210	<710	<110,000	<400	<1700	<180	1300
35	<200	380	<110,000	<230	<1800	<180	260
36A	<220	<260	<110,000	<200	<1900	<180	310
38	<250	610	<120,000	<210	<1800	<170	340
39	<220	<280	<120,000	<210	<1800	<180	310
49A	<210	<240	<170,000	<200	<1900	<180	320
50A	<210	<280	<120,000	<210	<1900	<170	300
8	<230	<270	<110,000	<210	<1900	<180	330
4	<210	<2220	<120,000	<200	<24,000	<160	310

Figure 7. Tritium concentration in beach seepage (freshwater component), 1986-2002



Groundwater

44 The authorisation permitting the burial of radioactivity in soil beneath concrete foundations, and disposal by tipping on the Sellafield site, requires the routine monitoring of groundwater from 14 boreholes around the perimeter of the site so that any significant migration of radioactivity in groundwater will be detected. The results in 2002 (table 19) were similar to those of recent years. Most were near or below limits of detection, except tritium (maximum 21 MBq m^{-3}) and technetium-99 (maximum 0.041 MBq m^{-3}) which were measured in borehole 139 in the vicinity of the main gate/southwest perimeter (relatively high levels of technetium-99 were also measured in borehole 138). The waste disposal trenches which were used before disposal operations commenced at Drigg, are believed to be the source of the tritium in borehole 139 and also of that monitored in groundwater upwelling on the Sellafield beach (figure 7). A redundant sea discharge storage tank is believed to be the source of the technetium-99.

Direct radiation

45 Some of the older Magnox buildings, principally the Calder reactors, have lower levels of radiation shielding than the modern buildings, such as Thorp. Consequently, it is possible to measure radiation dose rates above natural background beyond the site perimeter fence. These dose rates are dependent upon the amount of power being produced by the reactors.

46 Gamma dose rates are measured on a quarterly basis at 24 locations around the site perimeter and twice yearly at a further 28 locations in the surrounding district up to 4 km from the site. Dose rates at the site perimeter averaged 0.19 µGy h^{-1}. The highest dose rates were those closest to Calder Hall. Dose rates in the surrounding district averaged 0.11 µGy h^{-1}. These are total dose rates which include contributions from natural terrestrial background and cosmic rays. For dose assessment purposes the natural contributions are deducted.

Radiological impact of operations at Sellafield

Critical group doses

Marine pathways

47 Using habits surveys, the Food Standards Agency has identified the marine critical group for seafood consumption as a small number of people in the Cumbrian coastal community who are high-rate consumers of fish and shellfish obtained from the Sellafield area between St Bees and Selker. Consumption and occupancy rates are kept under regular review and are published annually[1]. The consumption and occupancy rates used by BNFL for dose assessment purposes (table 20) are averages of the data published by MAFF or the Food Standards Agency for the five years 1997-2001.

Table 20. Seafood consumption rates for people associated with marine discharges

Seafood	Consumption rates (kg y^{-1})		
	Critical group (St Bees-Selker)	Consumers associated with Whitehaven fishery	Typical fish eating public (Whitehaven)
Fish:			
cod	19.3	21.7	7.5
plaice	18.1	21.7	7.5
Crustaceans:			
crabs	13.5	-	-
lobsters	6.36	-	-
Nephrops	1.94[b]	12.0	-
Molluscs:			
winkles	7.14	-	-
whelks	-	14.2	-
other molluscs[a]	8.50	-	-

a. Equal quantities of limpets, cockles and mussels.
b. The consumption rate figure in the 2001 report should have been 1.59 kg y^{-1}.

Table 21. Summary of doses associated with marine discharges (µSv)

a. Critical group consumers of seafoods (St Bees - Selker)

Radionuclide	Cod	Plaice	Lobster	Crab	*Nephrops*	Winkles	Limpets	Mussels	Cockles	Total for radionuclide
Total tritium	0.02	0.02	-	-	-	-	-	-	-	0.04
Carbon-14	1.4	1.4	0.73	1.0	0.21	0.90	0.20	0.43	0.32	6.6
Cobalt-60	0.01	0.02	0.05	0.16	0.003	0.27	0.05	0.07	0.16	0.8
Strontium-90	0.08	0.07	0.08	0.38	0.02	0.28	0.44	0.13	0.15	1.6
Zirconium-95	0.008	0.005	0.005	0.01	0.001	0.009	0.003	0.003	0.006	0.05
Niobium-95	0.001	0.001	-	0.001	0.0002	0.002	-	0.0005	0.0007	0.007
Technetium-99	0.02	0.13	15	0.93	2.5	6.1	6.8	5.1	0.17	36
Ruthenium-106	0.19	0.19	0.08	0.27	0.05	1.6	0.40	0.42	0.20	3.4
Silver-110m	-	-	-	-	-	0.08	0.02	0.005	0.009	0.12
Iodine-129	0.95	0.03	3.9	0.21	0.008	0.36	0.12	0.13	-	5.7
Caesium-134	0.08	0.06	-	-	-	-	-	-	-	0.14
Caesium-137	1.6	1.1	0.13	0.28	0.6	0.63	0.29	0.09	0.2	4.4
Neptunium-237	-	-	0.01	0.007	0.0009	0.02	0.009	0.02	0.05	0.12
Plutonium alpha	0.14	0.23	0.49	1.3	0.40	8.9	9.2	7.1	11	38
Plutonium-241	-	-	0.08	0.02	0.05	1.3	1.4	1.1	1.5	5.4
Americium-241	0.15	0.29	5.9	4.3	1.2	12	13	10	19	66
Total for species	4.6	3.5	26	8.7	4.6	33	32	25	32	169
Total for group	169									

b. Local consumers of seafoods

Radionuclide	Whitehaven fisheries seafoods consumers	Typical seafoods consumers
Total tritium	0.05	0.02
Carbon-14	3.5	0.57
Cobalt-60	0.15	0.01
Strontium-90	0.15	0.07
Zirconium-95	0.03	0.005
Niobium-95	0.005	0.001
Technetium-99	11	0.07
Ruthenium-106	0.99	0.16
Silver-110m	0.04	-
Iodine-129	0.4	0.15
Caesium-134	0.21	0.07
Caesium-137	4.1	1.2
Neptunium-237	0.02	-
Plutonium alpha	6.2	0.09
Plutonium-241	0.81	-
Americium-241	13	0.09
Total	41	2.5

48 Tables 21a and 21b show doses to the critical group of consumers of seafood (caught locally between St Bees and Selker) and to other local groups of people, i.e. consumers associated with the Whitehaven fishery and typical members of the fish-eating public. The estimated critical group dose was about 170 µSv compared to 120 µSv in 2001. This increase was mainly due to increases in environmental concentrations of americium-241 and plutonium in molluscs; technetium-99 in crustaceans; and to a lesser extent, increases in consumption rates of these foodstuffs. An assessment has shown that the group may have also received about 10 µSv from other pathways, such

Table 22. Consumption rates of critical group consumers associated with aerial discharges

Foodstuff[a]	Consumption rate (kg y^{-1})		
	Adults	Children	Infant
milk	240	240	320
beef	15	15	3
beef liver	5.5	3	1
mutton	8	4	0.8
poultry	10	5.5	2
game	6	4	0.8
fish	15	6	3.5
leafy vegetables[b]	-	-	-
root vegetables[c]	50	45	10
fruit[d]	25	10	2
honey	2.5	2	2
eggs[e]	8.5	6.5	5

a. based on NRPB/MAFF recommendations[9].
b. Not available this year due to competition from local supermarkets.
c. local potatoes only. d. soft fruit only. e. hens' eggs only.

Table 23. Parameters for external radiation pathways (direct and plume immersion)[10, 11]

	Adults	Children	Infant
Occupancy (%)	100	100	100
Time indoors (%)	66	90	90
Building shielding factor	0.2	0.2	0.2

as inhalation and consumption of agricultural produce. The doses from the consumption of molluscs are likely to be overestimated because no account has been taken of the effects of food preparation procedures, such as the soaking of winkles to eliminate their gut contents which contain most of the actinide radioactivity (adsorbed onto silt particles). Doses to typical fish-eating members of the public were as usual very low and the same as last year (2.5 μSv). Doses to consumers associated with the Whitehaven fishery (41 μSv) were similar to those last year (45 μSv).

49 The Food Standards Agency and the Environment Agency[1] continue to keep under review the amount of time spent by members of the public on intertidal areas of the coastline bordering the north-east Irish Sea and more inland locations. In particular, it was considered that members of the critical group received an external contribution to their radiation exposure from spending up to 1000 hours each year on local beaches. This additional dose was estimated to be 28 μSv using averaged habit data for 1998-2002.

Airborne and terrestrial pathways

50 For some years BNFL has used consumption rates obtained from the approach used by MAFF/ Food Standards Agency[9], whereby several dose assessments are carried out to establish which foodstuffs contribute the maximum dose at higher critical group consumption rates. Using this process, the two food groups identified as making the highest contribution to dose are assigned critical group (higher) consumption rates. The remainder are assigned national mean consumption rates. The consumption rates used for 2002 are summarised in table 22. In addition to changes in food consumption rates, BNFL has adopted the generic advice of NRPB on parameters relating to external radiation pathways (table 23)[10,11].

51 Based on the average concentrations of radioactivity in milk (excluding ruthenium-106) reported in table 14, the estimated dose to infants who drink milk obtained only from local farms would have been about 14 μSv and the corresponding doses to adults and children about 3.5 and 5.8 μSv (table 24). The doses from ruthenium-106 in milk shown in table 24 were assessed using standard modelling techniques[9,12,13] (as used by NRPB and others) which are based on knowledge of the transfer of this radionuclide through the food chain. Realistic dose estimates cannot be obtained from the milk analytical data because they are all below the limit of detection.

52 Based on the average concentrations reported in tables 13, 15 and 16 for radioactivity in air, and in terrestrial foodstuffs other than milk, infants would have received an estimated dose of up to 3.5 μSv (9.4 and 6.9 μSv for adults and children) from these other foodstuffs and from inhalation. Detailed data are provided in tables 24 and 25.

53 Table 25 shows that the main radionuclides contributing to dose were iodine-131, strontium-90, caesium-137, ruthenium-106 (but probably greatly overestimated, as was previously the case with milk, because all analytical data are below detection limits), and iodine-129. Most of the dose from strontium-90 arose from site discharges, and fallout from the testing of nuclear weapons, in the 1950s and 1960s.

54 The adult members of the critical group also received a dose of about 4.5 μSv arising from liquid effluent discharges. This dose contained an external component (2 μSv) from radioactivity deposited on local beaches, based on an occupancy time of 30 hours per year, and an internal component (2.5, 1.2 and 1.3 μSv respectively to adults, children and infants) from an assumed consumption of locally caught fish (table 26).

55 The critical group will also receive exposure due to immersion in a plume containing argon-41 discharged from the reactors at Calder Hall and, to a lesser extent, from krypton-85 discharged from the reprocessing plants (table 27). The doses to adults, children and infants living near to Sellafield would have been respectively 6.6, 4.4 and 4.4 μSv using modelling and dosimetry published by the EU and the ICRP[12,13]. These doses arose mainly from argon-41 with krypton-85 contributing no more than 1.3 μSv. The argon-41 dose is lower than in 2001 reflecting reduced operation of the Calder Hall reactors (paragraph 5).

56 If all the above pathways are considered to be additive, the highest doses in 2002 were to infants (25 μSv) and adults (24 μSv), much lower that in 2001 because of reductions in doses from argon-41 and foodstuffs. Doses to children were a little lower. Doses to the terrestrial critical group from foodstuffs and inhalation are summarised in tables 24-26, whereas table 27 summarises the total doses to this group which include the contributions from argon-41 and krypton-85 in the air (an immersion dose) and from liquid effluent discharges. Pessimistically, it is assumed that members of this critical group are also exposed to direct radiation (see next paragraph and table 1).

Direct radiation

57 Reduced operations at Calder Hall (paragraph 5) have resulted in much reduced direct radiation doses to local residents. Thus the upper bound of the dose range to residents living closest to the site has decreased from 150 μSv (based on all four reactors operating throughput the year) to 19 μSv (for the much reduced operations in 2002).

Collective doses

58 Collective doses resulting from the effects of discharges from Sellafield in 2002, summed over 500 years, have been calculated in accordance with paragraphs 27-29 and 37 of the Introduction (amplified in the Appendix). The results (table 28) give collective dose commitments of about 5.5 man Sv to the UK population, 22 man Sv to the European population (including the UK) and 210 man Sv to the world population.

Table 24. Summary of doses to the terrestrial critical group from terrestrial foodstuffs and inhalation (μSv)

Radionuclide	Milk			Beef			Beef liver			Mutton		
	Adult	Child	Infant	Adult	Child	Infant	Adult	Child	Infant	Adult	Child	Infant
Tritium	0.03	0.04	0.11	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.0007
Carbon-14	0.15	0.20	0.54	0	0	0	-	-	-	0.007	0.005	0.002
Sulphur-35	0.03	0.06	0.26	0.0002	0.0004	0.0001	-	-	-	-	-	-
Strontium-90	1.02	2.18	3.53	0.05	0.10	0.03	0.02	0.02	0.009	0.02	0.03	0.006
Technetium-99	0.002	0.004	0.02	0.02	0.03	0.03	0.003	0.003	0.004	0.002	0.002	0.002
Ruthenium-106	0.0003	0.0006	0.002	0.08	0.17	0.11	0.02	0.03	0.03	0.04	0.04	0.02
Iodine-129	0.50	0.90	1.39	0.008	0.01	0.003	0.002	0.002	0.001	0.02	0.02	0.004
Iodine-131	0.60	1.47	6.78	-	-	-	-	-	-	-	-	-
Caesium-137	1.19	0.90	1.46	0.15	0.12	0.03	0.005	0.002	0.001	0.17	0.07	0.02
Plutonium alpha	0.009	0.01	0.02	0.005	0.006	0.002	0.003	0.002	0.001	0.003	0.001	0.0005
Americium-241	0.008	0.009	0.02	0.006	0.007	0.002	0.002	0.001	0.001	0.003	0.001	0.0005
Total	3.53	5.77	14.13	0.31	0.45	0.19	0.05	0.06	0.05	0.27	0.16	0.05

Radionuclide	Poultry			Eggs			Game			Honey		
	Adult	Child	Infant	Adult	Child	Infant	Adult	Child	Infant	Adult	Child	Infant
Tritium	0.002	0.002	0.001	-	-	-	0.001	0.001	0.0005	0.001	0.001	0.002
Carbon-14	0.006	0.005	0.004	0.010	0.008	0.02	0.006	0.004	0.002	0.008	0.007	0.02
Sulphur-35	-	-	-	-	-	-	-	-	-	-	-	-
Strontium-90	0.03	0.04	0.02	0.02	0.02	0.04	0.02	0.01	0.007	0.002	0.002	0.005
Technetium-99	0.07	0.08	0.10	0.002	0.001	0.008	0.006	0.004	0.006	-	-	-
Ruthenium-106	0.23	0.23	0.32	0.04	0.03	0.16	0.13	0.08	0.12	0.04	0.03	0.23
Iodine-129	0.004	0.004	0.002	0.04	0.03	0.05	-	-	-	-	-	-
Caesium-137	0.06	0.03	0.01	0.02	0.01	0.008	0.28	0.19	0.04	0.06	0.05	0.05
Plutonium alpha	0.005	0.003	0.002	0.003	0.002	0.003	0.002	0.002	0.001	0.001	0.001	0.001
Americium-241	0.004	0.002	0.001	0.002	0.002	0.002	0.002	0.002	0.001	-	-	-
Total	0.41	0.38	0.46	0.13	0.10	0.28	0.45	0.30	0.17	0.12	0.09	0.30

Radionuclide	Potatoes			Blackberries			Inhalation		
	Adult	Child	Infant	Adult	Child	Infant	Adult	Child	Infant
Tritium	0.006	0.007	0.003	0.008	0.004	0.002	-	-	-
Carbon-14	0.02	0.02	0.01	0.05	0.03	0.01	-	-	-
Sulphur-35	0.005	0.01	0.007	0.007	0.006	0.004	-	-	-
Strontium-90	0.09	0.18	0.05	3.1	2.66	0.65	0.001	0.001	0.001
Zirconium-95	-	-	-	-	-	-	0.0004	0.0004	0.0003
Niobium-95	-	-	-	-	-	-	0.00002	0.00003	0.00002
Technetium-99	0.05	0.08	0.07	0.004	0.003	0.002	-	-	-
Ruthenium-103	-	-	-	-	-	-	0.0003	0.0001	0.0001
Ruthenium-106	0.30	0.57	0.42	0.57	0.49	0.32	0.01	0.01	0.01
Iodine-129	0.02	0.04	0.009	0.05	0.03	0.007	-	-	-
Caesium-134	-	-	-	-	-	-	0.0003	0.0002	0.00009
Caesium-137	0.07	0.05	0.01	2.74	0.84	0.20	0.001	0.001	0.0004
Plutonium alpha	0.02	0.02	0.005	0.03	0.01	0.004	0.21	0.15	0.08
Plutonium-241	-	-	-	-	-	-	0.09	0.06	0.02
Americium-241	0.009	0.008	0.003	0.02	0.008	0.003	0.19	0.14	0.08
Total	0.58	0.98	0.58	6.57	4.08	1.20	0.50	0.36	0.20

Table 25. Summary of radionuclide doses to the terrestrial critical group from terrestrial foodstuffs and inhalation

Radionuclide	Total dose per radionuclide (μSv)		
	Adult	Child	Infant
Tritium	0.05	0.06	0.12
Carbon-14	0.25	0.28	0.60
Sulphur-35	0.04	0.08	0.27
Strontium-90	4.38	5.24	4.33
Zirconium-95	0.0004	0.0004	0.0003
Niobium-95	0.00002	0.00003	0.00002
Technetium-99	0.15	0.21	0.24
Ruthenium-103	0.0001	0.0001	0.0001
Ruthenium-106	1.44	1.68	1.72
Iodine-129	0.64	1.03	1.46
Iodine-131	0.60	1.47	6.78
Caesium-134	0.0003	0.0002	0.00009
Caesium-137	4.74	2.25	1.82
Plutonium alpha	0.28	0.20	0.12
Plutonium-241	0.09	0.06	0.02
Americium-241	0.25	0.18	0.11
Total	12.9	12.7	17.6
Total (foodstuffs only)	12.4	12.3	17.4
of which milk	3.5	5.8	14.1

Table 26. Summary of doses to the terrestrial critical group from seafood consumption (μSv)

Radionuclide	Fish (cod and plaice)		
	Adult	Child	Infant
Tritium	0.02	0.009	0.01
Carbon-14	0.77	0.43	0.50
Cobalt-60	0.01	0.02	0.02
Strontium-90	0.06	0.05	0.04
Zirconium-90	0.003	0.003	0.005
Niobium-95	0.0007	0.0005	0.0009
Technetium-99	0.07	0.06	0.12
Ruthenium-106	0.13	0.11	0.22
Iodine-129	0.03	0.02	0.01
Caesium-134	0.05	0.02	0.01
Caesium-137	1.2	0.36	0.25
Plutonium alpha	0.09	0.04	0.03
Americium-241	0.10	0.05	0.05
Total	2.51	1.15	1.27

59 Most of the collective dose commitment from Sellafield's discharges results from carbon-14 because of its long radioactive half-life (5760 years) and its incorporation into the global carbon cycle. However, individual doses from this source are generally small.

60 Concentrations of carbon-14 in the atmosphere which are attributable to Sellafield are indistinguishable from naturally occurring background concentrations at distances exceeding 100 km. The natural background gives rise to collective doses that are many orders of magnitude higher than the doses resulting from Sellafield's discharges of carbon-14 (table 29). This reflects the fact that natural sources of radiation constitute the largest source of public radiation exposure on a national or global scale[14].

Table 27. Summary of doses to the terrestrial critical group (μSv)

Pathway	Adult	Child	Infant
Food consumption:			
terrestrial foods	12.4	12.3	17.4
marine foods	2.5	1.2	1.3
Inhalation	0.5	0.4	0.2
Immersion:			
argon-41	5.3	3.2	3.2
krypton-85	1.3	1.2	1.2
External	2	2	2
Total	24	20	25

Table 28. Collective doses from Sellafield's discharges

Radionuclide	Collective dose (man Sv)					
	Aerial discharges			Marine discharges		
	UK	Europe	World	UK	Europe	World
Tritium	0.18	0.41	0.48	0.002	0.007	0.15
Carbon-14	0.18	1.6	15	3.1	12	160
Krypton-85	0.51	2.7	28	-	-	-
Technetium-99	-	-	-	0.16	0.43	0.45
Iodine-129	0.92	4.4	6.3	0.02	0.05	0.21
Caesium-137	0.02	0.04	0.04	0.12	0.29	0.34
Plutonium alpha	0.003	0.005	0.005	0.03	0.05	0.05
Americium-241	0.002	0.004	0.004	0.001	0.001	0.001
Other nuclides	0.03	0.04	0.04	0.20	0.41	0.43
Total	1.8	9.3	51	3.6	13	160

Table 29. Annual collective dose commitments from natural radiation

Source of collective dose	Collective dose commitment (man Sv per year)		
	UK population[a]	European population[a]	World population[a]
Natural carbon-14	660	8400	72,000
All sources of natural radiation	130,000	1,600,000	13,000,000

a. In this context, Europe includes Greenland, Iceland, Scandinavia, and Western Russia up to 50°E. This represents a total European population of 700 million, including 55 million in the UK. The world population is taken to be six billion.

Non-radioactive discharges and disposals

61 Non-radioactive discharges and disposals from the Sellafield site are made in accordance with the requirements of the authorisations, consents and licences which are discussed below and listed in the annex to this chapter. Liquid effluent discharges are summarised in table 30 and include all discharges for which load or concentration limits are specified, together with other discharges for which no limits have been specified. Aerial effluent discharges are summarised in table 31. Unless otherwise specified, all discharges were within the relevant limits.

Discharges made under the terms of Prescribed Process authorisations

62 Two of the main activities on the Sellafield site, the reprocessing of irradiated Magnox and oxide reactor fuels, are subject to the requirements of two separate Part A (non-ferrous metals) IPC authorisations. These contain limits on both liquid and aerial non-radioactive discharges.

63 The encapsulation plants (paragraph 7) are also subject to authorisation by the local authority as Part B Prescribed Processes (bulk cement handling processes) for air pollution control only. This authorisation contains no numerical limits on discharges. Liquid effluents from these plants are discharged under the terms of consents issued by the Environment Agency (see below).

Discharges made under the terms of consents

64 Liquid effluent discharges, from plants on the Sellafield site not covered by the IPC authorisation, are subject to separate discharge consents. These include the Calder Hall nuclear power station, sewage and water treatment plants, encapsulation plants, and the Thorp cooling towers. These consents generally place limits on pH, temperature and a range of instantaneous concentrations.

65 In particular, the Calder interceptor sewer constructed on the southern side of the River Calder, receives outfalls which had previously discharged directly into the river. This sewer discharges directly to sea via a pipeline outfall. It was installed primarily to protect the River Calder from non-radioactive pollutants and consequently is not authorised to discharge radioactivity. Similarly, discharges from the Geoffrey Schofield Laboratories into the public sewerage system are subject to the conditions of a consent issued by North West Water.

66 In January, Calder Hall exceeded its 30°C limit on outfall temperature by 5°C when blowdown water was discharged to the Calder interceptor sewer while the cooling towers were out of service. Process water drawn from the River Ehen was diverted to provide dilution flow, preventing a recurrence. The station had previously advised the Environment Agency that the sampling point was inappropriate and recognising that this non-compliance was related to that issue, no enforcement action was taken.

Disposals made under the terms of Waste Disposal or Waste Management Licences

67 There are five licensed landfill sites at Sellafield although three are effectively closed. The South Landfill Site and the Calder Floodplain Landfill Extension are operational and are permitted to take a range of inert, non-radioactive wastes and are also authorised to take radioactive soil (see paragraph 25). In recent years, these two sites have been reserved almost exclusively for radioactive soil as the only alternative site is Drigg. Non-radioactive soil and other non-radioactive wastes are usually sent for off-site disposal.

Ozone depleting substances

68 The Company is committed to minimising the use of ozone depleting substances. Routine releases are estimated from the amounts used to top up systems on site. There were also a small number of accidental releases of HCFC-22 from refrigeration equipment. Site releases of ozone depleting substances are summarised in table 32.

Carbon dioxide and other greenhouse gases

69 The Calder Hall nuclear reactors use carbon dioxide gas for cooling. During the course of operation, some carbon dioxide is released to atmosphere (table 31). It should be noted that this carbon dioxide is produced as a by-product of another chemical industry and would otherwise have been released directly to the atmosphere. It is not produced in the reactor. There are other smaller adventitious releases of carbon monoxide and methane from the reactor gas circuit. In addition, small amounts of carbon dioxide are released from the waste oil burner and process plants.

70 Sulphur hexafluoride is used in small quantities for testing the effectiveness of stack and duct sampling systems (table 31).

Off-site disposals of solid waste

71 Non-radioactive controlled wastes consisting of office, canteen, workshop or general waste (mainly solid but including some sludges and liquids) are disposed of off-site via a specialist waste disposal contractor. Wherever possible, waste is recycled (1040 te in 2002) but if this is not

Table 30. Non-radioactive liquid effluent discharges (te)[a]

Release point	Hg	Cd	Cu	Zn	Pb	Cr	As	B	Ba	Ni	Fe	N as NH_3	N as NO_3	N as NO_2	Total suspended solids	COD	Glycol	TBP
Sea tanks, SETP, EARP	0.0002 (0.03)	-	0.009 (0.50)	0.010 (0.28)	0.008 (0.20)	0.025 (0.42)	-	0.19 (15.8)	-	0.009 (0.18)	0.46 (44)	-	1250 (4078)[b]	67	5.6	-	0.56 (12)	24
SIXEP	0	-	0.0004	0.002	0.0007	-	-	-	-	0.002	-	-	-	-	-	-	0.38 (12)	-
Lagoon	-	-	0.008 (0.05)	0.038 (0.12)	0.003	-	-	-	-	-	-	-	-	-	-	-	-	-
Laundry	-	-	0.001	0.013	0.001 (0.012)	0.0007	-	-	-	0.0005	-	-	-	-	3.1	-	-	-
Thorp ponds	-	-	-	-	-	-	-	0.008	-	-	-	-	-	-	-	-	-	-
Thorp carbon-14 removal plant	0	0	-	-	-	-	-	-	0.054 (0.54)	-	-	-	2.1 (26.9)[b]	4.7	-	-	-	-
Seaburn sewer	0	0.0002	0.027	0.058	0.007	0.005	0.007	-	-	0.003	0.89	0.13	15	0.73	25	28	-	0.004
Calder interceptor sewer	0	0.0002	0.22	0.16	0.022	0.003	0.008	-	-	0.004	1.5	0.18	5.6	0.30	15	41	-	-
Totals	0.0002	0.0004	0.27	0.28	0.042	0.034	0.015	0.20	0.054	0.019	2.9	0.31	1273	73	49	69	0.94	24

a. Data presented is either load data (based on bulk sampling) as reported under the terms of the IPC Authorisation, or is estimated from spot sample results. Load limits, where they are specified, are given in brackets.
b. Nitrogen load limits apply to nitrate plus nitrite nitrogen.

Figure 8. Non-radiological environmental monitoring at Sellafield

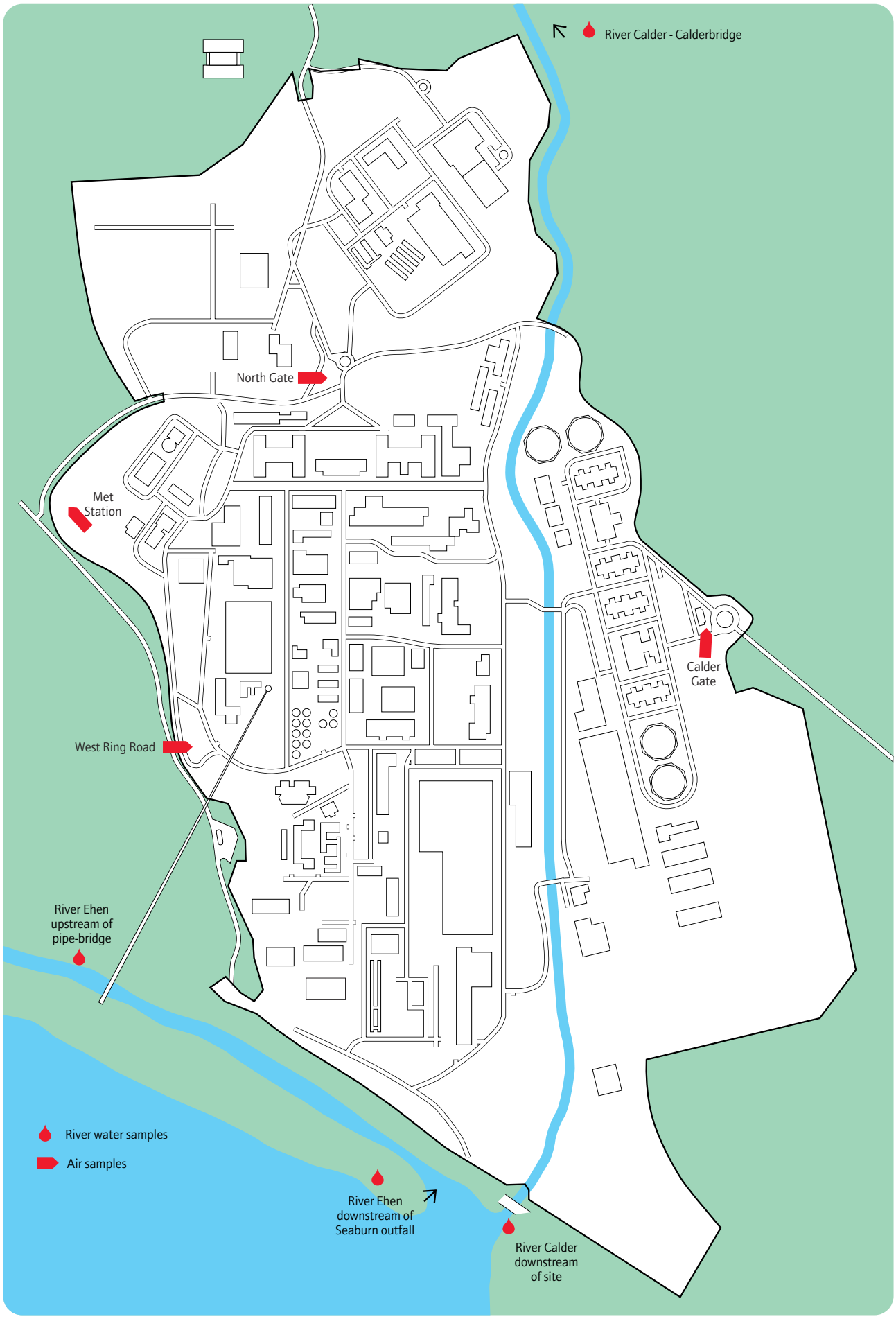


Table 31. Non-radioactive aerial effluent discharges

Substance	Release point	Discharge (te)	Annual Limit (te)
Oxides of nitrogen (as NO_2)	Thorp main stack	18	90
Oxides of nitrogen (as NO_2)	Thermal denitration plant scrubber, oil incinerator	0.81	35
Oxides of nitrogen (as NO_2)	B204 stack, B6 cell vent stack, WVP secondary off- gas system, B230 stack, EARP, SETP, STP stack	57	-
Volatile organic compounds (VOCs)	B204 stack, B6 cell vent stack, STP stack, flask maintenance paint spray booth, Thorp main stack	94	-
Particulate matter	STP stack, flask maintenance grit blast booth	0.00076	0.05
Uranium	B204 stack, B6 cell vent stack, thermal denitration plant scrubber, WVP secondary off-gas system, STP stack	0	-
Carbon dioxide	Calder Hall reactor stacks, B204 stack, B6 cell vent stack, SIXEP stack, oil incinerator	3000	-
Carbon monoxide	Calder Hall reactor stacks, B230 stack	2.2	-
Methane	Calder Hall reactor stacks, STP stack	0.27	-
Sulphur hexafluoride	Ventilation system commissioning and testing	0	-

Table 32. DIscharges of ozone depleting substances

Substance	Discharge (te)[a]
HCFC-22	0.62
Carbon tetrachloride	0.12
Halon	0

a. Based on usage rates.

Table 33. Disposals of non-radioactive solid wastes

	Quantity (te)
Controlled waste (excluding special waste)	2400
Special waste	
oils/oil contaminated materials	140
chemicals/chemical contaminated materials	45
cement powder	28
paints/resins	11
lead-acid batteries	13
asbestos	7.0
alkaline batteries	1.7
empty aerosol containers	1.2
fire fighting powders	1.0
ODS/ODS contaminated	0.5

practicable, it is disposed of to a licensed landfill. Waste which is particularly hazardous may have to be considered as special waste and disposed of to specially licensed disposal facilities after pre-notifying the Environment Agency. In order to reduce the amount of low-level radioactive waste sent for disposal at Drigg, which is a national resource with limited capacity, some wastes arising in process areas of the site are carefully monitored to confirm that they are not radioactive before they too are sent for disposal off-site with other controlled wastes. Disposals of these different categories of waste are summarised in table 33. It should be noted that radioactive special waste is also included in the Drigg disposal figures.

Non-radiological monitoring of the environment

72 Prior to 1996, there was no requirement on BNFL to carry out non-radiological environmental monitoring. However, the Prescribed Process authorisations, which came into force that year, included an improvement requirement for BNFL to agree a monitoring programme with the Environment Agency which was implemented from 1 January 1997 (see figure 8). Compared to the radiological environmental monitoring programme, its scope is limited and comprises local air sampling on the Sellafield site, water sampling from the Rivers Calder and Ehen, and offshore seawater sampling from near the end of the pipeline.

Air sampling

73 Measurements of nitrogen dioxide and sulphur dioxide concentrations in air are made at four locations on the Sellafield site: West Ring Road, Meteorological Station, North Group roundabout and Calder Gate. (It should be

Table 34. Non-radioactive air sampling

	Mean concentration in air (µg m^{-3})					
	NO_2	SO_2	Lead	Vanadium	Cadmium	Phosphorus
North Gate	15	2.5	0.001	0.0002	0.00003	0.006
Meteorological Station	11	3.8	0.003	0.0001	0.00004	0.005
Calder Gate	13	2.9	0.002	0.0002	0.00007	0.005
West Ring Road	17	2.2	0.002	0.0001	0.00004	0.004
NAQS objective[a]	40	20	0.25	-	-	-
1% LTEL[a]	-	-	-	0.5	0.5	6.7

a. See paragraph 76.

Table 35. Non-radioactive sampling of river waters

	pH	Conductivity (µSiemens cm^{-1})	milligrammes per litre			
			NO_3	N as NO_2	Fe	TBP
River Calder - Calderbridge	7.4	110	7.7	0.040	0.11	1.2
River Calder - downstream of site	7.3	87	3.0	0.021	0.11	1.0
River Ehen - upstream of pipebridge	7.5	1500	15	0.031	0.29	1.5
River Ehen - downstream of Seaburn outfall	7.7	170	5.5	0.039	0.23	2.0

Table 36. Water and gas sampling on Sellafield's landfill sites

Surface water analysis	pH	Temperature (°C)	Conductivity (µSiemens cm^{-1})	Dissolved O_2 (ppm)	N as NH_3 (mg l^{-1})	Cl (ppm)	COD (mg l^{-1})	Total suspended solids (mg l^{-1})
North Landfill Site Extension								
Stream to north	7.5	9.6	310	9.5	0.08	31	27	63
River Calder upstream	7.1	7.7	120	11	0.01	11	7.4	2.7
River Calder downstream	7.2	8.2	120	11	0.04	11	16	1.5
North Landfill Site								
River Calder upstream	7.2	8.2	120	11	0.01	11	9.4	8.7
River Calder downstream	7.4	8.2	120	11	0.02	11	7.2	9.1
Calder Floodplain Landfill								
River Calder downstream	7.6	8.0	360	10	0.19	56[a]	30	8.4
Calder Floodplain Landfill Extension								
New Mill Beck upstream	7.1	8.0	280	8.5	0.20	34	34	20
River Calder downstream	7.3	8.3	270	10	0.21	31	30	22
South Landfill Site								
River Calder upstream	-	-	-	-	-	-	-	-
River Calder downstream	7.4	7.5	0.14	11	0.02	14	8.6	1.4

a. This figure reflects the high seawater content at the sampling location.

Gas spike probe monitoring	CH_4 (ppm)	CO_2 (%)	O_2 (%)
North Landfill Site Extension	0	1.8	19
North Landfill Site	0	2.6	18
Calder Floodplain Landfill	0.09	2.5	17
Calder Floodplain Landfill Extension	0	2.2	18
South Landfill Site	0	1.1	20

noted that significant discharges of these gases are also made from the nearby Fellside Combined Heat and Power plant and these will strongly influence airborne concentrations measured in the environment in the vicinity of Sellafield.) Measurements are made using passive diffusion tubes which are exposed for one month before being analysed. In addition, air samplers are used at the same locations for making measurements of heavy metals associated with particulates in air. Air sampling results are summarised in table 34.

Water sampling

74 Water samples are obtained from the Rivers Calder and Ehen at locations both upstream and downstream of the site (table 35). The downstream samples are taken above the confluence of the two rivers, and at times which minimise contamination with seawater. Samples of seawater are also obtained from above the diffuser of the Sellafield marine outfall, at the edge of the mixing zone to the north and south and also at points 4 km to the north

and south. All are monthly spot samples which are analysed for a range of contaminants in the authorised discharges. It has previously been noted that concentrations of certain metals in offshore seawater samples were very close to, and in some cases exceeded, the relevant Environmental Quality Standard. Investigations in 1999 suggested that this was due to errors in the sampling method. Sampling procedures were changed to be consistent with those used by the Environment Agency but analytical results were largely unchanged. Further investigations have identified a flaw in the analytical method. Validation of a revised analytical method is at an advanced stage. Previously reported results can be considered as upper bounds as the analytical method had been introducing a positive bias.

Monitoring of Sellafield's landfill sites

75 The Waste Management Licences for the North Landfill Site and Calder Floodplain Landfill Extensions require that environmental monitoring be carried out in the vicinity of these two sites. Although not a requirement of their licences, environmental monitoring is also carried out in the vicinity of the other landfill sites. The monitoring comprises monthly spot sampling of water from the River Calder upstream and downstream of the sites and quarterly gas monitoring over their surfaces. The results are summarised in table 36.

Environmental impact of non-radioactive discharges

76 In this report, the impact of aerial discharges has been addressed (table 34) by comparing the measured environmental concentrations with the most restrictive (annual mean) objectives of the National Air Quality Strategy (NAQS)[15] and, where no objective is specified, the Health and Safety Executive's Long Term Exposure Limits (LTELs)[16] using a guideline limit set at 1% of the LTEL. Comparison of liquid discharges with relevant Environmental Quality Standards[17] will resume when the current investigations are complete (see paragraph 74).

77 The interpretation of these results is not straightforward since discharges are made not only from Sellafield but also from other industrial sites in West Cumbria and from natural sources. The data in table 34 show that the measured concentrations in air on the Sellafield site were all below the guideline value.

78 Environmental monitoring results (table 36) confirmed that the impact of Sellafield's landfill sites remained negligible. No significant concentrations of carbon dioxide or methane from off gas were measured at these sites.

Acknowledgements

This chapter was written by Alison Tulloch, Mike Hadwin and Tim Parker of Site Safety Group at Sellafield. Their colleagues in this Group collected the environmental samples and measured environmental dose rates. The Geoffrey Schofield Laboratories at Westlakes Science Park, Cumbria, analysed the samples. Members of the public who co-operated with the BNFL staff collecting samples and making measurements are especially thanked.

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Annex: Authorisations, consents and Waste Disposal and Waste Management Licences effective in 2002

Authorisations issued under the Radioactive Substances Act 1960 and 1993

Description	Effective Date
Disposal of waste gases, mists and dusts from Sellafield. Notice of Variation. Notice of Variation.	17 Jan 1994 31 Mar 1996 1 Jan 2000[a]
Disposal of liquid waste to sea from Sellafield. Notice of Variation.	17 Jan 1994 1 Jan 2000[a,d]
Disposal of combustible wastes at Sellafield.	17 Jan 1994
Disposal of solid radioactive waste at Sellafield.	11 May 1976[b]
Sellafield to Drigg Inter-Site Transfer. Notice of Variation.	1 Jan 1992 1 Apr 1995
Accumulation and disposal of wastes, Geoffrey Schofield Laboratories.	31 Nov 1991[c]
Accumulation and disposal of wastes (by transfer to BNFL), Geoffrey Schofield Laboratories	1 Jan 1992[b]
Replaced by new authorisation	1 Oct 2001[a]

a. Authorisations issued by Environment Agency.
b. Separate authorisations issued by DoE and MAFF.
c. Authorisation issued by HMIP.
d. A further Notice of Variation took effect on 23 July 2003.
All other authorisations in this list were issued jointly by HMIP and MAFF.

Prescribed Process authorisations issued under the Environmental Protection Act 1990

Number	Description	Effective Date
AS5598[a]	Reprocessing of oxide fuel at Sellafield, Cumbria.	31 Mar 1996
AS5601[a]	Reprocessing of Magnox fuel at Sellafield, Cumbria.	31 Mar 1996
CBC/95/009[a]	Blending, loading and use of bulk cement - MEP, WEP, WPEP and WTC.	15 Oct 1996
CBC/LAPC/22	Concrete crushing operations.	23 Feb 1999

a. Several variations have been issued to reflect changing environmental, process and commissioning circumstances.

Consents issued under the Control of Pollution Act 1974 and Water Resources Act 1991

Number	Description	Effective Date
1963/130	Discharge of trade effluent from Brow Top water treatment plant.	1 Jul 1966
017490082	Discharge of sewage effluent to the River Ehen.	7 Jun 1982
017490091	Discharge of water treatment plant regeneration liquid from F113 to Calder Interceptor Sewer.	20 Mar 1996
017490092	Discharge of cooling water via Point J to the River Calder.	3 Jul 1984
017490093	Discharge of cooling water via Point K to the River Calder.	3 Jul 1984
017490094	Discharge of trade effluent (boiler water, turbine hall water, blower house water) and cooling water via Point T.	3 Jul 1984
017490123	Discharge of bandscreen backwash waters via Point G to the River Calder.	22 Nov 1985
017490128	Discharge of process water from a River Calder water treatment plant to the River Ehen via site sewer outfall.	28 Apr 1986
017490278	Discharge of trade effluent (cement washings and steam condensate) from MEP to the River Ehen.	16 Apr 1993
017490280	Discharge from oil/water separators, rail tanker unloading facility adjacent to Sellafield station.	15 Jul 1993
017490298	Discharge of trade effluent to the River Calder by way of a storm overflow from the Calder Interceptor Sewer.	13 Mar 1995
017490316	Discharge of trade effluent from B386 Waste Encapsulation Plant.	18 Aug 1995
017490326	Discharge of B164 water treatment plant regeneration liquid to Calder Interceptor Sewer.	15 Aug 1996
017490330	Discharge of site drainage from the North Landfill Extension to the Calder Interceptor Sewer.	17 Jul 1997
017490337	Discharge of treated condensate from Sellafield Drypac Plant.	7 May 1999
017490343	Discharge of trade effluent comprising treated condensate, process water and domestic water (from B241).	26 May 2000
017490352-4	Discharge of condensates and cooling water from B33.	19 June 2001

Consents issued under the Water Industry Act 1991

Number	Description	Effective Date
C91/N51/02 /24/02	Discharge of trade effluent from Geoffrey Schofield Laboratories.	7 Nov 1991

Waste Disposal and Waste Management Licences issued under the Waste Management and Licensing Regulations 1994

Number	Description	Effective Date
55	North Landfill Site	25 Aug 1978
	- modification	14 Dec 1981
55/M3	- modification	21 Dec 1992
	- modification	16 Apr 1999
56	South Landfill Site	25 Aug 1978
	- modification	14 Dec 1981
	- modification	18 Jan 1985
56/M3	- modification	21 Dec 1992
56/M4	- modification	21 May 1997
	- modification	16 Apr 1999
79	Calder Floodplain Landfill Site	3 Nov 1981
	- modification	18 Jan 1985
	- modification	21 Dec 1992
	- modification	16 Apr 1999
128	Calder Floodplain Landfill Extension	6 Jan 1989
128/M1	- modification	21 Dec 1992
128/M3	- modification	10 May 1997
128/M4	- modification	23 Dec 1997
	- modification	16 Apr 1999
128/M6	- modification	18 Jul 2001
301	North Landfill Extension	11 Mar 1997
301/M1	- modification	2 Jul 1997

Discharges and Monitoring of the Environment in the UK Annual Report 2002

drigg

Summary

1 At no time during 2002 have disposals of radioactive wastes at Drigg or discharges of radioactivity from the site exceeded the numerical limits laid down in any of the Certificates of Authorisation.

2 Monitoring of the principal pathways by which members of the public may be affected by disposals at Drigg confirms their low radiological impact. Estimated doses in the vicinity of the Drigg site are summarised in table 1.

3 There were no instances in 2002 of non-compliance with numerical limits in consents covering non-radioactive discharges to the Irish Sea.

Operations at Drigg

4 The Drigg site is located about 6 km south-east of Sellafield and is owned and operated by BNFL. It receives low level, solid radioactive waste arising from operations at Sellafield and is also the principal disposal site for low level waste from nuclear sites throughout the UK as well as from UK industrial, academic and hospital sources.

5 Waste sent for disposal at Drigg is dispatched in accordance with the consignors' own RSA disposal authorisations issued to them by the Environment Agency and SEPA. In addition, all waste disposals must comply with BNFL's Conditions for Acceptance. These include requirements that ensure compliance with the authorisation applicable to the Drigg site itself and a requirement that consignors have their own appropriate quality assurance arrangements in place.

6 In the early years of waste disposal at Drigg, wastes were 'landfilled', i.e. tipped into open trenches before being covered with a layer of earth. The last trench was filled in March 1995. All trenches have now been covered with an impermeable membrane and landscaped (a final site cap will be installed as part of the eventual site closure). Wastes are now, wherever possible, compacted and containerised before transfer to Drigg. For the majority of wastes, this is done in the Waste Monitoring and Compaction (WAMAC) facility located on the Sellafield site. Uncompactable wastes are placed directly into the disposal containers. At Drigg, the waste is immobilised within the disposal containers by the addition of grout in the Drigg Grouting Facility prior to being emplaced in an engineered concrete vault. An operational strategy is being developed to accelerate processing of the last remaining batch of compactable wastes delivered to Drigg prior to the introduction of high force compaction; this is referred to as backlog waste. This waste is currently stored in the Drigg Vault within full height ISO-freight containers and has been progressively returned to Sellafield for compaction over recent years.

7 A quantity of plutonium contaminated waste (PCM), both drums and larger items, is currently stored at Drigg awaiting monitoring, retrieval and transfer to Sellafield for conditioning and treatment. Prior to final disposal, it will be stored at Sellafield. Movements of PCM from Drigg to Sellafield began in 1997. The construction of new facilities to provide enhanced PCM retrieval rates was completed in 2002. Commissioning and other operations are on course for achieving the December 2006 target for completing PCM removal from the Drigg site.

Radioactive discharges and disposals

8 Drigg holds a number of authorisations covering discharges and disposals of radioactive wastes to sea and to atmosphere and by transfer to other BNFL sites. They are listed in the Annex to this chapter.

9 The Environment Agency has advised BNFL that it will commence a full review of the solid waste disposal authorisation in Autumn 2003. Meanwhile, in April 2002 it issued new requirements, including monitoring of radioactive discharges, covering aerial effluents from stacks associated with PCM recovery operations and the Drigg grouting facility. As expected (see below), the results confirm that discharges are radiologically insignificant. To provide further confirmation of this, the site is required to operate a mobile high volume air sampler for a month at each of 12 approved places on the site and compare the results with those from the fixed air samplers in the Statutory Environmental Monitoring Programme. For convenience, the results are reported with that programme in table 9.

Solid wastes

10 Typical constituents of radioactive low level solid waste for disposal at Drigg (table 2) include, for example, paper, cardboard, plastic, protective clothing, electric cabling, scrap metal and excavation spoil. Wastes from some customers include process wastes, filters, resins, catalysts and luminising compounds

Table 1. Summary of critical group doses in the vicinity of Drigg (μSv)

Pathway	2001	2002	Position in text (paragraph no.)
Seafood consumption	0.01	0.01	26
Inhalation (adults)	0.2	0.2	28
Milk consumption (infants)	3.1	3.5	29
Fruit and vegetables (adults)	1.3	1.4	30
All discharge pathways (infants)	3.6	4.1	31
Direct radiation	84	84	33
Total dose to critical group	88	88	31, 33

Table 2. Disposals of solid radioactive waste at Drigg

Radionuclide	Radioactivity disposed (TBq)					Authorised Limit (TBq)
	1998	1999	2000	2001	2002	
Tritium	8.1	0.41	1.2	0.17	1.8	10
Carbon-14	0.013	0.007	0.012	0.006	0.013	0.05
Cobalt-60[a]	0.41	0.21	0.11	0.07	0.19	2
Iodine-129	0.0001	0.0002	0.00004	0.00007	0.00004	0.05
Others[b]	8.6	3.5	1.9	1.9	2.4	15
Radium-226 + Thorium-232	0.011	0.004	0.003	0.001	0.001	0.03
Uranium	0.031	0.033	0.049	0.019	0.016	0.3
Other alpha[c]	0.17	0.08	0.04	0.03	0.03	0.3
Volume (m^3)[d]	12,600	8000	8400	6100	10,800	-

a. The cobalt-60 figure is included in 'others' as well as shown separately.
b. Defined in the current authorisation as:
i. iron-55 and beta emitting radionuclides with half lives greater than three months (excluding carbon-14, iodine-129 and tritium).
ii. not more than 2 TBq may be cobalt-60.
c. Alpha emitting radionuclides with half-lives greater than three months (excluding uranium, radium-226 and thorium-232).
d. These volumes represent the volume of the waste and its primary containment.

Table 3. Radioactivity in marine pipeline discharges and in the Drigg stream

Radionuclide	Marine pipeline[a]						Drigg stream					
	Annual discharge (TBq)					Authorised Limit (TBq)	Mean radioactivity concentration (Bq l^{-1})					Authorised Limit (Bq l^{-1})
	1998	1999	2000	2001	2002		1998	1999	2000	2001	2002	
Total alpha	<0.0001	<0.00007	0.0001	<0.00007	0.00007	0.1	<0.07	<0.05	0.13	<0.05	0.05	90
Total beta	0.002	0.001	0.002	0.001	0.001	0.3	0.85	0.56	0.54	<0.47	0.43	1200
Tritium	0.50	0.39	0.51	0.36	0.34	120	50	59	32	35	21	600,000
Strontium-90	-	-	-	-	-	-	<0.43	<0.45	<0.39	<0.39	<0.40	-
Caesium-137	-	-	-	-	-	-	<0.18	<0.17	<0.19	<0.16	<0.23	-
Uranium	-	-	-	-	-	-	0.021	0.023	<0.30	0.021	<0.018	-
Plutonium alpha	-	-	-	-	-	-	<0.005	<0.005	<0.006	<0.005	<0.004	-
Americium-241	-	-	-	-	-	-	<0.009	0.097	0.02	<0.008	<0.008	-

a. Total flow down the pipeline in 2002 was 89,000 m^3.

Liquid discharges via the marine pipeline and Drigg stream

11 Radioactive liquid leaching from the disposal trenches and surface water from the disposal area is discharged directly to sea via a marine pipeline (table 3).

12 Other surface water entering the Drigg stream discharges into the intertidal region of the River Irt at the southern corner of the site (table 3).

Aerial discharges

13 Low level waste and PCM operations at Drigg do not give rise to any significant aerial discharges of radioactivity. This was confirmed by sampling of discharges on stacks associated with the Drigg Grouting Facility and Magazine 3 Retrieval Facility (table 4).

Table 4. Airborne radioactive discharges

Radionuclide	Annual discharge (MBq)
Total alpha	0.002
Total beta	0.014

Monitoring of the environment for radioactivity

14 Discharges of radioactivity from Drigg are very small compared with those from Sellafield. Consequently, the radioactivity in the environment resulting from them is virtually unmeasurable against the Sellafield 'background' and no specific critical groups for marine and terrestrial pathways associated with discharges from Drigg have been identified. However, in this report, critical group consumption and occupancy data for Sellafield were combined with environmental radioactivity and dose rate measurements in the vicinity of Drigg to give the estimates of dose in table 1. Monitoring locations are illustrated in figures 1 and 2.

Table 5. Radioactivity in molluscs and crustaceans from the Drigg area

Species	Mean radionuclide concentration (Bq kg^{-1} wet weight)										
	Total alpha	Total beta	^{60}Co	^{90}Sr	^{106}Ru	^{110m}Ag	^{137}Cs	Pu(α)	^{241}Pu	^{241}Am	U
Molluscs											
winkles	42	280	12	1.8	28	3.9	4.6	9.9	73	16	1.6
mussels	49	290	9.2	1.5	24	<0.62	2.3	9.9	80	19	2.1
limpets	48	480	5.6	2.7	15	3.4	5.4	9.5	72	16	3.3
Crustaceans											
crabs	-	-	1.5	0.58	<2.2	0.47	1.2	<0.36	2.6	1.3	0.22
lobsters	6.6	190	1.5	<0.20	<1.6	0.87	1.1	0.26	1.9	3.7	0.08

Table 6. Radioactivity in fish and seaweed from the Drigg area

Species	Mean radionuclide concentration (Bq kg^{-1} wet weight)								
	Total alpha	Total beta	^{60}Co	^{90}Sr	^{106}Ru	^{137}Cs	Pu(α)	^{241}Am	U
Fish									
cod/plaice	0.47	104	<0.27	<0.13	<1.7	5.0	0.019	0.033	-
Seaweed									
fucoid spp.	-	-	28	<9.0	8.6	6.4	32	9.2.	6.2

Table 7. Radioactivity in seawater particulates from the Drigg area

Mean radionuclide concentration (Bq in one litre of seawater)							
Total alpha	Total beta	^{60}Co	^{106}Ru	^{137}Cs	Pu(α)	^{241}Am	U
0.40	<0.72	<0.03	<0.23	0.048	0.24	0.13	0.003

Table 8. Mean gamma dose rates measured at 1m above ground level

Area of survey	Description	Nature of ground	No. of observations	Mean dose rate (μGy h^{-1})
Drigg beach	beach	sand	4	0.13
	Barn Scar	mussel beds/silt/rocks	4	0.12
Drigg dunes	sand dunes	sand	1	0.10
Drigg stream	confluence with River Irt	soft mud	4	0.24
	stream banks	muddy grass banks	4	0.11

Marine pathways

Foodstuffs

15 Samples of winkles, mussels and limpets are collected each month from the area between Sellafield and Drigg Barn Scar. Cod and plaice or whiting are sampled monthly from the sea area identified as 'off Drigg' (figure 1). Samples of crabs (quarterly) and lobsters (monthly) are obtained from the area between the Sellafield pipeline and Selker (see figure 2 of the Sellafield chapter). The results are summarised in tables 5 and 6 and refer to the edible parts of seafoods.

Indicators

16 The marine indicator is fucoid seaweed from Drigg beach. The results (table 6) reflect discharges from Sellafield.

Seawater

17 Sampling of seawater for suspended sediment is carried out monthly from the shoreline at Drigg (table7).

External pathways

18 The external dose from gamma radiation emitted by radionuclides adsorbed on to silt and sediments is another potential exposure pathway. Accordingly, gamma dose

Figure 1. Environmental monitoring around Drigg

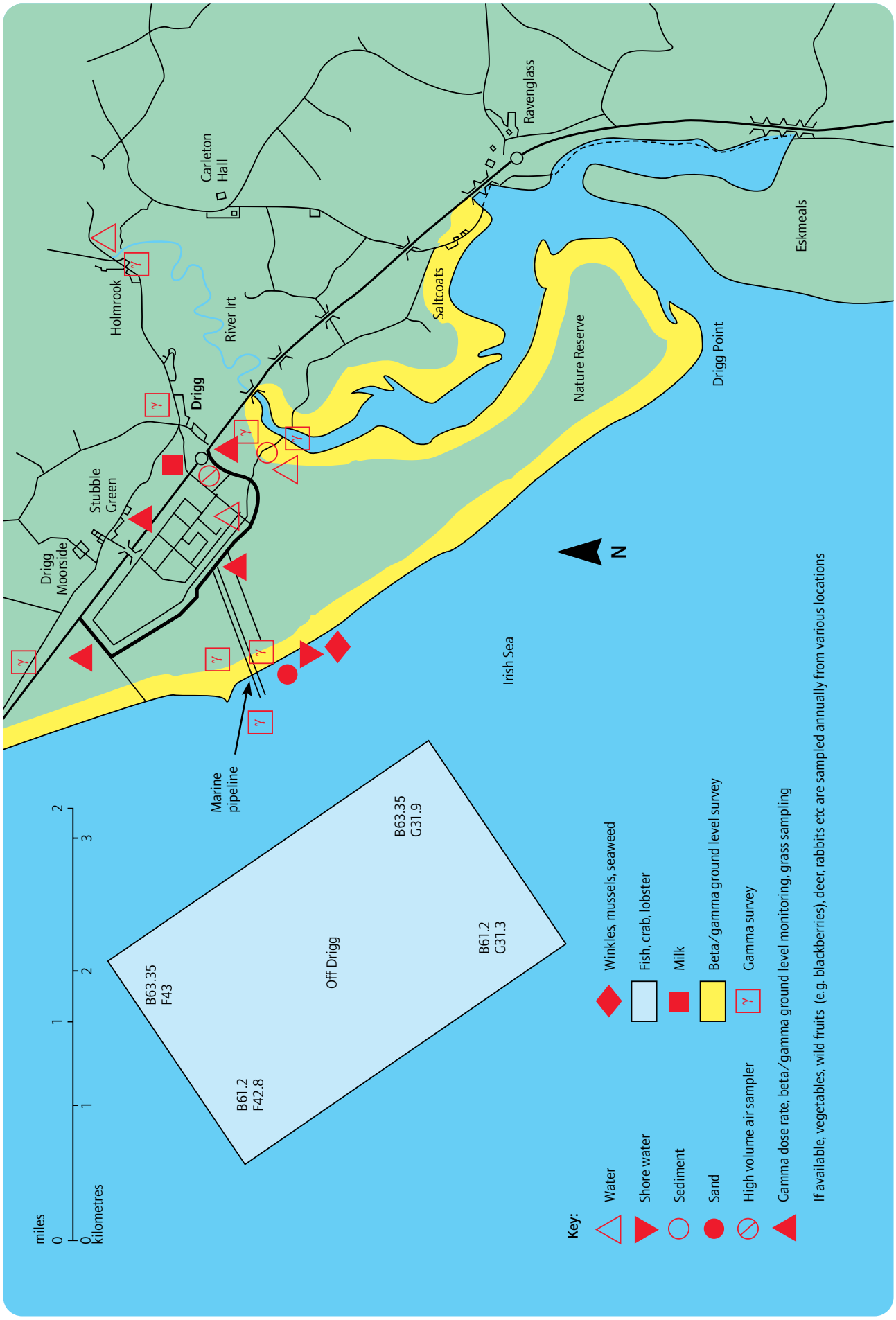

Figure 2. Statutory environmental monitoring on the Drigg site

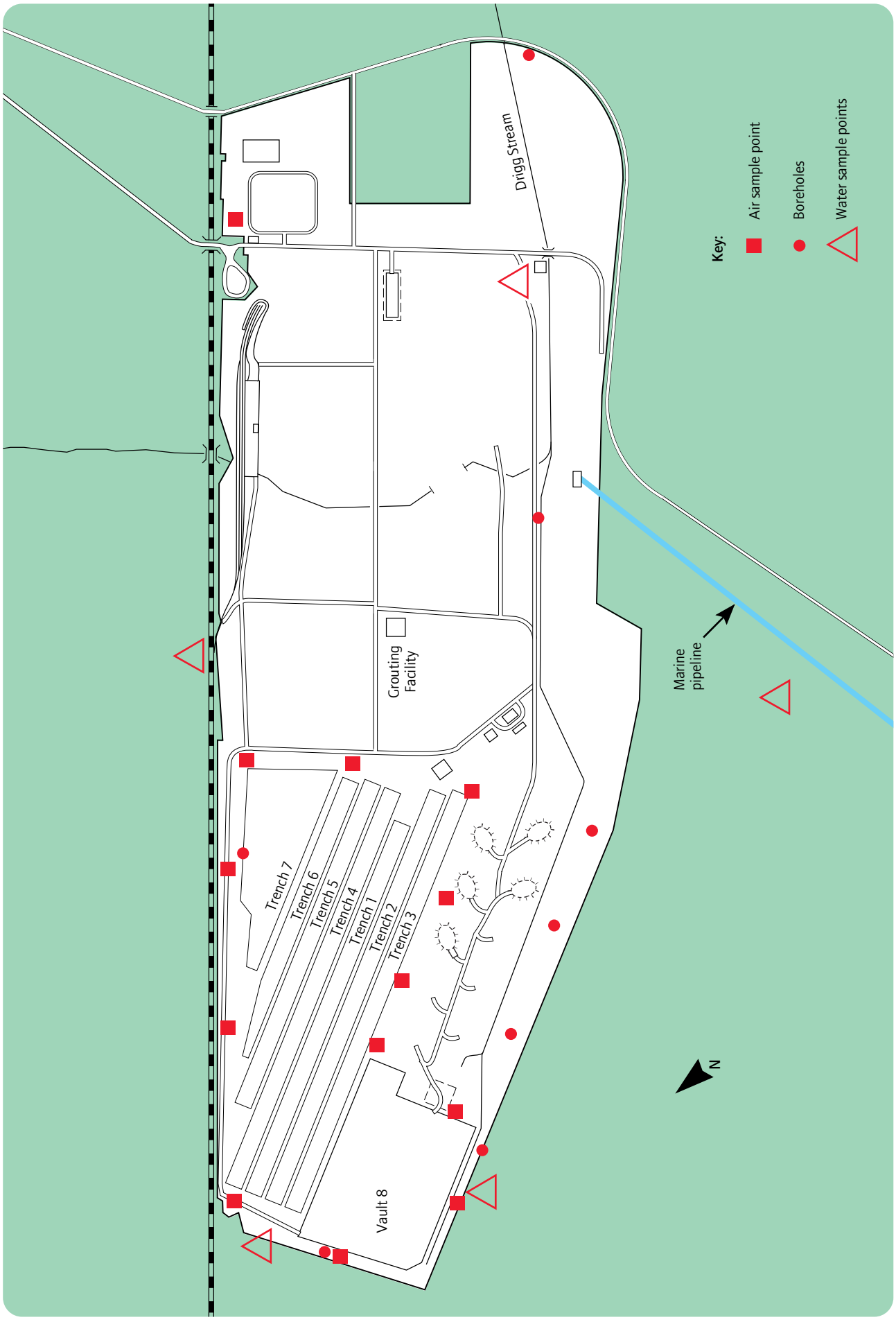

Table 9. Radioactivity in air at Drigg

Radionuclide	Mean radionuclide concentration (mBq m^{-3})
Fixed sampler (paragraph 19)	
Total alpha	0.017
Total beta	0.099
Strontium-90	<0.0005
Caesium-137	<0.005
Plutonium alpha	<0.00009
Plutonium-241	<0.009
Americium-241	0.0004
Mobile sampler (paragraph 9)	
Total alpha	<0.02[a]
Total beta	<0.24[a]

a. These figures do not relate to a full year as the sampler was not operating in December 2002 due to a power failure.

Table 10. Radioactivity in milk from a farm near Drigg

Radionuclide	Mean radionuclide concentration (Bq l^{-1})
Tritium	<5.1
Carbon-14[a]	0.55
Strontium-90	0.092
Caesium-137	0.23
Plutonium alpha	<0.0004
Americium-241	0.0006

a. Net of background (see paragraph 40 of the Sellafield chapter).

rates are measured quarterly on the banks of the Drigg stream at the point where it leaves the site but above the tidal reaches. Gamma dose rates are also measured quarterly at the confluence of the Drigg stream with the River Irt and on the Drigg sand dunes. Dose rates on Drigg beach are measured monthly. None of these locations is subject to significant occupation by members of the public. The results are summarised in table 8.

Airborne and terrestrial pathways

Airborne

19 A high volume air sampler is used to collect airborne particulate radioactivity on the site, in order to achieve large sample volumes and correspondingly low limits of detection. Filter papers are checked regularly and bulked monthly for analysis. Concentrations of particulate radioactivity in air measured during the year are presented in table 9. In this table they may be compared with the mean results from the mobile sampler serving the twelve approved places (paragraph 9). The fixed and mobile results are consistent with each other.

Foodstuffs

20 Milk is sampled regularly from cows which graze intertidal pastures through which the Drigg stream flows. Data for carbon-14 are corrected for the levels that occur naturally. Data in table 10 confirm that the measured levels of previously reported and new radionuclides were very low.

21 Vegetables and wild fruit are sampled and analysed for the same radionuclides as in milk. The results (tables 11 and 12) show that the measured levels of all radionuclides were very low. No samples of deer or rabbits could be obtained in 2002.

Indicators

22 The terrestrial indicator is grass which is collected from four sample sites around the site perimeter (table 13). This requirement was introduced into the programme in 2001 but it was not then possible to obtain samples because of foot and mouth disease restrictions. Samples were taken for the first time in 2002.

Surface water and sediments

23 In addition to routine samples of water, samples of sediment from the bed of the stream are taken for analysis at the point where it leaves the site but above the tidal reaches (table 14). Concentrations of caesium-137 are now typically

Table 11. Radioactivity in vegetable produce

Species	Mean radionuclide concentration (Bq kg^{-1} wet weight)					
	^{3}H	^{14}C[a]	^{90}Sr	^{137}Cs	Pu(α)	^{241}Am
Cabbages	10	0.20	0.40	<0.10	<0.0009	<0.0009
Potatoes	9.0	0.50	<0.08	<0.08	<0.001	<0.0008

a. Net of background (see paragraph 40 of Sellafield chapter).

Table 12. Radioactivity in wild fruit

Species	Mean radionuclide concentration (Bq kg^{-1} wet weight)					
	^{3}H	^{14}C[a]	^{90}Sr	^{137}Cs	Pu(α)	^{241}Am
Blackberries	15	1.0	0.56	0.35	0.003	0.004

a. Net of background (see paragraph 40 of Sellafield chapter).

Table 13. Radioactivity in grass

Location	Mean radionuclide concentration (Bq kg^{-1} wet weight)					
	^{3}H	^{14}C[a]	^{90}Sr	^{137}Cs	Pu(α)	^{241}Am
North of site	27	3.4	0.99	1.8	0.33	0.47
South of site	7.3	1.2	0.45	2.5	0.38	0.25
East of site	7.4	1.9	0.50	1.6	0.11	0.09
West of site	6.9	1.3	2.1	1.1	0.20	0.28

a. Net of background (see paragraph 40 of Sellafield chapter).

a few hundred Bq kg^{-1} with actinide concentrations below 100 Bq kg^{-1}. These levels are a legacy of the time when leachate drained into the stream rather than being discharged directly to sea via the pipeline.

24 Water samples are taken from the River Irt, upstream and downstream of its confluence with the stream, and from a number of other minor watercourses around the periphery of the site. The results are summarised in table 15.

Table 14. Radioactivity in Drigg stream sediment

Radionuclide	Mean radionuclide concentration (Bq kg^{-1} dry weight)
Cobalt-60	<3.3
Strontium-90	<210
Ruthenium-106	<29
Caesium-137	210
Uranium alpha	66
Plutonium alpha	55
Americium-241	58

Groundwater

25 In addition to surface water, groundwater is sampled from a number of boreholes on the site (see figure 2). These are arranged in two groups: one monitors water leaving the vicinity of the old disposal trenches ('perched' groundwater) and the other, water near to the western perimeter of the site (regional groundwater). The results are summarised in table 16. With the main exception of tritium, results were generally below limits of detection. The groundwater monitoring programme remains under review as part of a wider study of the geology and hydrogeology of the Drigg site which has included the installation of additional boreholes off-site. There is some evidence that tritium is migrating away from the disposal trenches in groundwater. Lying at a depth of about 25 metres, it is very unlikely that such water would be extracted for use. In any event, assuming it to be potable, a person would need to drink more than 0.5 litres every day to receive the optimisation threshold dose of 20 μSv referred to in table 2 (page 7).

Table 15. Radioactivity in minor water courses

Radionuclide	Mean radionuclide concentration (Bq l^{-1})					
	Railtrack culvert	Seepage points			River Irt	
		North site	North West site	Peat bed	Upstream	Downstream
Total alpha	<0.54	<0.77	<0.98	<1.1	-	-
Total beta	<0.97	<0.35	<0.86	<0.31	-	-
Tritium	<110	<100	<120	<110	<6.9	<7.0
Strontium-90	-	-	-	-	0.007	0.007
Caesium-137	-	-	-	-	<0.02	<0.02
Uranium	-	-	-	-	0.001	0.001
Plutonium alpha	-	-	-	-	<0.002	<0.002
Americium-241	-	-	-	-	<0.003	<0.003

Table 16. Radioactivity in ground waters

Radionuclide	Mean radionuclide concentration (Bq l^{-1})							
	Regional groundwater				Perched groundwater			
	Borehole number				Borehole number			
	23	24	121	122	63	75[a]	94	117
Total alpha	<0.25	<0.22	<0.20	<0.26	<0.25	-	<0.22	<0.25
Total beta	<0.25	<0.34	<0.31	<0.33	<0.38	-	<0.24	<0.35
Tritium	<130	<160	<110	0.60	<110	-	<110	<110

a. Borehole 75 was inaccessible in 2002.

Radiological impact of operations at Drigg

Critical group doses

Marine pathways

26 As discussed in paragraph 14, the environmental impact of liquid radioactive discharges from Drigg is virtually unmeasurable against the much higher Sellafield 'background'. It is possible, however, to estimate their impact by modelling. The hypothetical critical group of seafood consumers received doses of the order of 0.01 μSv as a result of discharges from the Drigg marine pipeline.

Airborne and terrestrial pathways

27 As discussed in paragraph 14 there is no identified critical group for aerial discharges. A hypothetical critical group is assumed, based on local residents consuming locally produced food and breathing air at the concentrations measured on-site. The consumption rates used in the dose calculations are the same as those used in the Sellafield chapter (table 22).

28 The results of high volume air sampling can be used to estimate doses to members of the public from the inhalation of airborne radioactive particulate material in the vicinity of the site. Combining the results presented in table 9 with the pessimistic assumption of continuous occupancy results in a dose of about 0.2 μSv from inhalation (table 17). In reality, it is reasonable to assume that this dose is due to aerial discharges from Sellafield, with only a negligible contribution from Drigg.

29 The dose to the hypothetical most exposed individual (an infant) drinking milk from cows which graze close to the site and drink water from the stream, was about 3.5 μSv (table 17). The cows have access to sea-washed pasture and the activity concentrations in milk are very similar to those from other farms around the Ravenglass Estuary (see table 14 of the Sellafield chapter). Most of the dose may therefore be attributed to Sellafield's marine discharges.

30 The dose to the hypothetical most exposed individual (an adult) from the consumption of locally produced fruit and vegetables was about 1.4 μSv (table 17), mostly attributable to discharges from Sellafield.

31 If all the above pathways are considered to be additive, the maximum dose (to infants) from discharges in 2002 was about 4.1 μSv. More than half of this dose arose from strontium-90, mostly resulting from Sellafield's discharges, and the fallout from the testing of nuclear weapons, in the 1950s and 1960s. Doses to adults and children were lower at 2.9 and 3.3 μSv respectively. Pessimistically, it may be assumed that members of this critical group are also exposed to direct radiation (see paragraph 33 and table 1).

32 Streams and rivers close to the Drigg site are not sources of drinking water for humans, although cattle may use the stream. Data on the concentrations of radioactivity in the stream (see table 3) show that a person would need to drink more than 2.5 litres of stream water every day to receive an annual dose of 20 μSv (see table 2 on page 7). Consequently, any dose received from the inadvertent ingestion of water from this source would be negligible.

Table17. Summary of critical group doses from terrestrial foodstuffs and inhalation (μSv)

Radionuclide	Milk			Cabbage			Potato		
	Adult	Child	Infant	Adult	Child	Infant	Adult	Child	Infant
Tritium	0.02	0.03	0.08	0.008	0.005	0.005	0.008	0.009	0.004
Carbon-14	0.08	0.11	0.28	0.005	0.003	0.003	0.02	0.02	0.008
Strontium-90	0.62	1.33	2.15	0.50	0.48	0.29	0.11	0.22	0.06
Caesium-137	0.78	0.56	0.89	0.06	0.02	0.01	0.06	0.04	0.01
Plutonium alpha	0.03	0.03	0.06	0.01	0.005	0.003	0.02	0.02	0.007
Americium-241	0.03	0.03	0.08	0.008	0.004	0.003	0.009	0.008	0.003
Total	1.55	2.09	3.53	0.59	0.52	0.32	0.22	0.31	0.09

Radionuclide	Fruit			Inhalation			Total dose per radionuclide		
	Adult	Child	Infant	Adult	Child	Infant	Adult	Child	Infant
Tritium	0.007	0.004	0.001	-	-	-	0.05	0.05	0.09
Carbon-14	0.01	0.008	0.003	-	-	-	0.11	0.14	0.29
Strontium-90	0.39	0.34	0.08	-	-	-	1.63	2.36	2.58
Caesium-137	0.11	0.04	0.008	0.0002	0.0001	0.00005	1.01	0.65	0.92
Plutonium alpha	0.022	0.01	0.003	0.03	0.02	0.01	0.11	0.08	0.08
Plutonium-241	-	-	-	0.06	0.04	0.02	0.06	0.04	0.02
Americium-241	0.021	0.009	0.003	0.14	0.10	0.06	0.21	0.15	0.14
Total	0.57	0.40	0.10	0.23	0.16	0.09	3.17	3.48	4.13
Total (foodstuffs only)							2.94	3.32	4.04

Direct radiation

33 Gamma radiation surveys both along and outside the perimeter fence have identified a source at the north east corner of the site. This arises from radiation from ungrouted backlog waste in ISO-freight containers in Vault 8 being scattered by the atmosphere back to ground level ('skyshine'). This backlog waste is being treated on the shortest possible timescale. With the same dose assessment methodology used for Sellafield, the measurements indicate a maximum annual dose of 84 μSv to local residents living close to the perimeter. This is less than 5% of the annual dose from natural radioactivity to a person living in this part of Cumbria.

Collective doses

34 Collective doses to the populations of the UK and Europe (and hence to the world) from discharges to the marine environment, via the pipeline and stream, are extremely small and have negligible impact. The minimal arisings of radioactivity to atmosphere from the site do not give rise to any impact discernible above that attributable to operations at Sellafield.

Non-radioactive discharges and disposals

Discharges made under the terms of Prescribed Process authorisations

35 There is one Prescribed Process on the site subject to authorisation under EPA 1990. This is a bulk cement handling process within the Grouting Facility and is a Part B process subject to regulation by the local authority (Copeland Borough Council) for aerial discharges only. The plant operated within the requirements of the authorisation at all times in 2002.

Discharges made under the terms of consents

36 Discharges of leachate from the site to sea via the marine pipeline are subject to the requirements of a consent. This also permits discharges of other effluents to sea, including those from the Grouting Facility and, under certain conditions, permits discharges of surface water to be made to the stream. It places limits on a range of instantaneous concentrations and on pH. There were no instances of non-compliance with consent limits in 2002.

Acknowledgements

This chapter was written by Tim Parker, Mike Hadwin and Alison Tulloch of Site Safety Group at Sellafield. Their colleagues in this Group collected the environmental samples and measured environmental dose rates. The Geoffrey Schofield Laboratories at Westlakes Science Park, Cumbria, analysed the samples. Members of the public who cooperated with the BNFL staff collecting samples and making measurements are especially thanked.

References

The references in the Sellafield report are also applicable to Drigg.

Annex: Authorisations and consents effective in 2002

Authorisations issued under the Radioactive Substances Act 1960 and 1993

Description	Effective Date
Disposal of solid radioactive waste at Drigg Notice of Variation Notice of Variation	1 Feb 1988[a] 1 Jan 1991[a] 11 Feb 2000[b]
Drigg to Sellafield inter site transfer (plutonium contaminated materials).	1 Jul 1995[c]
Disposal of radioactive waste of any description by transfer from any premises situated on a licensed site occupied by the Company to any other premises situated on a licensed site occupied by the Company or to any premises occupied by the UKAEA.	1 Apr 1971[d]
Disposal of waste gases, mists and dusts from any premises situated on a licensed site occupied by the Company.	1 Apr 1971[d]

a. Authorisations issued jointly by DoE and MAFF.
b. Authorisations issued by Environment Agency.
c. Authorisation issued jointly by HMIP and MAFF.
d. Authorisations issued separately by DoE and MAFF.

Prescribed Process authorisations issued under the Environmental Protection Act 1990

Number	Description	Effective Date
CBC/93/0001	Blending, packing, loading and use of bulk cement - Drigg Grouting Facility	29 Oct 1993

Consents issued under the Water Resources Act 1991

Number	Description	Effective Date
01740269	Discharge of site leachate from Drigg to Drigg Stream and Irish Sea Notice of Variation Notice of Variation	1 Aug 1997 12 Jun 1998 28 April 2000
017490347	Discharge of biologically treated sewage effluent containing no trade effluent (to Drigg marine pipeline)	16 Aug 2000

Discharges and Monitoring of the Environment in the UK
Annual Report 2002

springfields

Summary

1 There were no instances in 2002 of non-compliance with numerical limits in authorisations regulating discharges and disposals of radioactive wastes at Springfields and the Clifton Marsh disposal site.

2 Liquid discharges were similar to those in recent years and overall aerial discharges were somewhat lower. Solid waste disposals to Clifton Marsh, both in bulk and radioactivity content terms, were higher than in 2001, and reflected the phasing of decommissioning operations on the site.

3 There is no single distinct critical group from Springfields' liquid discharges. A number of groups (houseboat dwellers, anglers, wildfowlers and seafood consumers) may receive similar doses. Annual variations in the impact of Springfields' discharges on these groups mean that on occasion any one of these groups could be the main critical group. In 2002, the highest critical group dose from Springfields discharges alone, was the 15 -21 µSv to seafood consumers. Houseboat dwellers received about 17 µSv from Springfields discharges, although their total dose, including that from Sellafield's discharges, was about 68 µSv. The dose to the most exposed members of the critical group from aerial discharges was estimated to be about 3 µSv. Doses from all discharge pathways are shown in table 1.

4 There were no instances in 2002 of non-compliance with numerical limits in consents covering non-radioactive discharges from the site.

Operations at Springfields

5 BNFL Westinghouse's UK Fuel Business manufacturing site at Springfields, near Preston, produces fuel and intermediate fuel products for the nuclear industry in the UK and abroad. Uranium ore concentrates are received on site and are processed to either uranium metal for use in Magnox reactors or to uranium hexafluoride. The latter is sent for enrichment at Capenhurst or abroad. Enriched uranium hexafluoride is also received on site and is converted by the Integrated Dry Route to provide oxide fuel or intermediates for use in Advanced Gas Cooled Reactors or Light Water Reactors. Recycled uranium, a product of reprocessing spent fuel, can also be processed. The former BNFL subsidiary company, F_2 Chemicals, is situated on the Springfields site under its own independent management. Its premises are not included in the nuclear site licence. It makes no radioactive discharges but does have an IPC authorisation. Further information may be obtained from W. Denison, F_2 Chemicals, Springfields, Preston PR4 0XJ.

6 The site's extensive decommissioning programme for plants and other buildings continued during 2002.

Radioactive discharges and disposals

7 The Company holds a number of authorisations for the discharge and transfer of radioactive waste (see Annex to this chapter). In October 2001, the Environment Agency announced the commencement of its review of these authorisations. The current aim is to issue the Company with new Certificates of Authorisation for Springfields in 2004. This process was ongoing throughout 2002.

Liquid discharges

8 The Company discharges liquid radioactive waste from uranium processing operations across the site, via pipelines, into the tidal waters of the River Ribble. The effluent is sampled and analysed (the sample volume being proportional to the volume discharged) to demonstrate compliance with the authorisation. Discharges for the last five years are shown in table 2 where they may be compared with authorised limits.

9 Total beta discharges reflect throughput in the uranium ore concentrate purification plant and this was slightly higher than in the previous year. Total alpha, thorium-230 and thorium-232 discharges reflect both the throughput and the specification (e.g. thorium content) of the ore concentrates being purified. Discharges of neptunium-237 and technetium-99 arise from trace activities in processing residues, including those from decommissioning activities, and continue to be small fractions of the authorised limits. The apparent increase in neptunium-237 compared to previous recent years reflects performance variations in analytical equipment which is due to be upgraded.

Table 1. Summary of critical group doses in the vicinity of Springfields (µSv)

Pathway[a] (Position in text, paragraph no.)	Contributions to doses arising from discharges from BNFL sites					
	Springfields		Sellafield		Total	
	2001	2002	2001	2002	2001	2002
boat dwelling (38)	17	17	52	51	69	68
wildfowlers (40)	5	1	7	8	12	9
anglers (39)	4	11	2	3	6	14
agricultural occupancy (42)	1	1	7	8	8	9
shellfish (mussels, shrimps) (41)	4[b]	15-21	9	24-30	13	45
terrestrial foodstuffs (45)	0.5	0.5	Not applicable			
inhalation (44)	4	3				

a. Direct radiation is discussed in paragraphs 33 and 46. b. Mussels only.

Table 2. Radioactive discharges to the Ribble Estuary

Radionuclide	Annual discharge (TBq)					Authorised Limit (TBq)
	1998	1999	2000	2001	2002	
Thorium-230	0.085	0.15	0.069	0.069	0.10	2
Thorium-232	0.0012	0.0047	0.0009	0.0047	0.0025	0.2
Uranium alpha	0.047	0.050	0.059	0.048	0.050	0.15
Neptunium-237	0.0002	0.0003	0.0005	0.0003	0.0014	0.04
Technetium-99	0.027	0.039	0.035	0.018	0.017	0.6
Total alpha	0.20	0.24	0.17	0.16	0.22	4
Total beta	150	130	71	85	110	240

Aerial discharges

10 Discharges of radioactive aerial effluents at Springfields are made from a number of stacks specified in the authorisation schedule, and from other approved outlets found in most operational buildings on the site and in some others awaiting decommissioning. They consist almost entirely of uranium accompanied by beta activity from short lived uranium daughters. Overall, discharges were lower than in previous years (table 3), but following a review of sampling and calculational methods in 2002, the method of calculating aerial discharges was refined. This had the effect of increasing discharges reported for 'specified discharge points' and reducing those for 'other approved places'. Calculation of the radiological impact of discharges was not affected by these changes.

Solid wastes

Disposals to Clifton Marsh

11 Springfields and Capenhurst share an authorisation regulating the disposal of solid wastes (arising from uranium processing operations on these sites) at Clifton Marsh, a landfill site operated by SITA Ltd. The conditions in the authorisation relate to weights and the uranium contents of waste. Disposals to Clifton Marsh are shown in table 4. The amount of material disposed of from Capenhurst is referred to in that site's chapter. The bulk weight and uranium activity disposals, both of which were higher than in 2001, continue to reflect, respectively, the phasing of decommissioning operations and the quantities of decommissioning wastes and process residues disposed.

Disposals to Ulnes Walton

12 Springfields and Capenhurst share an authorisation to dispose of waste at Ulnes Walton. In 1992, the site was taken over by Lancashire Waste Services Ltd as part of an expansion of their neighbouring landfill site. The company has not made any disposals at this site since 1983 and will not do so in the future. The site has now been capped and covered with topsoil. BNFL has requested that the authorisation be revoked and to this end has prepared a post-closure risk assessment. Meanwhile, the Statutory Environmental Monitoring Programme relating to this site continues and details are given in paragraphs 34 to 36.

Transfer of waste for disposal at Drigg

13 An authorisation permitting wastes to be transferred to Drigg for disposal if they do not conform to the conditions of the authorisation for Clifton Marsh and cannot be decontaminated in a reasonably practicable way, has not been used since 1993, but may be used in the future.

Transfer of waste for incineration at Capenhurst

14 An authorisation permitting some combustible wastes (including oil) to be transferred to BNFL Capenhurst for incineration if they do not conform to the conditions of the authorisation for Clifton Marsh and cannot be decontaminated in a reasonably practicable way, was not used in 2002 (table 5).

Table 3. Airborne radioactive discharges

	Annual discharge (GBq uranic alpha)					Authorised Limit (GBq)
	1998	1999	2000	2001	2002	
Specified outlets	0.4	0.4	0.4	0.4	0.8	3
All other approved outlets	1.2	1.2	0.9	0.9	0.1	3

a. See paragraph 10.

Table 4. Disposals of solid radioactive waste to Clifton Marsh from Springfields

	1998	1999	2000	2001	2002
Bulk weight (te)	36,000	34,000	20,000	8,000	16,000
Uranium activity (TBq)	0.05	0.06	0.08	0.04	0.05

Table 5. Transfers of radioactive waste to Capenhurst for incineration

	1998	1999	2000	2001	2002
Bulk weight (te)	15	7.7	0	0	0
Volume (m^3)	280	100	0	0	0
Uranium alpha activity (TBq)	0.002	0.001	0	0	0

Monitoring of the environment for radioactivity

15 The principal exposure pathways for radioactivity discharged from the Springfields site, as identified by recent environmental monitoring and habit surveys, are the exposure of houseboat dwellers to gamma radiation from sediments; the exposure of farmers, wildfowlers and anglers to gamma and beta radiation from sediments; the consumption of seafood from the Ribble Estuary, and the inhalation of radioactivity from aerial discharges.

Table 6. Gamma dose rates in air in intertidal areas of the Ribble Estuary

Location	Mean dose rate in air ($\mu Gy\ h^{-1}$)
Lytham Boatyard[a]	0.09
Freckleton Boatyard[a]	0.11
Becconsall Boatyard[a]	0.10
Warton Marsh[a]	0.12
Longton Marsh	0.09
Near BNFL outfall[a]	0.13
460m upstream of outfall[a]	0.15
Savick Brook old vehicle crossing point[a]	0.14
Savick Brook at Lea	0.12
Penwortham Bridge[a]	0.09
Penwortham Park	0.10
Confluence of Rivers Ribble and Darwen	0.07
London Road Bridge	0.07
Tramway Bridge (Avenham Park)	0.07
Background in muddy estuaries	0.07

a. Statutory monitoring locations.

Table 7. Beta dose rates in intertidal areas of the Ribble Estuary

Location	Surface dose rate[b] ($\mu Sv\ h^{-1}$)	
	mean	max
Lytham Boatyard[a]	0.0	0.0
Freckleton Boatyard[a]	0.2	1.4
Becconsall Boatyard[a]	0.0	0.0
Warton Marsh[a]	0.0	0.0
Longton Marsh	0.2	2.8
Near BNFL outfall[a]	1.7	26
460m upstream of outfall[a]	0.9	7.0
Savick Brook old vehicle crossing point[a]	1.2	5.5
Savick Brook at Lea	2.0	5.8
Penwortham Bridge[a]	1.7	5.0
Penwortham Park	1.4	6.5
London Road Bridge	0.4	2.8
Tramway Bridge (Avenham Park)	0.2	1.1
Confluence of Rivers Ribble and Darwen	0.7	3.3

a. Statutory monitoring locations.
b. Net of background dose rate.

16 Environmental monitoring is carried out in accordance with the Statutory Environmental Monitoring Programme, noting that pending a review of the latter in the ongoing authorisation review, Springfields has supplemented it with the monitoring of mussels and shrimps (paragraph 22). Figures 1 and 2 show the locations and types of monitoring undertaken in the Ribble Estuary. Routine supplementary monitoring and *ad hoc* monitoring continued; in particular, the more extensive monthly monitoring throughout the year to measure temporal variations of beta dose rates in areas used by wildfowlers or anglers during the year. Dose rates from direct radiation are also routinely measured.

Aquatic Pathways

External dose rate measurements in local estuaries

17 Gamma dose rates in air and beta dose rates are measured on a quarterly basis at eight statutory locations and several other locations in the Ribble Estuary, including those frequented by anglers and wildfowlers. Mean gamma dose rates were similar to those in 2001, being in the range 0.07 to 0.15$\mu Gy\ h^{-1}$ including natural background. Higher individual readings may occur if river flows are very low. The mean gamma dose rates are shown in table 6 and beta dose rates in table 7.

18 Beta dose rates were generally similar to those seen in 2001 and within the range experienced in recent years. Environmental concentrations of beta-emitting radionuclides can be subject to significant variability due to the complex pattern of sediment movement in the estuary. Beta dose rates can be used to calculate doses to skin from short-term exposure, e.g. to people engaging in leisure activities in the river in hot, dry weather. The relevant annual dose limit for such exposures is 50 mSv.

Table 8. Gamma dose rates in air in intertidal areas of the Ribble, Wyre and Lune Estuaries and Morecambe Bay

Location	Mean dose rate in air ($\mu Gy\ h^{-1}$)
Ribble	
Brockholes Bridge	0.08
London Road Bridge	0.10
Wyre	
Skipool Creek	0.11
Wardley's Creek	0.09
Out Rawcliffe	0.08
Ratten Row	0.08
Shard Bridge	0.09
St Michael's Bridge	0.07
Lune	
Cockersand Abbey	0.09
Morecambe Bay	
Preesall Sands	0.08
Pilling Sands	0.11
Fluke Hall	0.09

Figure 1. Environmental monitoring around Springfields

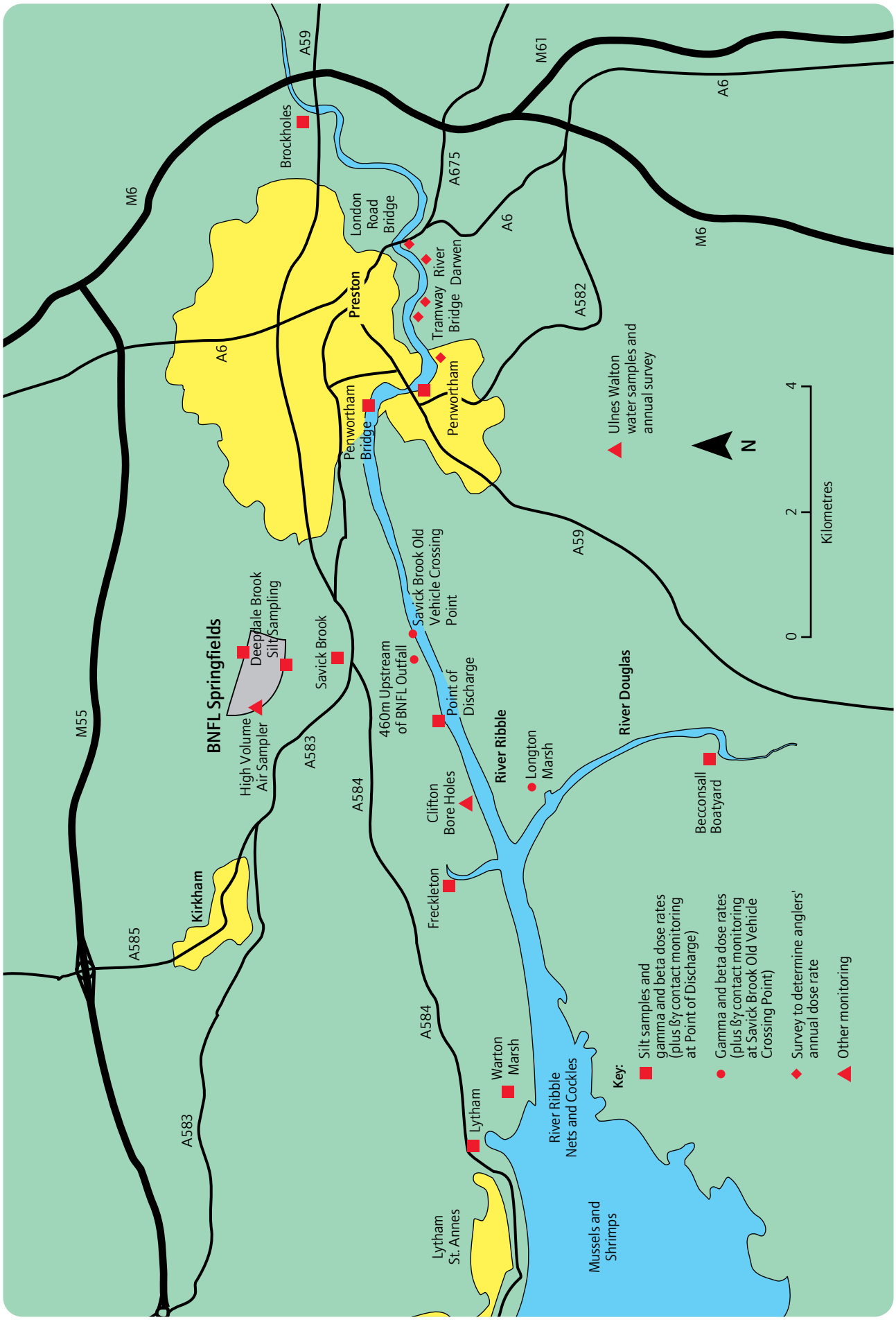

Figure 2. Environmental monitoring in Morecambe Bay and the estuaries of the Rivers Wyre and Lune

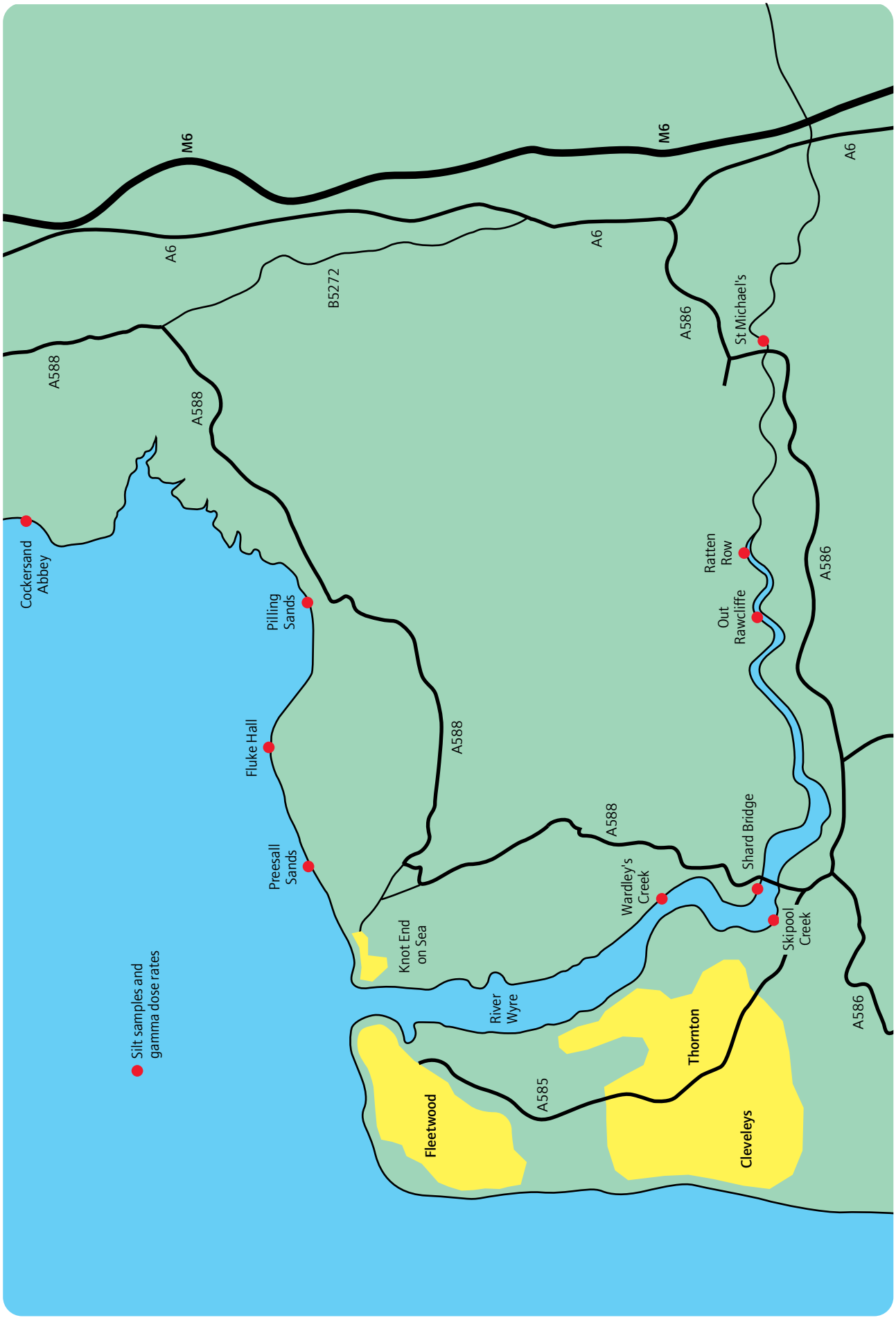

Table 9. Gamma emitting radionuclides in silts of the Ribble Estuary

Location	Mean radionuclide concentration (Bq kg^{-1} dry weight)						
	^{40}K	^{60}Co	^{137}Cs	^{212}Pb	^{214}Bi	^{228}Ac	^{234m}Pa
Lytham Boatyard[a]	640	<2.6	380	44	23	39	15,000
BNFL outfall[a]	470	<2.3	170	33	21	27	37,000
Penwortham Bridge[a]	530	<2.7	260	39	22	39	64,000
River Douglas[a]	550	2.2	210	37	23	35	6,700
Savick Brook	590	<2.8	240	39	23	41	100,000
Warton Marsh[a]	680	3.5	420	45	23	39	9,400
Freckleton	620	3.4	340	43	24	38	37,000
Penwortham Park	570	<3.0	290	43	26	41	160,000
Longton Marsh	430	<2.1	130	37	24	30	3,400

The following radionuclides were below the limits of detection: ^{95}Zr, ^{103}Ru, ^{106}Ru, ^{110m}Ag, ^{125}Sb, ^{134}Cs, ^{144}Ce, ^{154}Eu, ^{155}Eu, ^{233}Pa.

a. Statutory sampling locations.

Table 10. Alpha emitting radionuclides and plutonium-241 in silts of the Ribble Estuary

Location	Mean radionuclide concentration (Bq kg^{-1} dry weight)							
	U[b]	^{228}Th	^{230}Th	^{232}Th	^{238}Pu	$^{239/240}$Pu	^{241}Pu	^{241}Am
Lytham Boatyard[a]	3.1	47	160	44	22	120	1000	220
BNFL outfall[a]	3.0	35	140	33	9.5	52	650	100
Penwortham Bridge[a]	3.4	42	310	41	15	85	690	150
River Douglas[a]	2.9	37	120	35	12	80	630	120
Savick Brook	3.7	48	310	42	13	81	820	140
Warton Marsh[a]	3.2	52	180	46	25	140	1100	250
Freckleton	3.5	46	230	46	19	110	930	190
Penwortham Park	3.6	47	450	43	16	94	760	170
Longton Marsh	2.8	37	75	34	7.2	41	600	77

a. Statutory sampling locations.

b. μg g^{-1} dry weight.

Table 11. Gamma emitting radionuclides in silts of the Ribble, Wyre and Lune Estuaries and Morecambe Bay

Location	Mean radionuclide concentration (Bq kg^{-1} dry weight)						
	^{40}K	^{60}Co	^{137}Cs	^{212}Pb	^{214}Bi	^{228}Ac	^{234m}Pa
Ribble							
Brockholes Bridge	390	<2.0	8.2	38	30	36	<500
London Road Bridge	620	<2.9	430	43	23	40	49,000
Wyre							
Skipool Creek	550	<2.5	290	34	20	31	<500
Wardley's Creek	460	<2.2	140	39	30	41	<500
Out Rawcliffe	520	<2.3	250	30	20	30	<600
Ratten Row	520	2.8	250	29	21	27	<600
Shard Bridge	440	<2.0	140	28	21	29	<500
St Michael's Bridge	570	4.8	370	38	24	30	<500
Lune							
Cockersand Abbey	460	<2.3	110	32	23	36	<600
Morecambe Bay							
Preesall Sands	380	<2.0	51	23	20	32	<500
Pilling Sands	500	3.3	230	31	23	34	<600
Fluke Hall	480	<2.7	220	30	22	33	<600

The following radionuclides were below the limit of detection: ^{95}Zr, ^{103}Ru, ^{106}Ru, ^{110m}Ag, ^{125}Sb, ^{134}Cs, ^{144}Ce, ^{154}Eu. All results for ^{155}Eu were below the limit of detection except for the sample from St. Michael's Bridge. All results for ^{233}Pa were below the limit of detection except for the sample from Out Rawcliffe.

Table 12. Alpha emitting radionuclides and plutonium-241 in silts of the Ribble, Lune and Wyre Estuaries and Morecambe Bay

Location	Mean radionuclide concentration (Bq kg^{-1} dry weight)							
	U[a]	^{228}Th	^{230}Th	^{232}Th	^{238}Pu	$^{239/240}Pu$	^{241}Pu	^{241}Am
Ribble								
Brockholes Bridge	2.6	36	37	34	<1.7	<1.1	<600	<2.0
London Road Bridge	3.2	48	250	50	23	140	940	250
Wyre								
Skipool Creek	2.3	47	55	40	15	92	600	190
Wardley's Creek	2.7	34	53	36	20	100	660	120
Out Rawcliffe	2.1	26	49	32	20	95	780	170
Ratten Row	2.0	30	44	28	16	95	770	180
Shard Bridge	2.1	44	45	42	11	61	600	110
St Michael's Bridge	2.4	40	56	39	25	130	<600	240
Lune								
Cockersand Abbey	2.4	36	35	29	7.6	42	600	88
Morecambe Bay								
Preesall Sands	1.9	24	29	20	5.3	29	<600	47
Pilling Sands	2.1	35	40	29	14	76	620	150
Fluke Hall	2.0	36	41	30	10	55	<600	160

a. µg g^{-1} dry weight.

19 Gamma dose rates, measured annually at further locations in the Ribble Estuary and in the estuaries of the River Wyre and River Lune and adjacent coastal areas, are shown in table 8.

Sampling and analysis of surface sediments.

20 Samples of surface sediments are taken quarterly from five statutory and several other locations in the Ribble Estuary (tables 9 and 10) and analysed for a range of radionuclides linked or potentially linked to site discharges. In the case of the site's main beta discharge, the radionuclide reported in sediment analysis, as required by the Statutory Environmental Monitoring Programme, is protactinium-234m. This is the daughter of the principal radionuclide discharged (thorium-234) and as it is in equilibrium with its parent, provides a suitable surrogate indicator for environmental concentrations of thorium-234. Similarly, bismuth-214 is a short-lived daughter of, and indicator for, the alpha emitter radium-226. The levels recorded are consistent with natural background levels and confirm that radium-226 is not discharged in significant quantities. Actinium-228 and lead-212 are short-lived daughters of thorium-232 and the measured concentrations of these are also consistent with natural background levels.

21 Sediments are also sampled annually from a number of additional locations in the Ribble Estuary and in the estuaries of the River Wyre and River Lune and adjacent coastal areas (tables 11 and 12). Overall, the range of the results was similar to that in recent years. Although protactinium-234m in silt at London Road Bridge was higher than in 2001, it was within the range seen here over the last decade.

Shellfish

22 The Statutory Environmental Monitoring Programme specifies that cockles be obtained from a commercial fisherman twice per year. Due to the cockle beds being no longer commercially viable, samples of mussels were again obtained as an alternative as agreed with the Environment Agency. In addition, samples of shrimps have been collected as recent reviews of local seafood consumption habits (paragraph 41), together with the cockle bed situation, suggests that consumption of mussels and shrimps is a more realistic reflection of the habits of members of the critical group than the historic assumption that cockles were their main local seafood. The concentrations of radionuclides in the edible parts of the mussels and shrimps are presented in table 13. The comments in paragraph 20 relating to radium-226 and thorium-232 and their short-lived daughters are also applicable to this table.

Other monitoring

23 Monitoring of commercial fishermen's nets showed no readings above background.

24 Monitoring of the surface of intertidal areas is carried out quarterly near the pipeline outfall and the confluence of Savick Brook and the River Ribble. Although these areas are not readily accessible to the public and are not used for recreational purposes, loose items of potential interest to the public, such as driftwood, are monitored. No loose objects with count rates exceeding the statutory criterion for removal and further investigation were found.

Table 13. Radioactivity in mussels and shrimps

Radionuclide	Mean radionuclide concentration (Bq kg^{-1} wet weight)[a]	
	Mussels	Shrimps
Caesium-137	2.4	2.3
Lead-212	0.78	0.17
Bismuth-214	0.69	<0.96
Thorium-228	1.3	<1.6
Thorium-230	1.2	1.1
Thorium-232	0.53	0.39
Protactinium-234m	290	<180
Neptunium-237	1.7	1.8
Plutonium-238	0.32	<0.39
Plutonium-239/240	0.51	0.78
Americium-241	0.89	<0.43

a The following radionuclides were below the limits of detection: ^{60}Co, ^{95}Zr, ^{103}Ru, ^{106}Ru, ^{110m}Ag, ^{125}Sb, ^{134}Cs, ^{144}Ce, ^{154}Eu, ^{155}Eu, ^{228}Ac, ^{231}Pa, ^{233}Pa, ^{241}Pu.

Deepdale Brook

25 Deepdale Brook is culverted through the site and is flow-proportionally sampled before it leaves the site. The mean uranium concentration was 0.03 µg ml^{-1}. This is in the range of past experience. The brook is not used as a source of human drinking water, and in respect of its use by cattle, the uranium concentration was less than 2% of the appropriate limit for protecting animals' health (see paragraph 28).

26 Samples of silt are taken from the bed of the brook close to the points where it enters and leaves the site. Samples are analysed for uranium and demonstrate that there is no significant accumulation. The mean uranium concentrations were 5.8 µg g^{-1} at the north end and 11.2 µg g^{-1} at the south end of the site.

Airborne and terrestrial pathways

27 Analysis of high volume continuous air sampler filters showed that the mean concentration of uranium in air at the south-west corner of the site was 0.14 mBq m^{-3} , slightly lower than in 2001.

28 The radiotoxicity of uranium is low compared with its chemical toxicity and it is not accumulated to any appreciable extent in the edible tissues of grazing animals or secreted in significant amounts in milk[1]. Consequently, the health of grazing animals would be affected before the consumption of their milk or meat would represent a significant route for dose uptake. It is estimated that the uranium concentration in bovine faeces that would result from uranium ingestion sufficient to begin to affect their health is between 130 and 160 µg g^{-1} dry weight[1].

29 During 2002, the local defra (see Glossary) agency was unable to collect bovine and ovine faecal samples from farms near the site, for analysis by the Company, owing to operational difficulties.

30 Results over past years have shown no particular trend or levels of concern when compared with the samples taken from control farms. Operations on site have been similar to those in recent years, and the Environment Agency's nuclear regulator for the site has agreed that monitoring of these particular indicators are no longer necessary in view of the many other more direct controls and measurements in place.

31 Grass and soil samples from close to the site perimeter are collected by Springfields and analysed for uranium content. The mean concentrations in soil and grass were 13 µg g^{-1} (range 2.6 – 56) and 5.2 µg g^{-1} dry weight (range 0.17-70) respectively. The reported single result of 70 µg g^{-1} in grass was not confirmed by repeat sampling which reduced the mean from 5.2 to 1.4 µg g^{-1}. These radiologically insignificant concentrations are similar to those found in previous years.

32 Springfields samples and analyses water from four boreholes sunk into the Fylde aquifers which are used to supply water for process purposes. The mean uranium level was <0.0004 µg ml^{-1} which is typical of background concentrations in water.

Direct radiation

33 Gamma dose rates are measured annually at the site perimeter; any increase above natural background levels of radiation is attributable to radiation from facilities on the site rather than from waste discharges. The measured dose rates are generally only marginally above background level. A recent programme to determine dose rates from natural background radiation in the vicinity of the site gave results in the range 0.065-0.087 µSv h^{-1}. Measurements of direct radiation dose rates in the vicinity of dwellings close to the site boundary were also made and found to be indistinguishable from natural background levels.

The Ulnes Walton disposal site

34 Springfields samples water from various locations in the vicinity of this site and reports the results of the subsequent uranium analyses to the Environment Agency. The results are shown in table 14.

35 In addition to these samples, supplementary samples of drainage water are taken from an old outfall to the River Lostock and from the River Lostock upstream of the outfalls.

36 An annual radiation survey is carried out on the surface of the Ulnes Walton disposal site. These measurements are taken at 48 points on a grid plan of the site. The average gamma dose rate was 0.08 µGy h^{-1} with the highest reading being 0.09 µGy h^{-1}. These levels are virtually indistinguishable from natural background because the site has been capped with clay and topsoil. The site is not accessible to members of the public.

Table 14. Uranium concentrations in unfiltered water samples from the vicinity of Ulnes Walton

Position	Uranium concentration (μg ml^{-1})	
	Range	Mean
New outfall to River Lostock	0.0033 - 0.75	0.25
River Lostock at bridge	0.0007 - 0.0022	0.0015
Broadfield Farm	<0.0004 - 0.0012	0.0010
Finney House Farm	<0.0004	<0.0004
Old outfall to River Lostock	0.0014 - 0.0024	0.0018
River Lostock upstream of outfalls	0.0004 - 0.0008	0.0006

The Clifton Marsh disposal site

37 Samples of water are taken from boreholes on the Clifton Marsh site by SITA (formerly Lancashire Waste Services Ltd) and submitted to the Company for uranium analysis. A total of 143 such (unfiltered) samples were analysed with a mean uranium concentration of 0.0008 μg ml^{-1} and a range from less than 0.0004 to 0.0058 μg ml^{-1}. These levels are of no radiological or toxicological significance.

Radiological impact of operations at Springfields

Critical group doses

Aquatic pathways

38 The estimated external dose to the houseboat dwellers was 68 μSv, about 25% (17μSv) of which, based on recent analyses of the radionuclides in mud in the dwellers' area, was due to discharges from Springfields. The total dose was very similar to that in 2001. A revised effective occupancy over mud figure of 2700 h y^{-1} (table 15) based on habit survey data for the last five years[2,3] , was used for the 2002 assessment. Although protactinium-234m dominates radionuclide concentrations, the excess dose rate to the boat dwellers is dominated by caesium-137 which originates mainly from past discharges from Sellafield.

39 The estimated dose to anglers fishing along the banks of the River Ribble in Preston was 14 μSv, of which about 11 μSv arose from Springfields' discharges. Corresponding beta and gamma dose rates were recorded and the mean annual dose calculated, using an increased occupancy of 980 hours per year (table 15), also based on habit survey data for the last five years[2,3]. An occupancy weighting factor is applied to take account of the fractions of the total occupancy spent in different areas of the riverbanks.

40 The dose to wildfowlers lying in gullies (table 15) on Warton and Longton Marshes was calculated to be 9 μSv, using an occupancy of 324 hours per year (based on habit survey data for the last five years[2,3]) of which about 1 μSv arose from discharges from Springfields.

41 The mean dose from an annual consumption of 7 kg of mussels and 23 kg shrimps (table 15) based on habit survey data for the last five years[3], would be 45 μSv of which up to 21 μSv would have arisen from radionuclide species, principally thorium-230 and thorium-228 (a daughter of thorium-232) discharged by Springfields (table 1).

42 It is estimated that agricultural occupancy of the salt marshes of 324 hours per year (table 15) would lead to a dose of 9 μSv, almost all of which was due to historic caesium-137 discharges from Sellafield.

43 The assessment of doses from the consumption of beef and lamb from animals grazing on salt marshes was examined in detail in the 1995 report and shown to be negligible. It is considered that radionuclide concentrations in sheep and beef meat are unlikely to differ significantly from those in 1995.

Airborne and terrestrial pathways

44 The doses quoted in table 1 are for the adult members of the critical group living in the vicinity of the Windmill Tavern situated near the south west of the site. The principal pathway is by inhalation of uranium isotopes. The different uranium isotopes are of similar radiotoxicity, so no breakdown is given. The dose (3 μSv, very similar to 2001) is calculated from the mean uranium concentration in air (see paragraph 27 and the annual breathing rate (table 15).

45 The dose (to adults) from aerial discharges via the food chain has been calculated, using extremely pessimistic assumptions, as less than 0.5 μSv. This figure continues to represent an approximate but upper bound estimate for this very minor pathway.

Table 15. Consumption and occupancy data for critical group dose assessments.

Group	Annual Occupancy/Consumption
Houseboat dwellers[a]	2700 h
Wildfowlers/Agricultural	324 h
Anglers	980 h
Shellfish: Mussels	7 kg
Shellfish: Shrimp	23 kg
Inhalation: Breathing rate	7300 m^3
Direct Radiation	8760 h

a Effective occupancy taking account of shielding provided by the hull and via the tidal cycle.

Table 16. Collective doses from Springfields' discharges

Discharge route	Collective dose (man Sv)		
	UK	Europe	World
Aerial	0.03	0.05	0.05
Liquid	0.005	0.009	0.009

Direct radiation

46 Members of the public spend very little time in the immediate vicinity of the site perimeter. Measured radiation levels, which at the site perimeter have a mean value marginally above background, are of little significance in terms of public exposure. The programme of direct radiation measurements (paragraph 33) showed that within approximately 10 metres of the site boundary fence, in the vicinity of the nearest dwellings, direct radiation from the site was within the range of natural background levels. Accordingly, there is no detectable excess dose to members of reference groups (inhabitants of various dwellings and another building located near the site perimeter). An alternative approach has been suggested involving the extrapolation of the measurements at the site perimeter to the reference group locations. This approach gives a theoretical annual dose from direct radiation in the range 0-80 μSv, the figure being wholly dependent on the choice of background dose (paragraph 33) subtracted from the measured dose.

Collective doses

47 The collective doses from Springfields' discharges have been calculated in accordance with paragraphs 27-29 and 37 of the Introduction (amplified in the Appendix) and are presented in table 16. They are similar to those in 2001 and radiologically insignificant.

Non-radioactive discharges and disposals

48 The regulation of non-radioactive discharges and disposals is described in paragraphs 7-11 of the Introduction. Discharges from the Springfields site are made in accordance with the requirements of two IPC authorisations and a consent for trade effluent discharges to the sewer (see Annex). There were no non-compliances with discharge limits and conditions. Off-site disposals of solid waste were made in accordance with Duty of Care requirements and Special Waste Regulations.

49 The site has made an application for a permit to operate under the PPC Regulations (see paragraph 9 of the Introduction) as a non-ferrous metals activity. This permit will supersede both IPC authorisations. The regulator deemed the application 'duly made' within the statutory time period. However, concerns raised by the Environment Agency about national security, in relation to some of the information required to be given in the submission, have delayed the determination process.

Table 17. Discharges made under the terms of the non-ferrous metals process IPC authorisation

Substance	Aerial discharges (te)			Annual Limit (te)
Oxides of nitrogen (as NO_2)	9.0			-
Fluorine and hydrogen fluoride (as HF)	0.66			-
Organic compounds (as total carbon)	0			-
Cd, Hg, As, Pb, Cr, Ni, Cu and Mn (in total)	0			-
Dioxins and furans (as Total Equivalent Quantity)	0			-
	Liquid discharges (te)			
	Trade effluent	Storm water	Trade effluent + storm water	
Suspended solids	280	-	280	2100
Chemical Oxygen Demand (COD)	76	-	76	210
Ammoniacal Nitrogen (as N)	26	-	26	72
Nitrate	2200	-	2200	4600
Arsenic and its compounds (as As)	0.30	0.0061	0.31	2.5
Cadmium and its compounds (as Cd)	0.0097	0.000075	0.0098	0.096
Chromium and its compounds (as Cr)	0.17	0.0016	0.17	1.9
Copper and its compounds (as Cu)	0.63	0.0065	0.64	4.9
Iron and its compounds (as Fe)	19	0.43	19	64
Mercury and its compounds (as Hg)	0.0014	0.00013	0.0015	0.048
Nickel and its compounds (as Ni)	0.65	0.0022	0.65	2.5
Lead and its compounds (as Pb)	0.14	0.0026	0.14	2.4
Uranium and its compounds (as U)	1.7	0.11	1.8	6.4
Vanadium and its compounds (as V)	0.32	0.0061	0.32	4.9
Zinc and its compounds (as Zn)	0.51	0.028	0.54	3.1

Discharges made under the terms of Prescribed Process authorisations

Non-ferrous metals process IPC authorisation

50 Trade effluent and storm water are combined prior to discharge and this combined effluent (also authorised under RSA 1993) is discharged via pipelines to the Ribble Estuary.

51 The site's non-ferrous metals authorisation came into force in 1997. Liquid and aerial discharges made under the terms of this authorisation are given in table 17.

52 All formal actions and IPC improvement programme conditions have been completed to dates agreed with the Environment Agency.

Combustion Plant IPC authorisation

53 The site also has an authorisation covering the operation of the Combined Heat and Power Plant. This comprises two gas fired turbines linked to two waste heat recovery boilers and two separate auxiliary boilers. It generates the site's steam requirements and about 70% of the electricity requirements. Discharges are shown in table 18.

Discharges made under the terms of consents

54 Trade effluent discharges are made to the sewer from the Component Manufacturing Plant. Regular samples are requested by United Utilities (formerly North West Water Ltd) for analysis in its own laboratories. United Utilities has reported no instances of non-compliance with the conditions of this consent.

Ozone depleting substances

55 The site has a policy for minimising discharges of ozone depleting substances. In 2002, approximately 1.5 te of HCFC-22 (used in site refrigerant systems) were discharged.

Carbon dioxide

56 Discharges of about 71,000 te of carbon dioxide were made in 2002. This largely reflects the operation of the Combined Heat and Power Plant.

Off-site disposals of solid waste

57 The basic principles observed on the site are to minimise, recycle, reuse, decontaminate and finally dispose. Uranium recovered during decontamination can generally be fed back into the manufacturing cycle. These principles apply to both manufacturing and support areas.

58 No waste disposals are made on site although construction spoil has been used on site for landscaping purposes. The vast majority of waste disposals are made to the Clifton Marsh landfill site. A proportion of the waste disposed of under the terms of the RSA 1993 authorisation will not be radioactive. However if the volume of a waste stream or its value indicates a benefit, then the waste will be monitored to a standard that enables free release. This is the case with valuable metals and alloys such as copper, Inconel and Monel, and also with rubble. The operators of Clifton Marsh can use clean rubble for construction of internal roads and ramps rather than having to specifically purchase materials for these purposes.

Table 18. Discharges made under the terms of the combustion plant IPC authorisation

Substance	Discharge (te)	Annual Limit (te)
Sulphur dioxide	0.022	-
Oxides of nitrogen	93	-
Mercury	0.000066	0.0001

59 Approximately 990 te of special wastes were disposed of in 2002, of which about 85% were process residues classed as special waste. These figures, similar to 2001, reflect decommissioning programmes and the clearance of historic process residues from the site. Some other wastes which would otherwise have been designated as special wastes were recycled.

Acknowledgements

John Nobbs, Andrew Taylor, Mick Lyons, David Watson and Sean Byrne of Environment, Safety and Health at Springfields wrote this chapter. Their colleagues in this unit collected the environmental samples and measured environmental dose rates. Chemical and Metallurgical Services at Springfields analysed the samples. Members of the public who co-operated with the BNFL staff collecting samples and making measurements are especially thanked.

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1 Garner, R. J. (1963). **Environmental Contamination and Grazing Animals**. Health Physics 9: 597-605.

2 Environment Agency (2002). **Radioactivity in the Environment. A summary and radiological assessment of the Environment Agency's monitoring programmes**. Report for 2001.

3 Environment Agency, Environment and Heritage Service of Northern Ireland, Food Standards Agency and Scottish Environment Protection Agency (2003). **Radioactivity in food and the environment, 2002**. RIFE-8. EA, EHS, Food Standards Agency and SEPA, Lancaster, Belfast, London and Stirling (and RIFE reports for previous years).

Annex: Authorisations and consents effective in 2002

Authorisations issued under the Radioactive Substances Act 1960 and 1993

Description	Effective Date
Disposal of liquid waste to the tidal waters of the River Ribble	1 Oct 1991
Disposal of gases, mists and dusts to atmosphere	1 Nov 1995
Disposal of solid wastes on site	1 Apr 1971[a]
Disposal of solid wastes at Ulnes Walton (Joint authorisation with Capenhurst)	1 Apr 1971[a]
Disposal of solid wastes at Clifton Marsh (Joint authorisation with Capenhurst) Notice of Variation	27 Mar 1974[a] 23 Jan 1986[a]
Disposal of solid waste by transfer to Drigg Notice of Variation	1 Jan 1992 28 Mar 1996
Disposal of combustible waste by transfer to Capenhurst	1 Jun 1994

a. Separate authorisations issued by DoE and MAFF. All other authorisations in this table were issued jointly by HMIP and MAFF.

Prescribed Process authorisations issued under the Environmental Protection Act 1990

Number	Description	Effective Date
AA2283	Combustion process authorisation (for the Combined Heat and Power Plant)	27 May 1993
AS4494	Non-ferrous metals authorisation A large number of variations (currently in excess of 23) have been issued to AS4494 to reflect changing environmental and process circumstances. A full list can be viewed on application to BNFL or to the Environment Agency area office at Birchwood.	1 May 1997

Consents issued under the Water Industries Act 1991

Number	Description	Effective Date
716T2-1-303	Discharge of trade effluent to the North West Water sewer from the Component Manufacturing Plant	30 Sep 1997

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Summary

1 At no time during 2002 have discharges and disposals of radioactive waste through authorised and scheduled outlets at Capenhurst exceeded numerical limits in any of the authorisations. The annual radiation doses to the critical groups from liquid and aerial discharges continued to be less than 1 μSv (table 1) and were therefore radiologically insignificant. There were no instances in 2002 of non-compliance with numerical limits in non-radioactive discharge consents.

Table 1. Summary of critical group doses in the vicinity of Capenhurst (μSv)

Pathway[a]	Liquid discharges		Aerial discharges		Position in text (paragraph no.)
	2001	2002	2001	2002	
Rivacre Brook: child playing	<1	<1	-	-	22
Milk consumption: infant	-	-	<1	<1	24

a. Direct radiation is discussed in paragraphs 21 and 25.

Operations at Capenhurst

2 Capenhurst, situated near Ellesmere Port on the Wirral, consists principally of centrifuge plants and a redundant gaseous diffusion plant. In March 1993, the Capenhurst site was split into two companies: BNFL Capenhurst, and URENCO (Capenhurst) who own and operate the centrifuge plants on site. The main activities undertaken during 2002 by BNFL at Capenhurst were the continued decommissioning of the gaseous diffusion plant and of a small redundant facility which used to process tritium gas. BNFL Capenhurst continued to provide a uranic storage service to the nuclear industry.

3 URENCO (Capenhurst) has been granted its own authorisations for the transfer of both liquid and solid waste to BNFL Capenhurst for onward disposal. Summaries of these transfers are given in the Health, Safety and Environmental Report 2002 published by URENCO (Capenhurst). This is available from the latter's Health, Physics and Safety Records Office, Capenhurst, Chester CH1 6ER.

Radioactive discharges and disposals

4 Capenhurst holds a number of authorisations covering discharges and disposals of radioactive wastes to the Rivacre Brook, to atmosphere and by burial in the ground at Ulnes Walton (no longer used), Clifton Marsh and Drigg. A further authorisation covers very low levels of radioactivity in special waste. They are all listed in the Annex to this chapter. The Environment Agency commenced a review of all of the site's authorisations in 2001.

Liquid discharges into the Rivacre Brook

5 Liquid wastes principally arise from decommissioning operations. These wastes, together with those from URENCO (Capenhurst), are all discharged into the Rivacre Brook by means of a culvert and ditch. The discharges are covered by two quantitative authorisations, one for uranic type discharges and one specific to discharges from the former tritium processing facility.

6 Collectively, the authorisations and associated variation include quarterly limits for a number of individual radionuclides. Discharges of 'total alpha' activity are subject to daily (24 hour) limits. In order to demonstrate compliance with the terms of the authorisation and variation, samples from each waste stream are analysed daily (e.g. incinerator water trough) or prior to discharge

Table 2. Radioactive discharges to Rivacre Brook

Radionuclide	Mean radionuclide concentration					
	1998	1999	2000	2001	2002	Authorised Limit[a]
Total alpha (Bq l^{-1})	<5	<5	<5	<5	<5	100
Tritium (Bq ml^{-1})	0.1	0.1	0.1	0.1	0.1	111
	Annual discharge (GBq)					
Total uranium alpha activity	1.3	2.3	1.2	1.5	1.2	20
Uranium daughters	<2.9	<1.9	<2.4	<2.2	<1.1	20
Non-uranic alpha emitters (mostly neptunium-237)	0.014	0.021	0.035	0.021	0.006	3
Technetium-99	1.4	1.1	1.5	1.3	1.1	100
Tritium	150	120	120	120	130	78,000[b]

a. Where authorised limits are specified for periods of three consecutive calendar months, annual equivalents have been derived by multiplying these limits by four.
b. Derived limit based on quarterly limit and average brook flow of 80 m^3 h^{-1}.

Table 3. Airborne radioactive waste discharges

Radionuclide	Annual discharge (TBq)					Authorised Limit (TBq)
	1998	1999	2000	2001	2002	
Uranium	0.000006	0.00003	0.000005	<0.000007[a]	0.000007	-
Tritium	5.1	0.53	0.57	0.04	0.01	1600

a. Amended figure

(e.g. decommissioning effluent delay tanks) along with daily sampling and analysis of the site outlet.

7 Table 2 presents data on discharges for the past five years and provides a basis for comparison with the authorised limits. Variations in these small discharge levels reflect the various phasing of decommissioning operations.

Other liquid wastes

8 BNFL Capenhurst is authorised under the Radioactive Substances Act 1960 to dispose of Special Waste within the meaning of, and in accordance with, the Control of Pollution (Special Waste) Regulations 1980. The quantities of radioactivity in this waste are very low. Under the terms of the authorisation the Company is required to use Best Practicable means (BPM) to limit the activity content and to ensure that the total activity, excluding decay products, does not exceed 1 MBq m^{-3}. There were no disposals of such waste in 2002.

Aerial discharges

9 Radioactive effluents are discharged to atmosphere via stacks on the Capenhurst site. These discharges consist principally of incinerator gases and ventilation air from decommissioning operations.

10 The radioactive content of discharges from the incinerator and the majority of other release points on site consist predominantly of uranium accompanied by an approximately equal beta activity from uranium daughters and lesser activities of technetium-99. The Environment Agency's current review of the site's authorisations will include the introduction of quantitative limits on airborne radioactive discharges.

11 In addition, and as a result of the continued decommissioning operations on the former tritium processing facility, tritium has also been discharged to atmosphere from the facility's stack. The present authorisation, which contains numerical limits, came into effect in 1994. Prior to this, the authorisation required only that Best Practicable Means (BPM) be employed to minimise discharges.

12 Discharges of uranium and tritium over the past five years are shown in table 3. Variations in these small discharge levels reflect various phasing of decommissioning operations.

Solid wastes

13 Authorisations for disposal at Ulnes Walton disused clay pits and Clifton Marsh refuse pits are shared with Springfields. Neither Capenhurst nor Springfields has disposed of any waste to Ulnes Walton since 1974 and 1983 respectively and no further disposals will be made. The authorisation is in the process of revocation (see Springfields paragraph 12). Meanwhile, the Statutory Environmental Monitoring Programme relating to this site is continuing, and details are given in paragraphs 34-36 of the Springfields chapter.

14 Solid waste disposals at Clifton Marsh are shown in table 4. Recent increases reflect accelerated decommissioning activities. The waste consists of ash, scrap metal and other non-combustible materials, such as glassware and building rubble. It can also include incinerator ash generated from waste transferred from URENCO under the terms of an RSA inter-site transfer authorisation. The alpha radioactivity in the solid waste, due almost entirely to uranium is accompanied by an approximately equal amount of beta activity from uranium daughters.

15 Solid waste which does not conform to the requirements of the Clifton Marsh authorisation is disposed of to Drigg. An authorisation specific to Capenhurst for the disposal of waste to Drigg came into force in 1992. A variation to this authorisation allowing disposal to Drigg via the Waste Monitoring and Compaction (WAMAC) plant at Sellafield came into effect in 1996. There were no transfers to Drigg in the period 1995-2000 but they re-commenced in the latter part of 2001 (table 5) as a result of decommissioning operations.

Table 4. Disposals of solid waste to Clifton Marsh from Capenhurst

	1998	1999	2000	2001	2002
Bulk weight (tonnes)	17	28	14	24	208
Uranium alpha content (MBq)	610	360	460	1260	1030

Table 5. Disposals of solid radioactive waste to Drigg from Capenhurst

	1996-2000	2001	2002	Authorised Limit
Volume (m^3)	nil	19	736	1500
Uranium (GBq)	nil	0.008	1.20	250
Other alpha emitters (GBq)	nil	0.013	0.29	15
Others (GBq)	nil	1.7	55	3000

Table 6. Environmental monitoring related to discharges to the Rivacre Brook

Location/sample	Number of samples	Mean radionuclide concentration (Bq kg^{-1} wet weight for *Cladophora*, Bq kg^{-1} dry weight for silt)			
		Uranium	Technetium-99	Neptunium-237	Total tritium
Point A (see figure 1)					
silt	12	1400	1100	23	-
Point B (see figure 1)					
water (unfiltered)	12	1.0	1.0	0.01	<50
algae - *Cladophora*	5	18	240	2	70
silt	12	160	210	11	-

Monitoring of the environment for radioactivity

16 The principal exposure pathways for radioactivity discharged from the Capenhurst site, as identified by environmental monitoring and habits surveys, are the ingestion of milk produced at local farms and the external radiation to, and potential inadvertent ingestion of water and silt by, children playing in the Rivacre Brook. These pathways are covered by the Food Standards Agency's monitoring programme[1] and the site's Statutory Environmental and Monitoring Programme illustrated in figure 1 (updated to take account of changes) which also includes the sampling of water weed, grass and bovine faeces. The very low direct radiation dose rates from the site are also routinely monitored.

Aquatic pathways

17 There is a requirement under the Statutory Environmental Monitoring Programme to analyse samples from the Rivacre Brook of water, silt and the water weed *Cladophora* (see figure 1 and table 6). The levels of radioactivity are similar to those in the previous year as they arise from ongoing decommissioning activities on the site. Levels of activity at the plant outlet (Point A), which is within the boundary of the licensed site, are significantly higher than downstream (Point B) due to accumulation of radioactivity in silt. The silt is periodically removed from the outlet and disposed of to a local landfill site or to Drigg, depending on the radioactive content. Measurements have also been carried out by the regulatory bodies for many years.

Airborne and terrestrial pathways

18. The discharges to atmosphere are radiologically insignificant. However, BNFL collects samples of grass from two on-site locations and bovine faeces from five local farms (figure 1) and analyses them for technetium-99 and uranium. The results for grass and bovine faeces were all below the limit of detection for technetium-99 (37 Bq kg^{-1}) and averaged 1.7 Bq kg^{-1} and 3.4 Bq kg^{-1} respectively for uranium .

19 The Food Standards Agency undertakes a monitoring programme for uranium and technetium-99 in samples of milk. Recent results[1] show that mean uranium and technetium-99 concentrations in milk samples collected from a local farm were less than the limits of detection (0.0065 Bq l^{-1} and 0.006 Bq l^{-1} respectively).

20 BNFL also undertakes a quarterly monitoring programme for tritium levels in on-site grass samples and a monthly monitoring programme for milk from five local farms. Tritium levels in on-site grass samples were below the limit of detection (50 Bq kg^{-1}) apart from one result which was 80 Bq kg^{-1}. Levels in milk were below the limit of detection (50 Bq l^{-1}).

Direct radiation

21 Dose rates at the site perimeter and other locations are measured annually. Any increase above the background level of about 0.1 µGy h^{-1} is attributable to direct radiation from the plant rather than waste discharges. The mean dose rate was less than 0.2 µGy h^{-1}, including natural background, with a peak level of 0.35 µGy h^{-1} at part of the site perimeter.

Radiological impact of operations at Capenhurst

Critical group doses

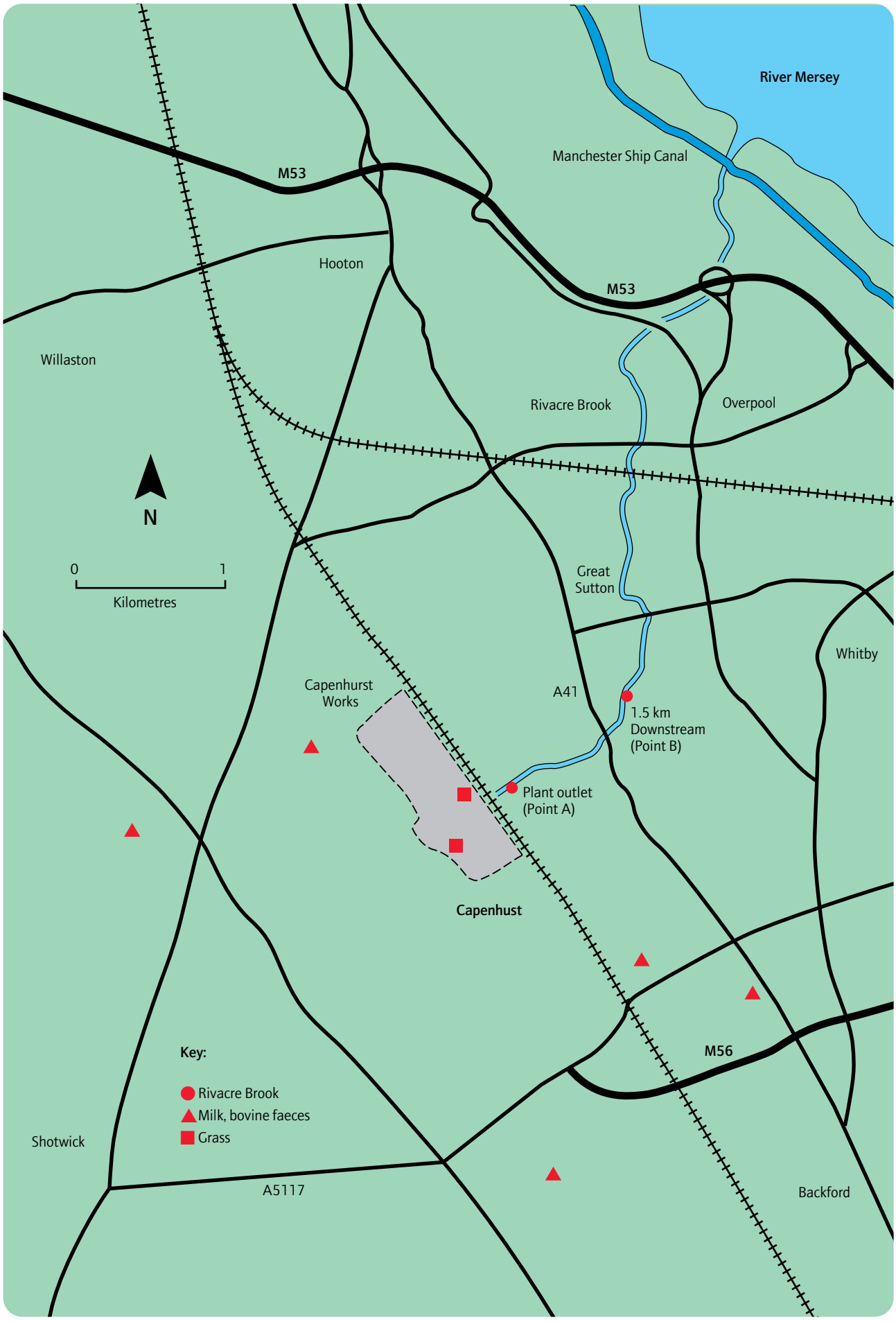
Aquatic pathways

22 The only identified critical pathway[2] for liquid discharges is the dose due to the inadvertent ingestion of water or silt by children playing on or near the Rivacre Brook. This dose is estimated at less than 1 µSv per year from all site discharges (table 1). Potential doses (3 µSv) from external radiation over the banks of the brook could be attributable to variations in natural background dose rates[2].

Airborne and terrestrial pathways

23 The radiotoxicity of uranium is low compared with its chemical toxicity. The uranium concentrations in bovine faeces have been historically equivalent to about 0.1% of the concentration estimated to begin to affect the health of cattle (see paragraph 28 of the Springfields chapter) and are within the range of concentrations observed naturally. Hence there are no radiological implications for food safety.

Figure 1. Environmental monitoring around Capenhurst



24 Assuming that all milk consumed comes from local farms, the dose to the most exposed member of the public (i.e. a one year old infant) was estimated as less than 1 µSv, including the contribution from tritium (table 1).

Direct radiation

25 Members of the public spend very little time in the immediate vicinity of the perimeter of the combined sites and so radiation levels here (paragraph 21) are of very little significance in terms of public radiation exposure. Detailed studies into the direct radiation exposure to the general public in the vicinity of the site are continuing. A combination of dose rate measurements and theoretical extrapolation to locations occupied by the public has given a maximum potential dose of 70 µSv, principally from the adjacent URENCO licensed site, although the actual dose is likely to be much lower.

Collective doses

26 Collective doses from discharges from Capenhurst were calculated in accordance with paragraphs 27 to 29 and 37 of the Introduction (amplified in the Appendix). The collective doses were estimated to be 0.001 man Sv to the UK population, 0.001 man Sv to the EU and 0.002 man Sv to the world population. Most of these doses (over 99%) will be delivered in the first year and arise predominantly from tritium.

Non-radioactive discharges and disposals

27 The regulation of non-radioactive discharges and disposals is described in paragraphs 7-11 of the Introduction. Thus, discharges from the Capenhurst incinerator are made in accordance with the requirements of a Prescribed Process authorisation and discharges to the Rivacre Brook in accordance with a consent (see Annex). Except for events unconnected with the BNFL site (paragraph 30), there were no non-compliances with discharge limits and conditions. Off-site disposals of solid waste were made in accordance with Duty of Care requirements and Special Waste Regulations.

Discharges made under the terms of Prescribed Process authorisations

28 Combustible waste which is necessarily generated and for which there is no further use under the site's recycling initiatives is burnt within BNFL Capenhurst's incinerator. Consequently, a Prescribed Process authorisation regulates the discharge of gaseous effluents from the incinerator stack. Concentration limits are specified for certain off-gases generated as a result of the high temperature combustion process. Compliance checking is effected by passing the flue gases through bubbler trains, filters and by direct spectrometry. The resultant solutions and used filters are sampled and analysed by approved methods. Discharges are summarised in table 7.

Table 7. Non-radioactive aerial discharges from the incinerator

Species	Discharge (kg)
Hydrogen chloride	7.8
Hydrogen fluoride	4.1
Sulphur dioxide	14

Table 8. Non-radioactive discharges to the Rivacre Brook from the sewage farm

Species	Discharge (te)
Copper	0.003
Zinc	0.006
Aluminium	0.009
Iron	0.008
Suspended solids	0.93
Fluoride	0.030

Discharges made under terms of consents

29 Non-radioactive liquid wastes arise principally from decommissioning operations on the BNFL licensed site. These wastes, together with those transferred to BNFL from the URENCO (Capenhurst) site (paragraph 3), and those from neighbouring companies (e.g. Capenhurst Technology Centre, EA Technology, Sutton Nurseries) and certain local domestic properties, are all discharged into the Rivacre Brook by means of the culvert and ditch used for radioactive effluents (paragraph 5).

30 The discharges from BNFL Capenhurst are made under the terms of a consent relating to treated sewage effluent, River Dee water and a delay tank (see Annex). From 2002, compliance with the consent has been checked by regular and periodic sampling at the point of discharge. Consequently, site discharges are assumed to originate predominantly from the sewage farm (table 8) rather than at the site outlet where the results can be affected by events unrelated to BNFL or URENCO operations. Accordingly the discharges reported in table 8 are significantly lower than those reported in the previous year.

Ozone depleting substances

31 Use of ozone depleting substances is limited to those which are necessarily contained within refrigeration units. Wherever practicable, the use of these will be gradually phased out or environmentally friendly substitutes used. An active programme driven by the site environmental committee ensures that the elimination of these substances will occur well in advance of current legislation.

Off-site disposals of solid waste

32 If they cannot be recycled, controlled wastes from offices, workshops and other sources are disposed of to a local

landfill site via a specialist waste contractor, and special wastes to licensed disposal facilities. Special wastes, which are also radioactive, are included in the Drigg disposal figures. The total amounts of wastes disposed of or recycled in 2002 are categorised and summarised in table 9. The site's accelerated decommissioning programme has involved the dismantling of a number of redundant buildings, resulting in increased quantities of building rubble and other associated waste streams. The rubble is ordinarily disposed of to landfill. However, much of it has been processed and reused on site to minimise the overall disposal quantities.

Table 9. Disposal and recycling of non-radioactive solid wastes

	Quantity (te)
Controlled waste (excluding special waste)	
General site waste	100
General demolition waste[a]	160
General spoil[a]	500 (m^3)
On-site crushing[b]	130 (m^3)
Plastic cups[b]	0.3
Aluminium[b]	970
Aluminium cans[b]	0.04
Steel[b]	100
Miscellaneous metals[b]	100
Paper[b]	7
Cardboard[b]	5
Special waste	
Asbestos containing products	600 (m^3)
Oil[b] and oily water[b]	46 (m^3)
Sludges	800
Miscellaneous Used Chemicals[a]	5 (m^3)
Batteries (vehicle)[a]	2

a. Some recycled.
b. Waste consigned for recycling.

Acknowledgements

This chapter was written by Ray Atherton and Mark Lister of the Environment Health and Safety Department at Capenhurst. Their departmental colleagues and those at URENCO (Capenhurst) collected the environmental samples and measured environmental dose rates. The laboratories at BNFL Capenhurst and URENCO (Capenhurst) analysed the samples. Members of the public who cooperated with staff collecting samples and making measurements are especially thanked.

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1 Environment Agency, Environment and Heritage Service of Northern Ireland, Food Standards Agency and Scottish Environment Protection Agency (2003). **Radioactivity in food and the environment, 2002**. RIFE-8. EA, EHS, Food Standards Agency and SEPA, Lancaster, Belfast, London and Stirling.

2 Environment Agency (2002). **Radioactivity in the Environment. A summary and radiological assessment of the Environment Agency's monitoring programmes. Report for 2001**.

Annex: Authorisations and consents effective in 2002

Authorisations issued under the Radioactive Substances Act 1960 and 1993

Description	Effective Date
Disposal of liquid waste to the Rivacre Brook Notice of Variation	1 Apr 1971[a] 1 May 1989[a]
Disposal of liquid waste to the Rivacre Brook (tritium)	1 Apr 1971[a]
Disposal of liquid waste which is also Special Waste	1 Jun 1989[b]
Disposal of waste gases, mists and dusts to atmosphere (tritium)	9 May 1994[c]
Disposal of waste gases, mists and dusts from any premises situated on a licensed site occupied by the Company	1 Apr 1971[a]
Disposal of solid wastes at Ulnes Walton (Joint authorisation with Springfields)	1 Apr 1971[a]
Disposal of solid wastes at Clifton Marsh (Joint authorisation with Springfields) Notice of Variation	27 Mar 1974[a] 23 Jan 1986[a]
Disposal of solid waste by transfer to Drigg Notice of Variation	1 Jan 1992[c] 3 May 1996[d]

a Separate authorisations issued by DoE and MAFF.
b. Joint authorisation issued by DoE and MAFF.
c. Joint authorisation issued by HMIP and MAFF.
d. Authorisation issued by the Environment Agency.

Prescribed Process authorisations issued under the Environmental Protection Act 1990

Number	Description	Effective Date
AJ 0698	Waste incineration process authorisation Notice of Variation No 1 Notice of Variation No 2 Notice of Variation No 3 Notice of Variation No 4	1 Dec 1993 23 Dec 1994 3 Mar 1998 4 Sep 1998 20 Apr 2001

Consents issued under the Control of Pollution Act 1974 and Water Industries Act 1991

Number	Description	Effective Date
01689 0908	Discharge of trade effluent, treated sewage effluent and surface water to the Rivacre Brook Notice of modification No 1 Notice of variation No 1 Notice of modification No 2	12 Dec 1988 1 Jul 2001 3 Dec 2001 12 Feb 2002

Discharges and Monitoring of the Environment in the UK
Annual Report 2002

magnox stations

Summary

1 At no time during 2002 have discharges and disposals of radioactive waste from any of the operating or decommissioning Magnox sites exceeded quantitative limits in any of the relevant authorisations.

2 Critical group doses in the vicinity of each Magnox station from liquid and aerial discharges are summarised in tables 1 and 2. The highest dose in the vicinity of Magnox stations arising from liquid discharges was 29 µSv at Bradwell and Hunterston A. The highest dose from aerial discharges was 55 µSv at Hinkley Point A (including a contribution from the adjacent British Energy station). Doses from direct radiation to the most exposed members of the public living near Magnox stations are summarised in table 3. The highest dose was 560 µSv at Dungeness A. Finally, critical group doses for each station, taking account of additivity across the above pathways, are summarised in table 4. The highest dose was 590 µSv at Dungeness A.

3 There were no instances of non-compliance with IPC authorisations for aerial discharges from combustion plant at any operating or decommissioning Magnox site. On one occasion the temperature limit in the consent covering discharges from Calder Hall was exceeded (paragraph 151) and on two occasions Oldbury exceeded its limit on suspended solids in discharges (paragraphs 152 and 153).

Introduction

4 BNFL operates the Magnox nuclear power stations at Calder Hall (which ceased generation in March 2003), Chapelcross and Hunterston A (which is decommissioning). In December 2002, BNFL took over operation of the two other decommissioning Magnox stations, Berkeley and Trawsfynydd, from its subsidiary company, Magnox Electric. BNFL's site licence and authorisation for Berkeley station includes the adjacent Berkeley Centre. Magnox Electric (a wholly owned subsidiary of BNFL) operates the other Magnox stations, four of which were generating in 2002, one (Hinkley Point A) continued defuelling throughout the year and the other (Bradwell) ceased generation in March 2002 and has since been defuelling. Nuclear power stations do not start formal decommissioning until all the fuel has been removed from the site, so defuelling stations are grouped with the generating stations in this report. Magnox Electric also operates the Facility for Reactor Engineering and Design at Littlebrook in Kent and the hydro-electric power station at Maentwrog in Gwynedd. The identity and status of each site is given in table 5 and their locations are included on the map (figure 1) on page 5.

Table 1. Critical group doses from liquid discharges in the vicinity of Magnox stations (µSv)

Station	2001	2002	Main pathways (2002)[a]	Paragraph
Bradwell	15	29	External exposure + consumption of fish	129
Chapelcross[b]	38	21	External exposure + consumption of fish and shrimps	
Dungeness A[c]	28	25	External exposure + consumption of fish and crustaceans	
Hinkley Point A[c]	19	15	External exposure + consumption of fish	
Hunterston A[b,c]	31	29	External exposure	
Oldbury and Berkeley	9.8	3.3	External exposure + consumption of fish	
Sizewell A[c]	14	2.6	Consumption of fish	
Trawsfynydd	6.5	6.5	Consumption of fish	
Wylfa[b]	7.7	11	External exposure + consumption of fish	

a. Pathways listed in order of significance. b. Mainly from Sellafield's discharges. c. Includes contribution from neighbouring British Energy site (see paragraph 122).

Table 2. Critical group doses from aerial discharges in the vicinity of Magnox stations (µSv)

Station	2001	2002	Main pathway (2002)	Paragraph
Bradwell[a]	10[c]	16[c]	Consumption of milk (infants)	135
Chapelcross	16	12		
Dungeness A[b]	43[c]	52[c]		
Hinkley Point A[b]	46[c]	55[c]		
Hunterston A[b]	25	26		
Oldbury[a] and Berkeley	26[c]	33[c]		
Sizewell A[a,b]	9[c]	12[c]		
Trawsfynydd	2.0	<0.1	Plume (adults)	
Wylfa[a]	4.8[c]	3.7[c]	Consumption of milk (infants)	

a. Excludes external radiation doses calculated from argon-41 in the plume, which are included in the measurements of direct radiation doses (see paragraph 138).
b. Includes contribution from neighbouring British Energy site (see paragraph 122).
c. Upper bound.

Table 3. Direct radiation doses to the most exposed members of the public at Magnox stations (μSv)

Station	2001	2002	Paragraph
Berkeley	BG[a]	23	139
Bradwell[b]	430	220	
Chapelcross	110	110	
Dungeness A	390[c]	560	
Hinkley Point A	BG[a]	BG[a]	
Hunterston A	65[c]	43	
Oldbury[b]	2.5[c]	BG[a]	
Sizewell A[b]	24[c]	28	
Trawsfynydd	BG[b,c]	10	
Wylfa[b]	4.5[c]	5.1	

a. Indistinguishable from local background (see paragraph 139)
b. Includes external gamma doses from discharges to air (see paragraph 138).
c. Correction due to revision of background assessment (paragraph 139).

Operations at generating sites

Nuclear

5 Magnox reactors generate electricity by nuclear fission. The fuel is held in the reactor core as an array of natural uranium bars, each encased in Magnox, an alloy of magnesium and aluminium. The array is enclosed in a graphite matrix (the moderator). The hot core is cooled with carbon dioxide, which generates steam in the boilers before being routed back to the core. The steam is then passed through turbines to generate electricity.

6 Stations are equipped with a variety of plant to control the chemical purity of the coolant, both to prevent the accumulation of chemicals that might inhibit power generation and to maximise the generating life of the

Table 4. Summary of critical group doses in the vicinity of Magnox stations (μSv)

Station	2001	2002	Main pathways (2002)
Berkeley	26[b]	33	Milk (infants)
Bradwell	440	230	Direct + plume + consumption of vegetables and milk (adults)
Chapelcross	130	120	
Dungeness A[a]	460[c]	590	
Hinkley Point A[a]	46[b]	55	Consumption of milk (infants)
Hunterston A[a]	69[c]	47	Direct + plume + consumption of vegetables and milk (adults)
Oldbury	26[b]	33	Consumption of milk (infants)
Sizewell A[a]	27[c]	47	Direct (Group *B*) + consumption of fish
Trawsfynydd	6.5	10	Direct + plume + consumption of vegetables and milk (adults)
Wylfa	7.7	11	Liquid discharges

a. Includes contribution from neighbouring British Energy site. b. Upper bound.
c. Correction due to revision of background assessment for direct radiation (paragraph 139).

Table 5. Locations and status of Magnox power stations

Site	Status	Reactors		Date opened	Generation in 2002			Date closed	Date de-fuelled
		Number	Pressure vessel		Capacity (MW)	Output (GWh)			
						Gross	Supplied		
England:									
Berkeley[a]	decommissioning	2	steel	1962	-	-	-	1989	1992
Bradwell	defuelling[c]	2	steel	1962	246	340	330	2002	in progress
Calder Hall[b]	defuelling[d]	4	steel	1956	194	220	170	2003	in progress
Dungeness A	generating	2	steel	1965	450	3300	3200	-	-
Hinkley Point A	defuelling	2	steel	1964	-	-	-	2000	in progress
Oldbury	generating	2	concrete	1967	434	3600	3400	-	-
Sizewell A	generating	2	steel	1965	420	3500	3000	-	-
Wales									
Maentwrog	generating	Hydro-electric		1928[e]	30	61	61	-	-
Trawsfynydd[a]	decommissioning	2	steel	1965	-	-	-	1993	1995
Wylfa	generating	2	concrete	1971	980	8700	7500	-	-
Scotland									
Chapelcross[b]	generating	4	steel	1959	196	640	500	-	-
Hunterston A[b]	decommissioning	2	steel	1964	-	-	-	1990	1995

a. Station operated by BNFL since December 2002; previously operated by Magnox Electric. b. Station operated by BNFL.
c. Ceased generation in March 2002. d. Ceased generation in March 2003. e. New turbines installed in 1990.

reactor. In particular, the quantities of carbon monoxide, moisture and nitrogen in the coolant are limited. Carbon monoxide can be controlled by purging the coolant with clean carbon dioxide or by using a recombination unit to convert carbon monoxide to carbon dioxide on a catalyst. The recombination unit also converts gaseous species of hydrogen to water, thereby removing moisture from the coolant. In the process, tritium is converted to tritiated water. Moisture may also be removed by dryer units. Any tritiated water drained from the recombination unit or dryer unit is discharged as liquid effluent (paragraph 30).

7 The coolant is circulated through the core at high pressure (10 to 30 bar), so each reactor is enclosed in a pressure vessel. The older Magnox reactors have steel pressure vessels, which require an external concrete biological shield to protect station personnel from radiation. The interspace between the steel and the concrete is swept by air to cool the shield. This air is then discharged. The more recent stations (Oldbury and Wylfa) have pre-stressed concrete pressure vessels that provide adequate protection to personnel from radiation and so require no additional biological shield. These concrete pressure vessels are water-cooled, so do not discharge shield cooling air.

8 Where appropriate, contamination controlled areas in each station are served by ventilation systems equipped with high efficiency filters to minimise the aerial discharge of radioactive particles.

9 After about five years in the reactor, irradiated fuel is removed, then cooled for about 90 days to meet transport regulations and sent to Sellafield for reprocessing. It is cooled under water, except at Wylfa which has a dry storage system (paragraph 49).

Bradwell

10 Bradwell ceased generation according to plan at the end of March 2002 and is now being defuelled. The pond was cleared of spent fuel by the end of 2002 and is now being refurbished prior to defuelling the reactors. Decommissioning operations will take place in due course.

Calder Hall

11 Calder Hall is located at Sellafield. All four reactors were off load at the beginning of the year pending work on the reactor internals. Reactor 1 was brought back to power in July and continued to generate for the remainder of the year. However, it was decided that the operating costs of the station could no longer justify the output from the small reactors, so the closure date was brought forward. Consequently, the other three reactors did not return to power and reactor 1 finally ceased generation at the end of March 2003.

12 All liquid waste arisings are transferred to the main Sellafield site for treatment and disposal. Information on discharges, environmental monitoring and doses is included in the Sellafield chapter because data relating to the reactors cannot be practicably separated from the data relating to the rest of the site.

Chapelcross

13 Reactor 1 has been shut down all year pending work on the reactor internals. The other three reactors have been generating throughout the year, with intermittent periods off load for refuelling, maintenance and core inspection work.

14 The site also operates the Chapelcross processing plant which produces tritium.

Dungeness A

15 Reactor 1 underwent routine maintenance from April to June, but was otherwise at power throughout the year. Reactor 2 operated at normal power levels throughout the year.

Hinkley Point A

16 Hinkley Point A has been defuelling both reactors throughout the year. By the end of the year, about a quarter of the channels in each reactor had been defuelled.

Oldbury

17 Reactor 2 underwent routine maintenance for a month. Otherwise both reactors at Oldbury operated at normal power levels throughout the year.

Sizewell A

18 Reactor 1 underwent routine maintenance for two months during the year. Otherwise both reactors generated at normal power levels throughout the year. In January, the station achieved its highest electricity output since the 1960s.

Wylfa

19 Both reactors were at power throughout the year, except for routine maintenance on reactor 2.

Hydro-electric

Maentwrog

20 The generating capacity of the hydro-electric plant at Maentwrog in Gwynedd is small compared to the nuclear stations (table 5). The station has generated according to the requirements of the New Electricity Trading Arrangements (NETA). Output for February was much higher than planned due to unusually high rainfall.

Operations at decommissioning sites

Berkeley

21 Decommissioning activities continued throughout the year. There were few activities with significant impact on discharges in 2002.

Hunterston A

22 Decommissioning activities continued throughout the year. There were few activities with significant impact on discharges in 2002. Disposals of low level waste to Drigg were predominately from the de-planting and cleaning of the fuel graphite sleeve transfer tunnel and redundant pond building equipment disposal. The main contributions to liquid discharges were from change-rooms that serve contamination areas on site, pond de-sludging work and processing of historical arisings from Hunterston B (paragraph 56). The main contributions to gaseous discharges were from the decontamination and final sealing of the fuel graphite sleeve transfer tunnel, routine extraction of contamination areas on site and reactor vessel breathing.

Trawsfynydd

23 Various decommissioning activities progressed throughout the year. The ventilation for reactor 2 was changed from a forced system to a passive system via an engineered vent (in common with the arrangements on reactor 1 and at Berkeley). A new liquid effluent discharge line was commissioned and brought into service. Although this new line has no impact on the level of discharges it enables the site to decommission the site turbine hall and the former condenser water system which had also served as the effluent dilution water.

Operations at other sites

Berkeley Centre

24 Operation of Berkeley Centre (formerly known as Berkeley Nuclear Laboratory) was transferred to BNFL Environmental Services in December 2002, although it continues to act as the group headquarters for the generating stations. It also houses general support functions, such as the Reactor Services Organisation and the Central Radiochemical Laboratory (CRL), which analyses liquid effluents (paragraphs 35 and 36) and environmental samples on behalf of the generating and decommissioning stations. Routine operations continued throughout the year. Discharges, disposals and environmental measurements for Berkeley Centre are discussed under the relevant sections for Berkeley Station.

Littlebrook

25 The facility at Littlebrook (part of the Reactor Services Organisation) handles large-scale engineering projects for the stations. The facility is due to close in 2007.

Radioactive discharges and disposals

26 All Magnox stations are authorised to discharge liquid waste to local water bodies (sea, estuary or lake as appropriate), gaseous waste to the atmosphere and to send low-level solid waste for disposal at Drigg. Stations in England and Wales were also authorised to send waste to Drigg via Winfrith until December (paragraph 29). Several Magnox sites in England and Wales hold authorisations to dispose of combustible low level waste and oil, either by incineration on site or by transfer elsewhere for incineration under contract. Any radioactive ash generated is sent to Drigg as low level waste.

27 New authorisations to dispose of radioactive waste granted to BNFL in respect of Berkeley and Trawsfynydd took effect on 18 December, as did licences under the Nuclear Installations Act. The authorisation and licence for Berkeley includes both the decommissioning station and Berkeley Centre. At the same time, the authorisations granted to Magnox Electric in respect of Bradwell, Dungeness A, Hinkley Point A, Oldbury, Sizewell A and Wylfa were replaced with new ones. Liquid and gaseous discharge routes and the disposal route to Drigg were retained for all sites, although the disposal route to Winfrith was discontinued, as was the disposal route to Littlebrook D for waste oil. The disposal route to British Energy's Hinkley Point B site was retained only for Hinkley Point A. However, new disposal routes for waste oil were introduced to Shanks Chemical Services Ltd at Hythe for Berkeley and Wylfa and to British Energy's Sizewell B site for Sizewell A. For Bradwell, Dungeness A and Sizewell A, the new authorisations included a change in accounting method for Quarterly Notification Levels (QNLs); instead of accounting over a calendar quarter, these stations are now required to account over any period of three consecutive months, in common with the other stations. If a QNL is exceeded, the operator is required to submit a written report to the Environment Agency within 14 days, detailing the occurrence and the application of BPM to minimise relevant discharges. The operators are also required to include a review of BPM.

28 In the new authorisations granted to Magnox Electric, annual limits and QNLs were applied retrospectively from January 2002. Therefore, both old and new annual limits are shown in tables of discharges relating to generating and defuelling stations (tables 6 to 12 for liquid discharges and 16 to 22 for airborne discharges, excluding tables for Chapelcross, which is operated by BNFL). However, new limits were not applied retrospectively in the new authorisations granted to BNFL, as a new operator cannot be held accountable for the discharges made by its predecessor. Therefore, discharges in 2002 from the decommissioning stations are reported only against the annual limits applicable to Magnox Electric prior to 18 December 2002 (tables 13 and 15 for liquid discharges, 23 and 25 for airborne discharges). Special arrangements were required for Bradwell, as the new limits assumed the reactors were defuelling, but the retrospective 12 month period included the station's final 3 months of generation (paragraph 69).

The stations were able to avoid disposing of combustible waste or solid waste to Drigg between 18 December and the end of the year, so relevant disposals are reported against old limits only (tables 26 to 30).

29 All the above new Certificates of Authorisation (paragraph 27) are multi-media Certificates covering all the discharge and disposal routes referred to in paragraph 27 under a single Certificate for each site. Several conditions in the Certificates enable the Environment Agency to specify additional requirements, the details of which are specified in a new supplementary document, the 'Compilation of Environment Agency's Requirements' (CEAR). These details include the statutory environmental monitoring programme and the format of discharge returns. The Annex to this chapter lists all the authorisations that were in effect in 2002.

Liquid discharges

30 Radioactive liquid wastes from Magnox stations consist mainly of tritium (which has minimal radiological impact and toxicity) with a variety of activation and fission products arising from the active effluent treatment plant and the fuel cooling ponds. Tritium arises mainly as water condensed from the gas circuit in gas dryers or recombination units (paragraph 6). Where volumes are small, a station is able to accumulate tritiated water over several years before discharge, so as to reduce discharges of tritium and other shorter-lived radionuclides, such as sulphur-35 (half-life 87 days), which arise in the gas circuit . However, the annual discharge of tritium then increases in a year when tritiated water is eventually discharged. Tritium is so mobile that it escapes from fuel even in the cooling ponds, so it continues to dominate the quantity of radioactivity in liquid discharges at defuelling stations that no longer generate tritiated liquid waste from the gas circuit. Discharges of tritium are much smaller from decommissioning sites once all the fuel has been removed, although some increase is likely when cooling ponds are drained and during the decommissioning of gas drying plant.

31 Small quantities of fission products are released to the cooling ponds from residual traces of irradiated uranium on the outside of the fuel cans and from low level leakage from fuel elements arising from minor damage to the fuel cladding. Leakage is enhanced if the Magnox alloy cladding becomes corroded by dissolved ions in the cooling pond, particularly by negatively charged ions (anions), so the chemistry of the pond water is treated to minimise leakage and subsequent discharge of fission products. The treatment plants are variously equipped with:

- filters, because suspended particles encourage corrosion where they settle on the fuel,
- coolers, because corrosion accelerates with temperature and
- ion exchange plant, to minimise the concentration of dissolved anions.

32 Most anion beds are effective only if positively charged ions (cations) are also controlled, so separate cation beds are provided. As these ion exchange beds accumulate ions from the pond water, they become progressively less efficient and need regular regeneration with acid or alkali. The ion exchange materials may then be reused. The used acid and alkali are neutralised and discharged. Any fission products released from the fuel also adsorb onto the ion exchange materials and are discharged with these neutralised liquors. Radionuclides discharged with neutralised liquors from the cation beds include caesium-137 and strontium-90, whereas those discharged with neutralised liquors from the anion beds include sulphur-35, ruthenium-106 and antimony-125. Stations are also equipped with plant for the treatment of radioactive effluents from the controlled areas such as those from bays where the fuel transport flasks are washed down before dispatch to Sellafield. Caesium-137 is the most significant fission product discharged, so stations have additional caesium abatement plant (depending on need, pond conditions and available pond space) to minimise discharges of radiocaesium from the ponds. Used ion exchange materials from the caesium removal plant are stored as intermediate level waste.

33 Activation products in liquid waste derive from the gas circuit (as does tritium) and are discharged as either tritiated waste (paragraph 6) or via the active effluent treatment plant.

34 At most Magnox stations, quantitative limits apply to annual discharges of tritium, caesium-137 and other activity. Exceptions are discussed under the individual station sections.

35 Liquid effluents are sampled prior to discharge and the levels of radioactivity are assessed to ensure that discharge of the effluent will comply with the relevant limits. The effluent is then discharged via a pipeline that discharges via an outlet specified in the authorisation (usually with the cooling water). Samples proportional to the total discharge are taken from the discharge pipe and analysed by the station for those radionuclides subject to quantitative limits to demonstrate compliance. For quality assurance purposes the CRL performs the same analyses on representative samples of stations' effluents.

36 Samples of effluent that are representative of the annual discharge from each station are subject to full radiochemical analysis by the CRL as agreed with the Environment Agency. Results of these analyses are included in tables 6 to 15 under 'Other radionuclides'. If the method to determine other activity is sensitive to an equilibrium daughter radionuclide as well as its parent, then both are listed in tables 6 to 15. Thus, the daughters yttrium-90, rhodium-106 and praesodymium-144 are listed as well as their parents strontium-90, ruthenium-106 and cerium-144. However, if the method to determine other activity is sensitive only to the parent, then the daughter is excluded from the tables. Therefore, caesium-137 and antimony-125 are included, but barium-137m and tellurium-125m (their respective equilibrium daughters) are not. Zirconium-95 and its parent

Table 6. Liquid radioactive discharges from Bradwell

Radionuclide	1998	1999	2000	2001	2002	Authorised Limit (TBq)[a] To Dec 2002	Authorised Limit (TBq)[a] From Dec 2002
Subject to quantitative limits	Annual discharge (TBq)						
Tritium	1.8	0.52	0.65	1.8	1.9	30	7
Caesium-137	0.32	0.34[b]	0.49	0.47	0.31	0.75	0.7
Other activity[d]	0.36	0.30[c]	0.17	0.31	0.13	1	0.7
Other radionuclides	Annual discharge (GBq)						
Sulphur-35	130	95	12	99	28		
Calcium-45	17	1.2	1.3	5.4	1.5		
Manganese-54	0.59	<0.2	<0.2	<0.06	<0.09		
Iron-55	9.7	4.8	6.4	0.63	1.4		
Cobalt-58	<0.2	<0.2	<0.2	<0.2	<0.1		
Iron-59	<0.7	<0.6	<0.4	<0.4	<0.3		
Cobalt-60	1.5	1.1	0.35	0.40	0.45		
Zinc-65	0.98	0.57	<0.3	<0.3	<0.3		
Strontium-90	29	2.6	29	31	31		
Yttrium-90	29	2.6	29	31	31		
Zirconium-95	<0.6	<0.6	<0.4	<0.5	<0.3		
Niobium-95	<0.6	<0.5	<0.4	< 0.4	<0.3		
Ruthenium-106	<4	<2	<3	<2	<2		
Rhodium-106	<4	<2	<3	<2	<2		
Silver-110m	<0.4	<0.2	<0.2	<0.2	<0.2		
Antimony-124	2.3	2.2	0.55	1.8	0.61		
Antimony-125	<0.9	<0.8	6.5	8.9	<0.8		
Tellurium-125m	<0.3	<0.2	1.5	2.1	<0.2		
Caesium-134	85	94	91	59	47		
Cerium-144	<3	<2	<2	<1	<2		
Praesodymium-144	<3	<2	<2	<1	<2		
Europium-154	<0.2	<0.2	<0.2	<0.05	<0.09		
Europium-155	<0.4	<0.3	<0.4	<0.2	<0.3		
Plutonium-238	0.052	0.040	0.030	0.076	0.15		
Plutonium-239+240	0.16	0.12	0.076	0.15	0.33		
Plutonium-241	3.2	1.9	2.0	4.4	6.1		
Americium-241	0.28	0.19	0.054	0.074	0.24		
Curium-242	0.024	0.013	0.0064	0.0086	0.0087		
Curium-243+244	0.0042	0.0027	0.00083	0.0032	0.0070		

a. Annual limits changed with effect from 18 December 2002 (paragraph 28).
b. Includes 0.0002 TBq discharged as particulate in August 1999. c. Includes 0.0003 TBq discharged as particulate in August 1999.
d. 'Other activity' refers to a specified analytical determination. It does not reproduce precisely the contributions from individual radionuclides.

niobium-95 are both listed, as they are not in equilibrium in liquid effluent from Magnox sites. There are fewer data for 'other radionuclides' for Chapelcross and Hunterston A because these stations are regulated by SEPA, which undertakes its own independent monitoring of discharges.

Discharges from generating and defuelling power stations

37 All liquid discharges were within relevant quantitative limits in 2002. Oldbury and Sizewell A continued to experience elevated discharges of radiocaesium in 2002 (see tables 10 and 11 and paragraphs 47 and 48) due to the increase in radiocaesium levels at Sellafield's Fuel Handling Plant that was reported last year.

38 Except at Wylfa (paragraph 49), 'other activity' in liquid discharges is dominated by the fission product strontium-90 (in equilibrium with yttrium-90), and the activation products caesium-134 and sulphur-35. The latter has by far the lowest radiological impact. Sulphur-35 is relatively short lived (paragraph 30), so is far less significant in discharges from defuelling stations.

Bradwell

39 Radioactive liquid discharges over the past five years are shown in table 6. Discharges in 2002 were compliant with both old and new limits (paragraph 28). Discharges of 'other activity' were lower in 2002 than in previous years, mainly due to the loss of sulphur-35 through radioactive

Table 7. Liquid radioactive discharges from Chapelcross

Radionuclide	1998	1999	2000	2001	2002	Authorised Limit (TBq)
Subject to quantitative limits	Annual discharge (TBq)					
Tritium	0.22	0.71	0.55	0.17	0.28	5.5
Total beta[a]	0.04	0.07	0.19	0.026	0.12	25
Total alpha[a]	0.0004	0.0002	0.0006	0.00007	0.0001	0.1
Other radionuclides	Annual discharge (GBq)					
Sulphur-35	8.9	11	12	2.2	7.6	
Cobalt-60	1.7	0.4	0.7	0.3	0.3	
Zinc-65	<0.1	<0.2	<0.1	<0.02	<0.01	
Strontium-90	15	24	88	8.0	53	
Ruthenium-106	<0.9	<0.4	<0.6	<0.1	<0.1	
Antimony-125	<0.3	<0.5	<0.4	<0.05	<0.2	
Caesium-134	0.4	0.3	1.3	0.3	2.1	
Caesium-137	4.9	3.8	17	4.2	20	
Cerium-144	<0.5	<0.2	<0.2	<0.05	<0.1	
Europium-154	<0.1	<0.1	<0.1	<0.01	<0.05	

a. 'Total beta' and 'total alpha' refer to specified analytical determinations. They do not reproduce precisely the contributions from individual radionuclides.

decay after the station ceased generating in March. A submersible caesium removal unit, of the design used at Dungeness A (paragraph 43) has been installed, to supplement the caesium removal capacity of the pond water treatment plant during defuelling. Permission from the NII is awaited before the unit can complete commissioning and be used.

Chapelcross

40 Chapelcross has no active effluent treatment plant, but uses ion exchange filtration intermittently and mesh filters on the discharge pipeline to the Solway Firth. The pipeline carries discharges from the pond and overflow river water from the four cooling towers. Once a year or less, a pond is emptied of irradiated fuel and the lightly contaminated water discharged to the Solway Firth. This is done to facilitate inspection and maintenance of the fabric of the pond.

41 Radioactive liquid discharges over the past five years are shown in table 7. Discharges of tritium, 'total alpha' and 'total beta' activities are subject to authorised limits. Although neither pond was emptied in 2002, pond 1 was purged towards the end of the year to maintain water clarity, which gave rise to discharges similar to those in 2000.

Dungeness A

42 In addition to the routine liquid effluents (paragraphs 30 to 32), Dungeness A operates a dissolution plant for the disposal of waste Magnox cladding that has been removed from the fuel elements prior to dispatch to Sellafield. This cladding is dissolved in carbonic acid (mains water saturated with carbon dioxide) and is then discharged to the sea. Magnox metal is an alloy of magnesium, which is the second most common dissolved metal occurring naturally in seawater, so these discharges have negligible environmental impact. As there is very little radioactivity associated with the cladding, the radioactive discharges from this plant constitute a minor proportion of the site total.

43 Radioactive liquid discharges from Dungeness A over the past five years are shown in table 8. Discharges in 2002 were compliant with both old and new limits. Minor technical problems, soon resolved, caused an increase in discharges of caesium-137 from the small amount of pond liquor that is bled off routinely to discharge. Discharges of 'other activity' included a small quantity of chlorine-36 that arose through neutron irradiation of brackish groundwater that had seeped into one of the void spaces below the reactors through a leaking joint, which has subsequently been re-sealed. The Environment Agency was kept fully informed.

44 Only 2% of the radioactivity (40% by volume) in liquid discharges from the site arose from the Magnox dissolution plant in 2002. In addition to tritium and caesium-137, ten radionuclides were detectable in this effluent (table 8), although the quantities of most of these were also small compared with those discharged from the active effluent plant. However, as a result of the isolation of the cation unit on the pond water treatment plant discussed in last year's report, the quantity of cobalt-60 discharged from the active effluent plant in 2002 was only a quarter of that discharged from the Magnox dissolution plant. Data for 2000 and 2001 in table 8 have been revised from last year's report to include the contribution to other radionuclides from the Magnox dissolution plant. Corresponding data for earlier years are not available.

Table 8. Liquid radioactive discharges from Dungeness A

Radionuclide	1998	1999	2000[b]	2001[b]	2002[b]	Authorised Limit (TBq)[a]	
						To Dec 2002	From Dec 2002
Subject to quantitative limits	Annual discharge (TBq)						
Tritium	0.42	2.1	1.1	2.4	3.4	35	8
Caesium-137	0.71	0.33	0.13	0.11	0.31	1.2	1.1
Other activity[c]	0.39	0.44	0.44	0.21	0.19	1.4	0.8
Other radionuclides	Annual discharge (GBq)						
Sulphur-35	95	90	87	91	85		
Calcium-45	1.1	0.60	1.6[d]	<0.5	<0.2		
Manganese-54	<0.3	<0.2	<0.1	<0.08	<0.08		
Iron-55	0.51	2.4	0.93[d]	0.40[d]	0.14[d]		
Cobalt-58	<0.4	<0.3	<0.2	<0.2	<0.3		
Iron-59	<0.9	<0.7	<0.4	<0.4	<0.4		
Cobalt-60	0.29	0.33	0.81[d]	0.44[d]	0.072[d]		
Zinc-65	<1	<0.4	<0.4	<0.3	<0.3		
Strontium-90	14	3.9	5.1[d]	7.4[d]	7.5[d]		
Yttrium-90	14	3.9	5.1[d]	7.4[d]	7.5[d]		
Zirconium-95	<2	5.0	2.9	<0.6	<0.5		
Niobium-95	10	130	68[d]	5.5	1.6		
Ruthenium-106	<5	21	45	12	5.9		
Rhodium-106	<5	21	45	12	5.9		
Silver-110m	<0.6	<0.2	<0.2	<0.1	<0.2		
Antimony-124	4.3	3.9	2.7[d]	3.1	2.9		
Antimony-125	9.1	39	100	61	22		
Tellurium-125m	2.1	8.9	24	14	5.1		
Caesium-134	250	110	39[d]	30	84[d]		
Cerium-144	5.1	48	59	12	1.5		
Praesodymium-144	5.1	48	59	12	1.5		
Europium-154	<0.3	<0.2	0.88	0.44	<0.2		
Europium-155	<0.5	1.0	0.90	<0.3	<0.3		
Plutonium-238	0.032	0.17	0.29[d]	0.23[d]	0.091[d]		
Plutonium-239+240	0.053	0.24	0.41[d]	0.32[d]	0.13[d]		
Plutonium-241	3.3	14	20[d]	17[d]	6.7[d]		
Americium-241	0.028	0.20	0.21[d]	0.12[d]	0.039[d]		
Curium-242	0.19	2.1	1.6[d]	0.21	0.012[d]		
Curium-243+244	0.0070	0.063	0.093	0.041	0.0068		

a. Annual limits changed with effect from 18 December 2002 (paragraph 28).
b. 'Other radionuclides' includes discharges from the Magnox dissolution plant. Figures for 2000 and 2001 are amended accordingly.
c. 'Other activity' refers to a specified analytical determination. It does not reproduce precisely the contributions from individual radionuclides.
d. Other radionuclides present in effluent from the Magnox dissolution plant at levels above the limit of detection.

Hinkley Point A

45 Discharges from Hinkley Point A over the past five years are shown in table 9. Discharges in 2002 were compliant with both old and new limits. Discharges of tritium included a small contribution (30 MBq) from the boilers that were drained to sea via the storm water drains, following approval by the Environment Agency. The significant reduction in the discharges of 'other radionuclides' mentioned in last year's report has been maintained. Discharges of tritium and caesium-137 have remained similar to those during generation while fuel stocks in the cooling ponds are being reduced. A submersible caesium removal unit, of the design used at Dungeness A (paragraph 43) has been installed in one of the fuel cooling ponds, to supplement the caesium removal capacity of the pond water treatment plant during defuelling. Initial operation has been intermittent due to problems with the rapid blocking of inlet filters, which the manufacturers are now re-designing.

Oldbury

46 There is no mechanism at Oldbury for the removal of gaseous activity to the liquid waste stream. Instead, tritium is discharged to air preferentially by the liquefaction plant (paragraph 75).

47 Radioactive liquid discharges over the past five years are shown in table 10. Discharges in 2002 were compliant with both old and new limits. The elevated discharges of

Table 9. Liquid radioactive discharges from Hinkley Point A

Radionuclide	1998	1999	2000	2001	2002	Authorised Limit (TBq)[a]	
						To Dec 2002	From Dec 2002
Subject to quantitative limits	Annual discharge (TBq)						
Tritium	0.68	1.0	1.3	1.1	0.71	25	1.8
Caesium-137	0.47	0.54	0.30	0.43	0.33	1.5	1
Other activity[b]	0.26	0.34	0.12	0.15	0.076	1	0.7
Other radionuclides	Annual discharge (GBq)						
Sulphur-35	110	53	17	<0.5	<0.4		
Calcium-45	1.4	<0.5	2.6	3.1	<0.4		
Manganese-54	<0.3	<0.2	<0.09	<0.2	<0.04		
Iron-55	5.1	6.5	0.91	2.2	0.61		
Cobalt-58	<0.2	<0.3	<0.2	<0.2	<0.2		
Iron-59	<0.7	<0.6	<0.5	<0.5	<0.3		
Cobalt-60	1.1	1.5	0.81	0.86	0.51		
Zinc-65	<0.7	<0.4	<0.3	<0.3	<0.2		
Strontium-90	8.6	6.0	8.3	13	17		
Yttrium-90	8.6	6.0	8.3	13	17		
Zirconium-95	<0.8	<0.8	<0.5	<0.5	<0.4		
Niobium-95	2.3	<1	<0.5	<0.5	<0.3		
Ruthenium-106	<5	<3	<2	3.7	<2		
Rhodium-106	<5	<3	<2	3.7	<2		
Silver-110m	<0.5	<0.2	<0.2	<0.2	<0.1		
Antimony-124	1.4	1.2	0.22	<0.06	0.13		
Antimony-125	5.7	4.6	5.6	26	24		
Tellurium-125m	1.3	1.1	1.3	5.9	5.4		
Caesium-134	120	120	62	68	35		
Cerium-144	8.1	5.5	2.0	6.5	2.0		
Praesodymium-144	8.1	5.5	2.0	6.5	2.0		
Europium-154	0.81	0.54	0.51	1.1	0.62		
Europium-155	<0.6	<0.5	<0.4	<0.4	0.52		
Plutonium-238	0.21	0.32	0.19	0.48	0.35		
Plutonium-239+240	0.25	0.42	0.28	0.72	0.56		
Plutonium-241	10	14	8.3	22	17		
Americium-241	0.73	1.0	0.69	2.0	1.1		
Curium-242	0.76	0.36	0.073	0.13	0.032		
Curium-243+244	0.075	0.10	0.044	0.16	0.11		

a. Annual limits changed with effect from 18 December 2002 (paragraph 28).
b. 'Other activity' refers to a specified analytical determination. It does not reproduce precisely the contributions from individual radionuclides.

radiocaesium from fuel transport skips (paragraph 37) continued through 2002. Work is in progress jointly with Sellafield to reduce the impact of the problem. The submersible caesium removal unit (paragraph 43) has been commissioned and is in use, although Oldbury has experienced the same difficulties as Hinkley Point A with inlet filters blocking rapidly (paragraph 45). As a result of these discharges, Oldbury exceeded its QNL on discharges of caesium-137 in March, April and May. On 18 December, a much lower QNL was imposed retrospectively (reduced from 150 GBq to 30 GBq), based on the station's discharges prior to the skip problem, so that since December the stations quarterly discharges have exceeded the QNL every month. However, the Environment Agency, recognising that these circumstances are largely outside the station's control, has asked the site to provide an update on the situation once every three months, instead of the normal requirement to report their BPM approach every time a QNL is exceeded (paragraph 27), until the situation at Sellafield has been resolved.

Sizewell A

48 Radioactive liquid discharges from Sizewell A over the past five years are shown in table 11. Discharges in 2002 were compliant with both old and new limits. In common with Oldbury (paragraph 47), the elevated discharges of radiocaesium from fuel transport skips (paragraph 37) continued through 2002. Sizewell A also controlled discharges through pond management and rejection of transport skips with an unacceptable burden of caesium-137. The submersible caesium removal unit has

Table 10. Liquid radioactive discharges from Oldbury

Radionuclide	1998	1999	2000	2001	2002	Authorised Limit (TBq)[a]	
						To Dec 2002	From Dec 2002
Subject to quantitative limits	Annual discharge (TBq)						
Tritium	0.17	0.21	0.35	0.34	0.42	25	1
Caesium-137	0.063	0.066	0.064	0.48	0.54	0.7	0.7
Other activity[b]	0.18	0.17	0.15	0.32	0.31	1.3	0.7
Other radionuclides	Annual discharge (GBq)						
Sulphur-35	160	150	110	160	130		
Calcium-45	8.4	9.3	37	6.8	6.6		
Manganese-54	<0.08	<0.07	<0.04	0.25	<0.2		
Iron-55	0.99	0.41	0.10	0.24	0.31		
Cobalt-58	<0.2	<0.1	<0.08	< 0.2	<0.2		
Iron-59	<0.3	<0.4	<0.2	<0.5	<0.5		
Cobalt-60	0.26	0.21	0.21	0.19	0.27		
Zinc-65	0.39	0.31	0.20	< 0.6	<0.6		
Strontium-90	25	35	23	57	70		
Yttrium-90	25	35	23	57	70		
Zirconium-95	<0.4	<0.4	<0.3	<0.6	<0.6		
Niobium-95	<0.4	<0.8	<0.3	<0.6	<0.6		
Ruthenium-106	<2	<2	<1	<3	<3		
Rhodium-106	<3	<2	<1	<3	<3		
Silver-110m	<0.2	<0.1	<0.1	<0.2	<0.2		
Antimony-124	1.2	0.94	0.99	1.5	1.8		
Antimony-125	<0.5	<0.4	<0.4	<0.9	<1		
Tellurium-125m	<0.02	<0.09	<0.08	<0.3	<0.3		
Caesium-134	10	10	10	130	140		
Cerium-144	<0.8	<0.8	<0.5	<2	<2		
Praesodymium-144	<0.8	<0.8	<0.5	<2	<2		
Europium-154	<0.2	<0.07	0.18	<0.2	<2		
Europium-155	<0.2	<0.2	<0.06	<0.4	<0.5		
Plutonium-238	0.013	0.015	0.016	0.012	0.015		
Plutonium-239+240	0.045	0.045	0.045	0.035	0.029		
Plutonium-241	0.97	1.0	1.1	0.75	1.1		
Americium-241	0.094	0.067	0.11	0.038	0.040		
Curium-242	0.0041	0.0064	0.0031	0.0069	0.0084		
Curium-243+244	0.0016	0.0016	0.0023	0.0015	0.0022		

a. Annual limits changed with effect from 18 December 2002 (paragraph 28).
b. 'Other activity' refers to a specified analytical determination. It does not reproduce precisely the contributions from individual radionuclides.

been commissioned and is in use, although Sizewell A has experienced the same problems with the rapid blocking of filters as at Hinkley Point A and Oldbury (paragraphs 45 and 47).

Wylfa

49 Radioactive liquid discharges from Wylfa over the past five years are shown in table 12. Discharges in 2002 were compliant with both old and new limits. Fission products are normally absent from Wylfa's discharges, because it has no cooling ponds but has a dry storage system that uses carbon dioxide and air to cool irradiated fuel. Therefore, it has no specific limit on discharges of caesium-137 . 'Other activity' is usually dominated by sulphur-35, unlike other stations where strontium-90 arising from the cooling ponds dominates (paragraph 38). However, over the last two years 'other activity' has been dominated by caesium-137 in addition to sulphur-35, due to activity imported in fuel skips (paragraph 37).

Discharges from decommissioning sites

50 There is still potential for significant radioactive liquid discharges from decommissioning sites. Although fission products no longer arise from fuel in cooling ponds, they can arise from the decontamination of the pond itself and the processing and packaging of intermediate level waste. Therefore, it is still necessary to operate caesium removal plant to minimise discharges of fission products.

51 All liquid discharges from decommissioning sites were within relevant quantitative limits in 2002. No QNLs applicable to liquid discharges were exceeded.

Table 11. Liquid radioactive discharges from Sizewell A

Radionuclide	1998	1999	2000	2001	2002	Authorised Limit (TBq)[a]	
						To Dec 2002	From Dec 2002
Subject to quantitative limits	Annual discharge (TBq)						
Tritium	2.9	0.66	1.6	2.0	0.34	35	11
Caesium-137	0.071	0.069	0.14	0.76	0.54	1	1
Other activity[b]	0.15	0.12	0.17	0.32	0.28	0.7	0.7
Other radionuclides	Annual discharge (GBq)						
Sulphur-35	110	51	77	56	58		
Calcium-45	4.2	4.5	8.2	6.3	4.7		
Manganese-54	<0.06	<0.03	<0.04	3.6	<0.1		
Iron-55	0.72	0.21	0.13	0.46	0.98		
Cobalt-58	<0.07	<0.05	<0.2	<0.2	<0.2		
Iron-59	<0.2	<0.2	<0.2	<0.4	<0.3		
Cobalt-60	0.13	0.12	0.10	0.52	0.36		
Zinc-65	<0.3	0.15	<0.2	<0.3	<0.2		
Strontium-90	36	37	82	90	72		
Yttrium-90	36	37	82	90	72		
Zirconium-95	<0.2	<0.2	<0.2	<0.5	<0.4		
Niobium-95	<0.2	<0.2	<0.2	<0.6	<0.6		
Ruthenium-106	<0.9	<0.7	<0.9	<3	<2		
Rhodium-106	<0.9	<0.7	<0.9	<3	<2		
Silver-110m	<0.1	<0.06	<0.07	<0.2	<0.2		
Antimony-124	0.49	0.64	0.71	0.92	0.85		
Antimony-125	<0.04	<0.3	<0.4	<1	<0.7		
Tellurium-125m	<0.08	<0.06	<0.08	<0.3	<0.2		
Caesium-134	6.3	4.7	22	170	110		
Cerium-144	<0.9	<0.5	<0.6	<2	<2		
Praesodymium-144	<0.9	<0.5	<0.6	<2	<2		
Europium-154	<0.06	<0.04	<0.04	<0.09	<0.08		
Europium-155	<0.2	<0.2	<0.2	<0.4	<0.3		
Plutonium-238	0.0027	0.0030	0.0034	0.0070	0.018		
Plutonium-239+240	0.0073	0.0070	0.0074	0.014	0.020		
Plutonium-241	0.17	0.22	0.29	0.23	0.90		
Americium-241	0.013	0.012	0.011	0.025	0.029		
Curium-242	<0.001	0.00045	0.00042	0.12	0.12		
Curium-243+244	0.00040	0.00058	0.00043	0.0022	0.0048		

a. Annual limits changed with effect from 18 December 2002 (paragraph 28).
b. 'Other activity' refers to a specified analytical determination. It does not reproduce precisely the contributions from individual radionuclides.

52 Short-lived radionuclides are almost absent in discharges from decommissioning stations because of radioactive decay. Therefore, only those radionuclides that are likely to be detectable after the defuelling period are reported. Discharges of 'other activity' are usually dominated by strontium-90 (in equilibrium with yttrium-90). There are minor contributions from caesium-134 and iron-55. Caesium-134 is far less significant at decommissioning than at generating stations due to radioactive decay (half-life 2.1 years).

Berkeley

53 Liquid effluent is discharged to the River Severn through a dedicated discharge line. Liquid discharges include effluent from Berkeley Centre which is transferred to Berkeley station via an internal pipeline.

54 Radioactive liquid discharges over the past five years are shown in table 13. A new authorisation granted to BNFL took effect on 18 December 2002, in which limits on discharges apply to Berkeley station and separate limits apply to liquid transfers from Berkeley Centre to the station. Transfer disposals will be reported next year. Discharges in 2002 were compliant with relevant limits.

Hunterston A

55 Liquid effluent from Hunterston A is discharged to the Firth of Clyde via British Energy Hunterston B station's cooling water culvert.

56 Discharges from Hunterston A over the past five years are shown in table 14. Liquid radioactive effluent discharges remained much lower than relevant limits in 2002,

Table 12. Liquid radioactive discharges from Wylfa

Radionuclide	1998	1999	2000	2001	2002	Authorised Limit (TBq)[a]	
						To Dec 2002	From Dec 2002
Subject to quantitative limits	Annual discharge (TBq)						
Tritium	9.6	4.6	4.0	6.4	4.9	40	15
Other activity[b]	0.070	0.019	0.029	0.055	0.068	0.15	0.11
Other radionuclides	Annual discharge (GBq)						
Sulphur-35	64	27	5.3	6.4	11		
Calcium-45	<0.5	<0.4	0.73	<0.4	<0.4		
Manganese-54	0.27	0.18	<0.06	<0.09	0.18		
Iron-55	2.0	0.58	1.0	0.51	1.2		
Cobalt-58	<0.09	<0.08	<0.07	< 0.08	<0.09		
Iron-59	<0.4	<0.3	<0.2	< 0.2	<0.3		
Cobalt-60	1.4	1.3	1.4	1.5	1.9		
Zinc-65	<0.4	<0.2	<0.2	<0.2	<0.2		
Strontium-90	0.14	0.25	0.39	0.54	0.70		
Yttrium-90	0.14	0.25	0.39	0.54	0.70		
Zirconium-95	<0.3	<0.2	<0.2	<0.2	<0.3		
Niobium-95	<0.2	<0.2	<0.2	<0.3	<0.2		
Ruthenium-106	<0.5	<0.3	<0.3	<0.5	<0.7		
Rhodium-106	<0.5	<0.3	<0.3	<0.5	<0.7		
Silver-110m	<0.3	<0.09	<0.04	<0.08	<0.2		
Antimony-124	<0.2	<0.2	<0.07	<0.07	<0.06		
Antimony-125	<0.2	<0.06	<0.2	<0.2	<0.2		
Tellurium-125m	<0.03	<0.02	<0.03	<0.05	<0.05		
Caesium-134	1.2	0.25	2.3	4.9	6.3		
Caesium-137	1.2	1.3	10	18	30		
Cerium-144	<0.5	0.23	<0.2	<0.3	<0.4		
Praesodymium-144	<0.5	0.23	<0.2	<0.3	<0.4		
Europium-154	<0.05	<0.04	<0.06	<0.03	<0.07		
Europium-155	<0.08	<0.07	<0.08	<0.08	<0.09		
Plutonium-238	<0.0002	0.00060	0.00038	<0.0005	0.0012		
Plutonium-239+240	0.0037	0.00092	0.00079	0.00073	0.0014		
Plutonium-241	<0.09	<0.06	0.15	0.15	0.12		
Americium-241	0.0017	0.00094	0.0011	<0.0008	0.0021		
Curium-242	<0.002	<0.0004	<0.0002	<0.003	0.0012		
Curium-243+244	<0.0003	<0.00007	<0.00005	<0.0008	<0.0002		

a. Annual limits changed with effect from 18 December 2002 (paragraph 28).
b. 'Other activity' refers to a specified analytical determination. It does not reproduce precisely the contributions from individual radionuclides.

following the cessation of pond purging towards the end of 2000. The station's effluent system includes a tank containing historical arisings from Hunterston B. Processing of this effluent resulted in a slightly increased tritium discharge in 2002. Hunterston B now has an alternative route for this waste, so there will be no further discharge from this source.

Trawsfynydd

57 Effluent from the active effluent treatment plant is discharged through the cooling water culvert to Trawsfynydd Lake. This is a different situation to the other Magnox stations where discharges are made to the sea or an estuary. Consequently, a limit was placed on discharges of strontium-90 only at Trawsfynydd, as this radionuclide was more likely to accumulate in aquatic organisms in the enclosed environment of a lake. The only other measurable radioactivity discharged to the lake from the site is in surface and sub-surface water from the reactor area. This is intercepted and pumped to the lake via a diversion culvert.

58 Discharges from Trawsfynydd over the past five years are shown in table 15. A new authorisation granted to BNFL took effect on 18 December 2002. The specific limit on discharges of strontium-90 is retained in the new authorisation, although the limit on discharges of 'Other activity' now includes strontium-90, so is comparable with the quantity limited in discharges from Magnox stations in England. Previously, 'other activity' was dominated by yttrium-90. Discharges remained low during 2002 and compliant with relevant limits. Arisings were mainly from the routine decontamination of

Table 13. Liquid radioactive discharges from Berkeley[a]

Radionuclide	1998	1999	2000	2001	2002	Authorised Limit (GBq)[b]
Subject to quantitative limits	Annual discharge (GBq)					
Tritium	34	6.4	6.4	0.74	0.62	8000
Caesium-137	14	7.7	17	2.3	0.21	200
Other activity[c]	73	18	22	3.9	0.13	400
Other radionuclides[d]	Annual discharge (GBq)					
Iron-55	0.14	0.20	0.066	0.023	0.011	
Cobalt-60	0.15	0.068	0.064	0.036	<0.004	
Strontium-90	32	9.0	19	2.0	0.10	
Yttrium-90	32	9.0	19	2.0	0.10	
Antimony-125	<0.2	<0.07	<0.07	<0.04	<0.009	
Caesium-134	0.18	0.055	0.043	<0.01	0.023	
Europium-154	<0.02	<0.008	<0.02	<0.02	<0.007	
Europium-155	<0.07	<0.04	<0.02	<0.02	<0.006	
Plutonium-238	0.0024	0.0091	0.0033	0.0019	0.00048	
Plutonium-239+240	0.0081	0.016	0.010	0.0054	0.0013	
Plutonium-241	0.15	0.42	0.23	0.11	0.042	
Americium-241	0.013	0.020	0.014	0.0050	0.0025	
Curium-242	<0.0006	0.00073	<0.0002	0.00074	<0.00009	
Curium-243+244	0.00031	0.0017	0.00043	<0.0002	0.000064	

a. Includes Berkeley Power Station (decommissioning) and Berkeley Centre.
b. Effective to 18 December 2002 (paragraph 28).
c. 'Other activity' refers to a specified analytical determination. It does not reproduce precisely the contributions from individual radionuclides.
d. Only those radionuclides that might be detectable after defuelling (about 3 years after generation has ceased) are reported.

Table 14. Liquid radioactive discharges from Hunterston A

Radionuclide	1998	1999	2000	2001	2002	Authorised Limit (GBq)[e]
Subject to quantitative limits	Annual discharge (GBq)					
Tritium	6.7	22	2.8	4.0	0.80	700
Plutonium-241	-	-	0.68[a]	0.83	0.20	1000
Other beta activity[b,d]	-	-	40[a]	25	29	600
Alpha[c,d]	0.66	0.53	0.19	0.14	0.10	40
Other radionuclides	Annual discharge (GBq)					
Caesium-137	180	170	120	13	16	
Plutonium-238	0.028	0.023	0.014	0.0043	0.0023	
Plutonium-239+240	0.043	0.031	0.021	0.0067	0.0035	
Americium-241	0.086	0.068	0.035	0.18	0.083	
Curium-243+244	0.0054	0.0046	0.0022	0.00032	0.00028	

a. Part year only (from August), when new authorisation came into effect.
b. Defined in the certificate as 'Beta emitting radionuclides taken together (excluding tritium and plutonium-241)'.
c. Defined in the certificate as 'Alpha emitting radionuclides taken together'. Data for 1997 to July 2000 are included for comparison purposes.
d. 'Other beta activity' and 'alpha' refer to specified analytical determinations. They do not reproduce precisely the contributions from individual radionuclides.
e. Effective from August 2000.

plant and equipment together with decanted liquors from the storage vaults for wet intermediate level waste. The removal of redundant humidrier (i.e. gas drying) plant from the reactor buildings resulted in additional arisings of tritiated water during late 2001 and early 2002, hence the elevated tritium discharge during 2002.

59 Strontium-90 is determined by the station using a screening method based on Cherenkov counting. This is because use of the radiochemical method does not facilitate timely declaration of monthly discharges to the Environment Agency to demonstrate compliance with the authorised limit. However, a representative sample of effluent from the

Table 15. Liquid radioactive discharges from Trawsfynydd

Radionuclide	1998	1999	2000	2001	2002	Authorised Limit (GBq)[a]
Subject to quantitative limits	Annual discharge (GBq)					
Tritium	63	40	5.3	29	150	12,000
Caesium-137	6.5	4.3	1.8	1.9	2.0	50
Strontium-90	10	23	1.5	0.92	2.0	80
Other activity[b]	18	30	2.7	1.8	2.0	720
Other radionuclides[c,d]	Annual discharge (GBq)					
Iron-55	0.16	0.18	0.017	0.034	0.059	
Cobalt-60	<0.05	0.13	<0.02	<0.02	0.091	
Yttrium-90	12	26	2.7	0.51	1.4	
Antimony-125	0.37	0.40	<0.05	<0.04	<0.07	
Caesium-134	0.15	<0.03	<0.03	<0.03	0.16	
Europium-154	<0.06	<0.04	<0.04	<0.04	<0.03	
Europium-155	<0.1	<0.06	<0.02	<0.03	<0.03	
Plutonium-238	0.028	0.019	0.0049	0.0062	0.0091	
Plutonium-239+240	0.058	0.040	0.011	0.017	0.021	
Plutonium-241	2.1	1.2	0.38	0.45	0.48	
Americium-241	0.13	0.062	0.014	0.024	0.033	
Curium-242	0.0026	0.0028	<0.0002	0.0031	0.0017	
Curium-243+244	0.0089	0.0036	0.00056	0.0017	0.0019	

a. Effective to 18 December 2002 (paragraph 28).
b. 'Other activity' refers to a specified analytical determination. It does not reproduce precisely the contributions from individual radionuclides.
c. Excludes discharges from the sewage plant and diversion culvert.
d. Only those radionuclides that might be detectable after defuelling (about 3 years after generation has ceased) are reported.

station is analysed for strontium-90 by CRL using the full radiochemical analysis method. Generally, there is good agreement between the two methods. The analysis of effluents by the CRL (see paragraph 36) excludes discharges to Trawsfynydd Lake from the site's diversion culvert. Although these account for about 90% of the total volume discharged to Trawsfynydd Lake, concentrations of radioactivity are up to 100 times lower than in effluent from the station's active effluent treatment plant. Although discharges from the diversion culvert are not subject to detailed analysis by CRL, they are reported by the station for accounting against the discharge limits.

Aerial discharges

Discharges from generating and defuelling power stations

60 The carbon dioxide coolant in Magnox reactors becomes neutron-activated and contaminated with radioactivity as it passes through the reactor, so coolant releases contribute to aerial discharges of radioactivity from reactors. By design, there is a continuous small release of carbon dioxide from the reactors (termed leakage) while they are pressurised to allow displacement of reactor gas by the clean carbon dioxide fed to the system for detecting leaking fuel. Leakage is lower from concrete pressure vessels, as they encapsulate the boilers (unlike steel pressure vessels), so the complete gas circuit is held within the pressure vessel. Consequently, reactors with concrete pressure vessels need to make additional minor discharges daily to prevent over-pressurisation; leakage from steel pressure vessels is adequate to prevent this. More significant releases occur when the reactors are fully depressurised prior to routine maintenance. Shield cooling air, where relevant, is irradiated as it passes through the interspace between the pressure vessel and biological shield (see paragraph 7), so it also contributes to aerial discharges of radioactivity. There are also small aerial discharges of radioactive particles from the filtered contaminated ventilation systems, in addition to small quantities from reactor coolant and shield cooling air.

61 The main radioactive gases discharged from the stations are argon-41, tritium, carbon-14 and sulphur-35. Argon-41 is an activation product of argon-40, which comprises about 1% of air. Consequently, it is discharged with the shield cooling air in direct proportion to gross generation; data for each generating station are listed in table 5. As reactors with concrete pressure vessels have no shield cooling air (paragraph 7), they discharge much less argon-41 than generating reactors with steel pressure vessels. Argon-40 is also a trace impurity in the carbon dioxide supplied to cool the reactors, so argon-41 is present in discharges of coolant, but at levels about two orders of magnitude lower than those associated with shield cooling air. Argon-41 has a half-life of only 1.8 hours, so discharges rapidly fall to zero through radioactive decay whenever the reactor comes off load. Consequently, argon-41 is not discharged from defuelling stations.

62 Tritium is generated by two processes in the reactor; irradiation of lithium impurities in the moderator and as a product of ternary fission from the fuel. Lithium impurities are the major source during the early generating life of the reactors, but become less important with time as they are burnt out of the moderator. Generation from ternary fission is directly proportional to the reactor power loading. Under normal operating conditions with the gas circuits very dry, tritium accumulates on the reactor internal surfaces (it has a half-life of 12 years, so losses through radioactive decay in a generating reactor are not significant). However, tritium has a strong affinity for moisture, so if moisture enters the gas circuit, it displaces tritium from the reactor surfaces as tritiated water. This may be removed by installed dryers or by the recombination unit, where fitted (see paragraph 6) and discharged to the environment in the station's cooling water discharge, together with other liquid effluents. Otherwise, the tritiated water is discharged as a gas. Consequently, there is normally a peak in gaseous discharges whenever air is allowed into the circuit for maintenance following depressurisation of a reactor. Although this air is passed through dryers first, its moisture content is still higher than that of the carbon dioxide coolant.

63 Aerial discharges of carbon-14 derive mainly from the graphite moderator, where it accumulates with irradiation (the half-life is 5700 years, so losses through radioactive decay in a generating reactor are trivial). While the reactor is at power, there is a chemical exchange of carbon between the graphite moderator and the carbon dioxide coolant, which depends on reactor gas chemistry. Therefore, discharges of carbon-14 increase gradually with time as the radionuclide accumulates in the moderator, although any trend is usually apparent only over several years and only then if it is not masked by long outages when discharges are very low.

64 Sulphur-35 in coolant gas arises through activation of chlorine and stable sulphur impurities in the graphite moderator and oils used in the gas circulators. Because of its short half life, it usually reaches equilibrium in the coolant while the reactor is at power, but plates out onto internal reactor surfaces when the reactor comes off load. It is driven off again when the reactor returns to power, resulting in a peak in aerial sulphur-35 discharges. As defuelling typically takes about 3 years, discharges of sulphur-35 cease before defuelling is complete.

65 Quantitative limits on the annual discharge of each of the above radionuclides apply at generating stations in England and Wales and, until 18 December 2002 also applied to weekly discharges of carbon-14 and sulphur-35. From 18 December 2002, weekly limits have been replaced with Weekly Advisory Levels (WALs), which also apply to discharges of tritium. The weekly limits were intended to ensure that concentrations of carbon-14 and sulphur-35 in foods grown near generating power stations did not exceed the European Community Food Intervention Levels (CFILs), devised following the Chernobyl accident to protect the public after any subsequent nuclear accident. In replacing limits with WALs, the Environment Agency has recognised that the very pessimistic assumptions used to derive the limits were unduly restrictive on station operations, especially where there might be a requirement to depressurise both reactors in a week. Instead, the Environment Agency is notified immediately (preferably in advance) whenever a WAL has been exceeded, allowing monitoring against the CFILs if this occurs during a sensitive period. The WALs have been set at lower levels than the limits they replace, so there is a greater potential for them to be exceeded during routine operation. Neither WALs nor limits on short-lived radionuclides apply at decommissioning stations.

66 Quantitative limits also apply to annual discharges of 'beta emitting radionuclides associated with particulate matter' (beta particulate), although such discharges are much smaller than discharges of the gaseous species. Individual radionuclides in these particulates are not determined routinely. However, assessments have been made previously of their radionuclide composition from which it is known that cobalt-60 is the dominant species. Calcium-45, iron-59, nickel-63, zinc-65, silver-110m, antimony-124, caesium-134, caesium-137 and plutonium-241 are also present.

67 All aerial discharges from generating power stations were within relevant quantitative limits in 2002. No WALs were exceeded in the period between 18 December and the end of the year. Minor failures in discharge monitoring have continued at Bradwell, Dungeness A and Hinkley Point A. In all cases, discharges were assessed indirectly and there was no question of discharge limits being exceeded.

Bradwell

68 Bradwell makes discharges via a shield cooling air system. Therefore, discharges of argon-41 were directly proportional to reactor power until the station ceased generation at the end of March.

69 Discharges of tritium, carbon-14, sulphur-35, argon-41 and beta particulate over the past five years are shown in table 16. The large reduction in the limit on discharges of sulphur-35 was imposed because the station is defuelling. However, the Environment Agency was mindful that in applying the limits retrospectively, the last three months of generation were included. The discharge in January alone (35 GBq) was in excess of the new annual limit, so a requirement was included in the CEAR to discount discharges made before April 2002 when demonstrating compliance against the new limit. Only 2.3 GBq were discharged from April to December 2002, so discharges in 2002 remained compliant with both old and new limits. Discharges of carbon-14 were also much lower after generation ceased.

Chapelcross

70 The main discharge of tritium to atmosphere is from the processing plant (paragraph 14) which discharges air

Table 16. Airborne radioactive discharges from Bradwell

Radionuclide	Annual discharge (TBq)					Authorised Limit (TBq)[a]	
	1998	1999	2000	2001	2002	To Dec 2002	From Dec 2002
Tritium	0.84	0.78	0.64	0.90	0.65	1.5	1.5
Carbon-14	0.38	0.20	0.20	0.46	0.16	0.6	0.6
Sulphur-35	0.058	0.037	0.028	0.083	0.049[c]	0.2	0.02
Argon-41	720	280	240	620	140	1000	-
Beta particulate[b]	0.00026	0.00022	0.00020	0.00033	0.00014	0.001	0.0006

a. Annual limits changed with effect from 18 December 2002 (paragraph 28).
b. 'Beta particulate' refers to a specified analytical determination. It does not reproduce precisely the contributions from individual radionuclides.
c. For accounting against the new limit, the total is 0.0023 TBq (paragraph 69).

Table 17. Airborne radioactive discharges from Chapelcross

Radionuclide	Annual discharge (TBq)					Authorised Limit (TBq)
	1998	1999	2000	2001	2002	
Tritium[a]	1300	1400	1500	840	760	5000
Sulphur-35	0.022	0.027	0.024	0.020	0.007	0.05
Argon-41	2800	2800	2600	2100	1200	4500

a. Dominated by discharges from the Chapelcross processing plant.

Table 18. Airborne radioactive discharges from Dungeness A

Radionuclide	Annual discharge (TBq)					Authorised Limit (TBq)[a]	
	1998	1999	2000	2001	2002	To Dec 2002	From Dec 2002
Tritium	0.58	0.51	0.55	0.69	0.46	3	2.6
Carbon-14	3.3	3.6	3.3	3.0	3.5	5	5
Sulphur-35	0.062	0.052	0.052	0.036	0.039	0.4	0.15
Argon-41	1200	1200	1200[c]	860	1200	2000	1700
Beta particulate[b]	<0.0005[c]	<0.0004	<0.0004[c]	<0.0003	<0.0003	0.001	0.00055

a. Annual limits changed with effect from 18 December 2002 (paragraph 28).
b. 'Beta particulate' refers to a specified analytical determination. It does not reproduce precisely the contributions from individual radionuclides.
c. Minor rounding correction.

Table 19. Airborne radioactive discharges from Hinkley Point A

Radionuclide	Annual discharge (GBq)					Authorised Limit (GBq)[a]	
	1998	1999	2000	2001	2002	To Dec 2002	From Dec 2002
Tritium	2500	3300	79	630	36	25,000	1500
Carbon-14	3000[b]	1600[b]	56	2.1	2.6	4000	600
Sulphur-35	57	49	1.1	0.49	0.0025	200	-
Argon-41	2,700,000	1,100,000	0	0	0	4,500,000	-
Beta particulate[c]	0.11	0.049	0.0012	0.0021	0.0026	1	0.15

a. Annual limits changed with effect from 18 December 2002 (paragraph 28).
b. Best assessment of discharge – see report for 1999.
c. 'Beta particulate' refers to a specified analytical determination. It does not reproduce precisely the contributions from individual radionuclides.

containing tritium to atmosphere via the plant stack. These discharges of tritium significantly exceed those from the reactors.

71 Discharges of tritium, sulphur-35 and argon-41 over the past five years are shown in table 17. There is no limit on discharges of carbon-14. Tritium discharges were similar to those in 2001. Discharges of argon-41 and sulphur-35 were lower than in recent years due to reduced generation during the year.

Dungeness A

72 Dungeness A makes discharges via a shield cooling air system. Therefore, discharges of argon-41 are directly proportional to reactor power.

Table 20. Airborne radioactive discharges from Oldbury

Radionuclide	Annual discharge (TBq)						Authorised Limit (TBq)[a]	
	1998	1999	2000	2001	2002[b]		To Dec 2002	From Dec 2002
					Old method	New method		
Tritium	2.4	2.4	1.6	2.1	2.8	4.7	5	9
Carbon-14	3.7	3.9	4.0	4.7	4.5	2.6	6	4
Sulphur-35	0.31	0.33	0.33	0.34	0.34	0.22	0.75	0.45
Argon-41	180	190	160	220	280	260	500	500
Beta particulate[c]	0.00010	0.00011	0.00011	0.00014	0.00012	0.000065	0.001	0.0001

a. Annual limits changed with effect from 18 December 2002 (paragraph 28).
b. Revised assessment method effective from 18 December 2002 (paragraphs 76 and 77)
c. 'Beta particulate' refers to a specified analytical determination. It does not reproduce precisely the contributions from individual radionuclides.

73 Discharges of tritium, carbon-14, sulphur-35, argon-41 and beta particulate over the past five years are shown in table 18. Discharges in 2002 were compliant with both old and new limits.

Hinkley Point A

74 Discharges from Hinkley Point A over the past five years are shown in table 19. Discharges from defuelling reactors fall to low levels shortly after generation ends, so discharges are reported in units of GBq, rather than TBq in table 19. Under the new authorisation, limits no longer apply to discharges of sulphur-35 or argon-41, as each can no longer be detected in discharges. Discharges in 2002 were compliant with both old and new limits.

Oldbury

75 Chemical impurities (principally carbon monoxide) are removed from the coolant at Oldbury by condensing the gas as it is bled through a liquefaction plant. The carbon dioxide coolant vaporises as the gas mixture is allowed to regain ambient temperature and is returned to the gas circuit. The impurities vaporise at different temperatures and are discharged to atmosphere.

76 Discharges of tritium, carbon-14, sulphur-35, argon-41 and beta particulate over the past five years are shown in table 20. Changes to limits under the new authorisation accommodated revisions to the methods to assess discharges, so discharges for 2002 are presented using both assessment methods (paragraph 77). Discharges in 2002 were compliant with both old and new limits. The QNL for carbon-14 was exceeded in January, October, November and December. A higher QNL has been set in the new certificate to allow for such increased discharges of carbon-14, which are associated with increased irradiation (paragraph 63). The QNL on discharges of sulphur-35 was exceeded in December retrospectively under the new authorisation.

77 Most of Oldbury's gaseous discharge is directed via the depressurisation stack (paragraph 63). The flow detector on this stack was designed to detect flows from full depressurisation to the very low flows associated with operation of the liquefaction plant (about two orders of magnitude difference). However, it proved to be incapable of assessing such a wide range of flow accurately and over-estimated the flow by a factor of about two. Re-assessment of the processes in the liquefaction plant showed that tritium and argon-41 were discharged preferentially through this plant to the extent that tritium was 40-fold more concentrated in discharges from the liquefaction plant than in discharges of coolant. The consequent revision to the discharge assessment method revealed higher discharges of tritium than had been determined previously (even after accounting for the over-estimate of flow), but lower discharges of the other radionuclides (table 20). Indeed, discharges of tritium were so much higher that an increase in the limit on tritium discharges was required to allow for the change in assessment method, although there was no increase in actual discharges of tritium.

Sizewell A

78 Sizewell A makes discharges via a shield cooling air system. Therefore, discharges of argon-41 are directly proportional to reactor power.

79 Discharges of tritium, carbon-14, sulphur-35, argon-41 and beta particulate from Sizewell A are shown in table 21. Increases in the carbon-14 discharge limit and QNL were granted in the new authorisation to allow for increased discharges associated with increased irradiation (paragraph 63). Discharges in 2002 were compliant with both old and new limits, although the upward trend in discharges of carbon-14 (table 21) led to the QNL being exceeded in June and December.

Wylfa

80 Discharges of tritium, carbon-14, sulphur-35, argon-41 and beta particulate from Wylfa over the past five years are shown in table 22. Discharges in 2002 were compliant with both old and new limits. The QNL on discharges of carbon-14 was exceeded in March, October and November. A higher QNL has been set in the new certificate to allow for such increased discharges of carbon-14, which are associated with increased irradiation (paragraph 63).

Table 21. Airborne radioactive discharges from Sizewell A

Radionuclide	Annual discharge (TBq)					Authorised Limit (TBq)[a]	
	1998	1999	2000	2001	2002	To Dec 2002	From Dec 2002
Tritium	0.52	1.4	0.92	2.1	2.6	7	3.5
Carbon-14	0.46	1.1	1.1	1.0	1.2	1.5	2
Sulphur-35	0.019	0.12	0.16	0.16	0.13	0.6	0.35
Argon-41	840	1700	1800	1800	1900	3000	3000
Beta particulate[b]	0.000056	0.00015	0.00018	0.00019	0.00019	0.001	0.00085

a. Annual limits changed with effect from 18 December 2002 (paragraph 28).
b. 'Beta particulate' refers to a specified analytical determination. It does not reproduce precisely the contributions from individual radionuclides.

Table 22. Airborne radioactive discharges from Wylfa

Radionuclide	Annual discharge (TBq)					Authorised Limit (TBq)[a]	
	1998	1999	2000	2001	2002	To Dec 2002	From Dec 2002
Tritium	8.2	4.8	6.0	1.6	3.8	20	18
Carbon-14	1.5	1.5	0.52	0.40	1.5	2.4	2.3
Sulphur-35	0.30	0.30	0.077	0.035	0.20	0.5	0.45
Argon-41	61	36	7.5	13	32	120	100
Beta particulate[b]	0.000063	0.000078	0.000096	0.000023	0.000029	0.001	0.0007

a. Annual limits changed with effect from 18 December 2002 (paragraph 28).
b. 'Beta particulate' refers to a specified analytical determination. It does not reproduce precisely the contributions from individual radionuclides.

Table 23. Airborne radioactive discharges from Berkeley[a]

Radionuclide[b]	Annual discharge (GBq)					Authorised Limit (GBq)[c]
	1998	1999	2000	2001	2002	
Tritium[d]	15	3.9	4.8	4.2	4.2	2000
Carbon-14[d]	0.52	0.70	0.54	0.20	0.26	200
Alpha and beta particulate[e,f]	0.0019	0.0015	0.00052	0.00059	0.00037	0.2
Alpha and beta particulate (Berkeley Centre)[e,f]	0.0015	0.0013	0.00038	0.00053	0.00034	0.02

a. Includes Berkeley Power Station (decommissioning) and Berkeley Centre. b. Discharges of sulphur-35, although subject to an annual limit, are no longer measurable.
c. Effective to 18 December 2002 (paragraph 28). d. Passive discharges via engineered control vents only (see paragraph 83).
e. Includes discharges from the incinerator on Berkeley Centre (see paragraph 91)
f. 'Alpha and beta particulate' refers to a specified analytical determination. It does not reproduce precisely the contributions from all individual radionuclides.

Table 24. Airborne radioactive discharges from Hunterston A

Radionuclide	Annual discharge (GBq)					Authorised Limit (GBq)[a]
	1998	1999	2000	2001	2002	
Tritium[b]	0	0	0	0	0.0012	20
Carbon-14[b]	0	0	0	0	0.00018	2
Beta particulate[c]	0.00013	0.00047	0.00046	0.00036	0.00026	0.06

a. Effective from August 2000. b. Excludes passive exchange with the air (see paragraph 86).
c. 'Beta particulate' refers to a specified analytical determination. It does not reproduce precisely the contributions from individual radionuclides.

Table 25. Airborne radioactive discharges from Trawsfynydd

Radionuclide[a]	Annual discharge (GBq)					Authorised Limit (GBq)[b]
	1998	1999	2000	2001	2002	
Tritium	140	95	170	110	48	10000
Carbon-14[c]	16	9.0	12	2.9	0.90	5000
Beta particulate[d]	0.016	0.0021	0.0016	0.0018	0.00037	2

a. Discharges of sulphur-35 and argon-41, although subject to annual limits, are no longer measurable. b. Effective to 18 December 2002 (paragraph 28).
c. Discharges of carbon-14 have been re-assessed (see report for 2001).
d. 'Beta particulate' refers to a specified analytical determination. It does not reproduce precisely the contributions from individual radionuclides.

Discharges from decommissioning sites

81 Aerial discharges from decommissioning stations are very much smaller than from generating stations. Discharges of short-lived radionuclides will have ceased prior to decommissioning (paragraphs 61 and 64). Discharges of carbon-14 from decommissioning stations are very small because significant exchange with the moderator requires the reactor to be both under pressure in carbon dioxide and at power. Discharges of tritium are also small because the diffusion rate from the reactor core is very low at ambient temperature. Despite this, tritium is the major contributor to aerial discharges from decommissioning reactors because they are open to moist ambient air. Particulate discharges vary, depending on the phasing of decommissioning operations.

82 All aerial discharges from decommissioning sites were within relevant quantitative limits and no QNLs were exceeded.

Berkeley

83 Low levels of airborne radioactivity are discharged from the two reactor vessels via engineered control vents that manage reactor pressure, temperature and humidity. Low levels of radioactivity are also discharged from vent systems in the active effluent treatment plant, the caesium removal plant, the low level waste handling building and the intermediate level waste vault retrieval and process buildings.

84 Aerial radioactive discharges from Berkeley station and Berkeley Centre over the past five years are shown in table 23. The new authorisation granted to BNFL placed separate limits on discharges applied to Berkeley station and Berkeley Centre and these will be reported against separately next year. Discharges in 2002 were compliant with relevant limits. Of the total limit of 200 MBq applicable to annual discharges of particulates from the site under Magnox Electric's authorisation, no more than 20 MBq were permitted from Berkeley Centre.

Hunterston A

85 Airborne discharges are largely from the main active ventilation discharge routes. These serve both reactors' fuel separating rooms, the cartridge cooling pond enclosure and the solid active waste building. The reactors are valved closed; an anti-corrosion atmosphere is maintained via the occasional introduction of dry air to the vessels as required, discharges being made via the original stack but through a new high efficiency particulate air filter system.

86 Discharges from Hunterston A over the past five years are shown in table 24. Gaseous radioactive discharges have remained low. Purging of the reactors to maintain satisfactory anti-corrosion conditions were required for the first time since 1997. However, the gaseous atmosphere of each reactor also exchanges passively with the local air about once a year through various minor routes resulting in a discharge of about 220 MBq of tritium and 15 MBq of carbon-14 annually. The routine extract ventilation of active areas was the primary source of site discharge activities.

Trawsfynydd

87 The major airborne discharges are from vent systems in the reactor and ILW process buildings. The forced shield cooling air system which vented various parts of the reactor buildings was finally decommissioned during early 2002. The various active area vent systems are monitored for particulate discharges. The reactor vessels breathe naturally to air through engineered vent lines. Vessel air is monitored for carbon-14 and tritium; the vent from the ILW process building is monitored for tritium.

88 Discharges from Trawsfynydd over the past five years are shown in table 25. Discharges in 2002 were compliant with relevant limits.

Discharges from other sites

Littlebrook

89 No gaseous discharges were made from Littlebrook in 2002, as there was no work undertaken that would generate such discharges.

Table 26. Disposals of radioactive combustible waste to on-site incinerators (GBq)

Radionuclide		Station[a]			
		Dungeness A[b,c]	Oldbury[b]	Sizewell A	Wylfa
Tritium	disposal	0.10	1.2[f]	-	34
	limit[d,e]	6	9.6[f]	-	6000
Sulphur-35	disposal	0.28	included with	-	4.3
	limit[d,e]	6	tritium	-	60
Iron-55	disposal	0.2	-	-	-
	limit[d]	15	-	-	-
Alpha	disposal	-	-	-	0.013
	limit[d,e]	-	-	-	0.42
Other activity	disposal	0.51	1.9	0.28[g]	2.4
	limit[d,e]	15	9.6	4.4[g]	6

a. Berkeley declares discharges from the incinerator under the authorisation to dispose of radioactive waste gases, mists and dusts.
b. Includes disposals of waste oil (see table 28). *c. Includes arisings from the adjacent AGR station owned by British Energy.*
d. Effective to 18 December 2002. *e. Monthly limits apply at Oldbury, Sizewell A and Wylfa; these have been multiplied by 12 to derive annual equivalents.*
f. Includes disposals of sulphur-35. *g. Total activity.*

Disposals of combustible waste

90 Berkeley, Dungeness A, Oldbury, Sizewell A and Wylfa all dispose of combustible solid waste by incineration on site. The authorisations in effect at Dungeness A, Oldbury and Wylfa also permit the disposal of waste oil (including solvents etc.), although the oil burner at Wylfa is out of service. These routes have been retained under the new authorisations, although Berkeley and Wylfa are now additionally authorised to dispose of waste oil, solvents and scintillants by transfer to Shanks (paragraph 27). Hinkley Point A disposes of both solid waste and oil to British Energy's Hinkley Point B site for incineration (Berkeley, Oldbury and Trawsfynydd were similarly authorised until December 2002, but did not use this route during 2002). Until December 2002, Bradwell and Sizewell A were both authorised to dispose of waste oil by transfer to the oil-fired power station Littlebrook D (adjacent to the Company's facility at Littlebrook) where it was burnt along with the fuel oil (paragraph 27). Bradwell is now authorised to dispose of waste oil (including solvents and scintillants) by incineration on site, whereas Sizewell A is authorised to dispose of the equivalent waste to British Energy's Sizewell B site for incineration (paragraph 27). Bradwell, Chapelcross, Hunterston A and Trawsfynydd all send their combustible solid waste to Drigg where it is processed as normal Drigg waste.

91 Disposals of combustible waste by incineration on site are shown in table 26. Although Berkeley was operating its incinerator in 2002, it is excluded from table 26 because it declared radioactive emissions from its incinerator under its authorisation to dispose of radioactive gases to atmosphere (see table 23). Disposals will be declared separately under the new authorisation.

Table 27. Disposals of radioactive combustible waste from Hinkley Point A by transfer to Hinkley Point B[a] (GBq)

Radionuclide	Disposal		Authorised Limit[b]
	Solid	Oil	
Tritium	0	0.012	400
Carbon-14	0	0	6
Cobalt-60	0	<0.00001	300
Iodine-129	0	0	0.1
Alpha	0	0	82
Other activity	0	0.013	3000
Volume (m^3)			
solid	0	-	500
liquid	-	1.8	60

a. Until 18 December 2002, Trawsfynydd also had an authorisation to dispose of combustible waste to Hinkley Point B, but no disposals were made in 2002.
b. Effective to 18 December 2002.

Table 28. Disposals of radioactive waste oil (GBq)

Radionuclide		Station[a]		
		Dungeness A[c]	Oldbury	Sizewell A[b]
Tritium	disposal	0.12	0.031[d]	0.044
	limit[e]	see table 26	see table 26	400
Sulphur-35	disposal	0.088	included with	-
	limit[e]	see table 26	tritium	-
Iron-55	disposal	0.0032	-	-
	limit[e]	see table 26	-	-
Other activity	disposal	0.0048	0.0022	0.015
	limit[e]	see table 26	see table 26	40

a. Disposals of oil from Hinkley Point A are included with solid combustible waste in table 27. Berkeley and Hunterston A have no authorisation to dispose of waste oil. Bradwell, Trawsfynydd and Wylfa have authorisations, but no disposals were made in 2002.
b. Until 18 December 2002 Sizewell A disposed of oil by transfer to Littlebrook power station.
c. Includes arisings from the adjacent AGR owned by British Energy.
d. Includes disposals of sulphur-35. *e. Effective to 18 December 2002.*

Table 29. Disposals of solid radioactive waste to Drigg from generating and defuelling stations (GBq)

Radionuclide		Bradwell		Chapelcross	Dungeness A	Hinkley Point A	Oldbury		Sizewell A	Wylfa
		Direct	Via Winfrith				Direct	Via Winfrith		
Uranium	disposal	0	0	0	0.033	0	0.0007	0	0	0.0053
	limit[a]	1	1	-	1	0.5	1	1	1	1
Radium-226+	disposal	0	0	0	0	0	0	0	0	0
Thorium-232	limit[a]	0.2	0.2	-	2	0.1	0.2	0.2	0.2	0.2
Other alpha[b]	disposal	0.30	0.0006	0.05	1.8	0.48	0.15	0.020	0.0053	0.0050
	limit[a]	4	4	18	4	4	10	10	4	2
Carbon-14	disposal	0.0088	0.00013	0.12	0.44	0.045	0.41	0.00043	0.013	0.012
	limit[a]	3	3	-	2	3	12	12	2	2
Iodine-129	disposal	0	0	0	0.00002	0	0	0	0	0
	limit[a]	0.1	0.1	-	0.1	0.05	0.1	0.1	0.1	0.1
Tritium	disposal	0.043	0.00059	390	5.3	2.1	8.6	0	0.64	31
	limit[a]	80	80	500	80	40	80	80	80	200
Cobalt-60	disposal	0.74	0.011	3.1	2.6	0.40	0.40	0	0.27	0.25
	limit[a]	50	50	32	50	30	50	50	50	50
Others[c]	disposal	7.8	0.075	9.5	130	16	7.7	0.020	1.9	1.7
	limit[a]	600	600	70	400	350	600	600	400	400
Volume (m^3)	disposal	120	28	150	110	59	53	25	15	28
	limit[a]	400	400	600	500	300	350	350	200	150

a. Effective to 18 December 2002 (except for Chapelcross). b. Alpha emitting radionuclides with half lives greater than 3 months excluding uranium, radium-226 and thorium-232.
c. Iron-55 and beta emitting radionuclides with half lives greater than three months excluding carbon-14, iodine-129, tritium and cobalt-60.

Dungeness A also receives combustible waste from its neighbouring station, Dungeness B, owned by British Energy. These disposals are included in the figures in table 26.

92 Disposals of solid combustible waste (including oil) from Hinkley Point A by transfer to Hinkley Point B are shown in table 27.

93 Disposals of oil are shown in table 28, either by incineration on site (where data are available to distinguish these disposals from disposals of solid waste) or by transfer to other premises. Hinkley Point A is excluded as its activity data are included in table 27.

94 All disposals of combustible waste were within relevant quantitative limits.

Disposals to Drigg and Winfrith

95 Where appropriate, the volume of the waste is reduced by compaction in the waste monitoring and compaction plant at Sellafield or, until December 2002, Winfrith (paragraph 27). This waste consists of such items as gloves, protective clothing and cleaning materials. Where sites dispose of combustible low level waste by incineration on site, disposals to Drigg also include the ash from the incinerator.

96 Table 29 gives the volumes and activities consigned to Drigg by generating and defuelling stations. Table 30 gives the equivalent information for decommissioning sites. Bradwell, Oldbury and Trawsfynydd made disposals via Winfrith in 2002. Disposals from Berkeley were low as the major decommissioning projects either created little active waste or were on the conventional side of the site. Those from Berkeley Centre included small quantities of waste arising at Littlebrook, which is authorised to dispose of 120 kBq alpha activity and 450 MBq beta/gamma activity annually by transfer to Berkeley Centre. Since 18 December, Littlebrook have not been able to use this authorisation pending a minor variation to specify BNFL as the recipient of the waste.

97 Under the terms of the authorisation to dispose of solid radioactive waste to Drigg, intermediate level waste is also transferred from Chapelcross to Sellafield for conditioning. In 2002, 4.5 m^3 was so transferred, representing about 6.6% of the authorised limit.

98 All disposals were within relevant annual limits. However, a consignment from Berkeley Centre was found to contain 70 drums, rather than the 69 drums specified in the accompanying consignment documentation. Consequently, the consignment exceeded the limit on curium-244 under Drigg's 'Condition for Acceptance' by 0.5 MBq, thereby failing to comply with a condition of the RSA authorisation. Actions to prevent a recurrence have been completed.

Table 30. Disposals of solid radioactive waste to Drigg from decommissioning sites (GBq)

Radionuclide		Berkeley[a]		Hunterston A	Trawsfynydd[a]	
		Station	Centre		Direct	Via Winfrith
Uranium	disposal	0	0	0.00041	0	0.00030
	limit	1	1	1	1	1
Radium-226+ Thorium-232	disposal	0	0	0	0	0
	limit	0.2	0.2	0.2	0.2	0.2
Other alpha[b]	disposal	0.037	0.031	0.89	0.39	0.024
	limit	4	10	10	4	4
Carbon-14	disposal	0.0030	0	0.65	0.15	0.040
	limit	3	7	4	2	2
Iodine-129	disposal	0	0	0	0	0
	limit	0.1	0.1	0.1	0.1	0.1
Tritium	disposal	0.042	0.039	1.0	1.1	0.030
	limit	80	20	25	80	80
Cobalt-60	disposal	0.014	0.41	0.99	0.69	0.034
	limit	50	50	75	50	50
Others[c]	disposal	4.2	5.0	30	13	0.48
	limit	400	600	800	400	400
Volume (m^3)	disposal	20	14	130	280	96
	limit	450	540	600	300	300

a. Limits effective to 18 December 2002.
b. Alpha emitting radionuclides with half lives greater than 3 months excluding uranium, radium-226 and thorium-232.
c. Iron-55 and beta emitting radionuclides with half lives greater than three months excluding carbon-14, iodine-129, tritium and cobalt-60.

Disposals Exempt from the Radioactive Substances Act

99 Not all radionuclides are subject to control under the RSA. They may fall outside its scope altogether (such as potassium-40) or be covered by one of several exemption orders that permit disposals of certain radioactive items or types of radioactivity without an authorisation. One such order, used by all Magnox stations, is the Substances of Low Activity Exemption Order, which permits the disposal of waste as non-radioactive, providing its radioactive content falls below the very low levels defined in the order. Such waste is disposed of according to its chemical nature (for example, it might constitute Special Waste).

100 There were no events in 2002 relating to disposal of radionuclides under the Substances of Low Activity Exemption Order. However, following the events at Bradwell and Dungeness A that were discussed in last year's report, stations have been using revised guidance on the control of such waste and have purchased additional equipment to monitor such waste off site. Interpretation of the clearance levels specified in the order has proved to present considerable practical difficulties, so the industry has developed an industry code of practice in consultation with the Environment Agency, which was issued in June 2003.

Monitoring of the environment for radioactivity

101 Operations at Magnox stations give rise to radiation doses to members of the public through discharges and direct radiation. For generating stations, doses from aerial discharges are higher than those from liquid. For decommissioning stations, doses from aerial discharges are lower than those from liquid discharges, which are themselves lower than when the station was at power. Members of the public spending time in close proximity to the stations may be exposed to direct radiation from the plant. For most Magnox sites, the direct radiation emanates from the reactors themselves (usually via the ducting from the reactors to the boilers), although at Chapelcross the main source of direct radiation is a uranium store. This has only a minor impact on members of the public at most stations, but at Bradwell, Chapelcross and Dungeness A it was the main source of radiation dose in 2002. Clearly, direct radiation doses are greater from generating stations than from those being decommissioned, although there may still be some direct radiation from the latter arising from residual radioactivity.

102 The Environment Agency and SEPA require the operator to carry out environmental monitoring locally to each Magnox station to demonstrate that the radiation doses to members of the public from discharges of radioactive waste are

acceptable. The NII requires the assessment of doses to members of the public from direct radiation. The environmental monitoring programmes agreed with the relevant Agency involve the sampling and analysis of a wide range of materials and the measurement of dose rates. The Environment Agency has reviewed the statutory environmental monitoring programmes for stations in England and Wales and has subsequently enlarged the Statutory Environmental Monitoring Programmes in the CEAR documents issued in support of the new authorisations (paragraph 29). The revised programmes are effective for 2003 onwards, so monitoring of the environment under the programmes that were effective in 2002 is reported in tables 31 to 40.

103 Concentrations of radioactivity in the aquatic environment reflect liquid discharges, whereas radioactivity in the terrestrial environment generally reflects atmospheric discharges. Although some overlap may occur through sea to land transfer processes and on tidally inundated pastures, such overlap does not contribute significantly to public exposure around Magnox sites[1]. The main pathways identified as relevant to calculating critical group doses attributable to radioactive discharges from Magnox stations are:

- external gamma radiation from exposed intertidal sediments, particularly the fine silt and mud of estuaries and harbours,
- internal exposure from the high rate consumption of seafood (particularly fish and shellfish),
- external gamma radiation from airborne radioactivity,
- internal exposure from the high rate consumption of local agricultural produce (particularly milk),
- inhalation of airborne radioactivity.

The first two pathways relate to liquid discharges, the remainder to aerial discharges. The habits and consumption rates relating to each pathway are kept under regular review[1]. Doses from direct radiation, as distinct from discharges, are discussed separately.

Aquatic pathways

104 Seafood such as fish, crustaceans and molluscs, depending on local availability, are monitored in the vicinity of coastal sites. Environmental indicators such as seaweed and sediment are also monitored. Gamma dose rates are measured over beaches frequented by members of the public. The environmental monitoring programme carried out by Oldbury also covers the nearby decommissioning station, Berkeley, although each station has its own specific Statutory Environmental Monitoring Programme from 2003. Similarly, the programme for Hunterston A has been assimilated into that for Hunterston B (British Energy).

105 Trawsfynydd discharges into an inland lake, where the radioactivity is not dispersed as readily as would be discharges to sea. Accordingly, a detailed monitoring programme of the lake continues despite the reduction in discharges. Three species of freshwater fish are monitored: rainbow trout, indigenous brown trout and perch. The rainbow trout are replenished regularly with farmed trout to provide stocks for local anglers. Gamma dose rates are measured over lakeside beaches occupied by the public. Environmental indicators such as lake water and sediment are also monitored.

106 Trends in environmental concentrations of radioactivity discharged by Magnox stations are not usually discernible because of the presence of other sources of radioactivity. The situation is different at Trawsfynydd because, other than background fallout, the site's discharges are the only significant source of radioactivity in the lake (paragraph 57).

107 The concentrations of radioactivity in the edible parts of fish and shellfish caught near coastal stations are summarised in table 31. The results of analyses of indicators collected near coastal stations are summarised in tables 32 (seaweed) and 33 (sediments). Gamma dose rates over intertidal sediments (table 34) were similar to those in 2001 except for a single anomalous measurement at Bradwell (0.445 μGy h^{-1}) which was discounted (the other 19 measurements ranged from 0.013 to 0.065 μGy h^{-1}).

108 In recent years, a number of particles have been found at the pipeline outfall at Chapelcross and removed for analysis. Three particles of low beta gamma activity were detected in 2003. As in previous years the activity was associated with lime scale which had broken away from deposits inside the pipeline.

109 Results of analyses of radioactivity in fish and water from Trawsfynydd Lake are summarised in table 35. Radiocaesium is determined by the station, whereas other radionuclides are determined on bulked samples by CRL. However, as the results for 2002 are not yet available, the data in table 35 relate to the last quarter of 2001. No samples of perch were available in 2001 (see last year's report), so only data for radiocaesium are presented. The 'hot lagoon' is the semi-enclosed area of the lake closest to the station, into which the station's turbine condensers discharged warm water. Water in the hot lagoon then circulated through to the main lagoon. Concentrations of radionuclides are generally higher in the indigenous species than in the farmed rainbow trout, which are usually caught shortly after being transferred to the lake. Historical concentrations of caesium-137 are shown in figure 1. Concentrations were similar to those in 2001, although there has been a steady reduction in the concentration of caesium-137 in fish in recent years, reflecting the significant reductions in discharges after the station completed defuelling in 1995 (compare the discharges reported in table 15 with annual discharges of 30-40 GBq during the early 1990s). Concentrations of caesium-134, which has a half-life of only two years, have been below 5 Bq kg^{-1} in all sampled species of fish for the last four years.

Table 31. Radioactivity in seafoods in the vicinity of Magnox stations

Station	Food type	Mean radionuclide concentration (Bq kg^{-1} wet weight)								^{241}Am inferred[a]
		^{60}Co	^{65}Zn	^{90}Sr	^{99}Tc	^{110m}Ag	^{134}Cs	^{137}Cs	^{241}Am	
Bradwell	fish	1.2	< 3	-	-	< 2	< 1	1.5	< 3	< 0.18
	native oyster	< 0.5	1.2	-	-	< 0.4	0.38	1.9	< 2	0.0062
	pacific oyster	0.57	0.90	-	-	< 0.4	< 0.4	1.4	< 0.9	< 0.19
Chapelcross	flounder	-	-	0.1	< 0.9	-	< 0.2	12	-	-
	sea trout	-	-	0.1	< 1.2	-	< 0.1	0.4	-	-
	shrimp	-	-	0.25	7.5	-	< 0.1	4.0	-	-
Dungeness A	cod	< 0.3	< 0.6	-	-	-	< 0.2	0.78	< 0.7	< 0.17
	plaice	< 0.4	< 0.6	-	-	-	< 0.4	0.76	< 0.8	< 0.12
	shrimp	< 0.5	< 0.9	-	-	-	< 0.4	1.3	< 2	< 1.2
	cockle	1.0	< 1	-	-	-	< 0.5	1.4	< 2	-
	mussel	< 0.3	< 0.6	-	-	-	< 0.3	0.65	< 0.7	-
	whelk	0.27	< 0.6	-	-	-	< 0.4	0.73	< 0.8	0.0030
Hinkley Point A	fish	< 0.4	< 0.7	-	-	-	< 0.4	0.66	< 2	< 0.17
	shrimp	< 0.4	< 0.8	-	-	-	< 0.4	0.57	< 1	0.0018
Hunterston A	cod	< 0.02	0.066	-	-	< 0.02	0.033	1	-	< 0.24
	plaice	0.17	< 0.1	-	-	< 0.04	1.9	1	-	-
	hake	< 1	< 1	-	-	< 1	< 1	2	-	< 0.27
	flounder	< 1	< 1	-	-	< 1	< 1	< 1	-	-
	lobster	0.25	0.084	-	-	< 0.06	0.083		-	0.17
	winkles	0.043	0.022	-	-	0.011	0.032	< 1	-	0.22
Oldbury and Berkeley	cod	< 0.2	< 0.2	-	-	-	< 0.1	< 0.2	< 0.3	-
	conger	< 0.3	< 0.6	-	-	-	< 0.2	< 0.4	< 0.7	-
	dab	< 0.3	< 0.4	-	-	-	< 0.2	< 0.3	< 0.4	-
	eel	< 0.4	< 0.3	-	-	-	< 0.3	1.2	< 0.5	-
	salmon	< 0.4	< 0.8	-	-	-	< 0.3	< 0.5	< 2	< 0.16
	sea trout	< 0.6	< 2	-	-	-	< 0.4	< 0.6	< 2	-
Sizewell A	bass	< 0. 5	< 0. 8	-	-	-	< 0.5	1.6	< 0.8	-
	cod	< 0.4	< 0.7	-	-	-	< 0.4	0.43	< 0.6	< 0.14
	dab	< 0.2	< 0.3	-	-	-	< 0.2	0.25	< 0.7	-
	flounder	< 0.2	< 0.3	-	-	-	< 0.2	0.85	< 1	< 0.050
	mullet	< 0.4	< 0.9	-	-	-	< 0.4	< 0.5	< 2	-
	skate	< 0.4	< 0.8	-	-	-	< 0.5	0.67	< 0.3	-
	sole	< 0.4	< 0.7	-	-	-	< 0.4	0.52	< 0.7	< 0.20
	sprat	< 0.5	< 0.8	-	-	-	< 0.4	< 0.4	< 0.3	-
	whiting	< 0.4	< 0.8	-	-	-	< 0.4	0.63	< 0.3	-
	crab	< 0.4	< 0.9	-	-	-	< 0.5	< 0.4	< 1	0.0029
	lobster	< 0.3	< 0.6	-	-	-	< 0.3	< 0.3	< 2	-
	oyster	< 0.2	< 0.4	-	-	-	< 0.1	< 0.2	< 0.1	< 0.076
Wylfa	cod	< 0.3	< 0.8	-	-	-	< 0.2	0.83	< 0.5	-
	plaice	< 0.3	< 0.1	-	-	-	< 0.1	0.90	< 0.5	< 0.18
	crab	0.62	< 0. 5	-	-	-	< 0.2	0.43	< 2	0.070
	lobster	< 0.2	< 0.3	-	-	-	< 0.2	0.33	< 0.8	< 0.13
	mollusc	< 0.7	< 0.5	-	-	-	< 0.2	0.60	< 2	0.10

a. For use in dose assessment (paragraph 124).

Table 32. Radioactivity in seaweed in the vicinity of Magnox stations

Station	Species	Mean radionuclide concentration (Bq kg^{-1} wet weight)						
		^{60}Co	^{65}Zn	^{99}Tc	^{110m}Ag	^{134}Cs	^{137}Cs	^{241}Am
Bradwell	Unspecified	0.79	1.9	-	<0.9	0.71	5.1	<3
Chapelcross		0.6	-	5100	-	-	5.5	-
Dungeness A		0.90	<0.6	-	-	<0.3	0.98	<0.7
Hinkley Point A		<0.3	<0.5	-	-	0.21	1.3	<0.7
Hunterston A		-	-	-	-	-	0.44	-
Oldbury and Berkeley		<0.3	0.49	-	-	0.25	0.70	<0.7
Wylfa	*Fucus vesiculosus*	0.69	<0.4	-	-	<0.2	1.0	<0.8
	Porphyra	<0.3	<0.6	-	-	<0.2	0.50	<2

Seaweed is not sampled at Sizewell A

Table 33. Radioactivity in sediments in the vicinity of Magnox stations

Station	Sediment type	Mean radionuclide concentration (Bq kg^{-1} dry weight)					
		^{60}Co	^{65}Zn	^{110m}Ag	^{134}Cs	^{137}Cs	^{241}Am
Bradwell	mud	2.4	5.1	<3	3.0	36	<7
Chapelcross	mud	1.5	-	-	<1	130	65
Dungeness A	mud silt/sand sand	1.9 1.2 <0.9	<4 <3 <2	- - -	<2 <2 <2	3.9 2.2 1.9	<7 <5 <4
Hinkley Point A	silt silt/sand sand	<2 <1 <0.8	<4 <3 <3	- - -	2.8 1.6 <1	39 21 12	<6 <5 <5
Oldbury and Berkeley	silt	<2	<3	-	1.8	26	<5
Sizewell A	silt sand	1.2 <0.7	<3 <2	- -	1.8 <0.7	11 <0.7	<3 <2
Wylfa	silt	<0.4	<0.6	-	<0.3	23	5.4

Sediments are not sampled at Hunterston A.

110 Results of sediment and moss analyses are shown in table 36. These include sediment cores from the lake and lake edge to assess if there has been any change in the deposition rates of radionuclides from the lake. Generally, radioactivity concentrations are lower in the top fraction (0-3 cm) of the cores than in the lower fraction, which indicates that the accumulation rate of radionuclides in the sediment has fallen since the station began decommissioning. Concentrations were similar to those in 2001. The two moss samples are taken from the river Prysor, which flows into the lake and the Gwylan stream, which flows out of the lake. There is a clear enhancement of caesium-137 in the sample taken from the Gwylan stream.

111 Measurements of environmental gamma dose rates around the lake edge are summarised in table 37. They include background contributions and are similar to those in 2001.

Airborne and terrestrial pathways

112 In the terrestrial environment, the primary pathway for radioactivity into food is via milk; hence, grass and milk are monitored at local farms. Grass is taken from a location near to the site and the four nearest farms. Milk is collected from farms selected to represent the area around the station, preferably with four farms in an inner zone (1-5 km) and another four in an outer zone (5-10 km). Control samples may also be selected from farms at a greater distance. Where no farms are available in the inner zone, a larger number of farms in the outer zone are monitored. Results of the analyses on grass are used as an indicator for radioactivity in vegetables for calculating radiation doses to the public. The exception is Chapelcross where vegetables are grown locally for environmental monitoring.

113 The airborne concentration of tritium oxide is continuously monitored across the Chapelcross site using a number of monitors. The average concentration during 2002 was 21 Bq m^{-3}, comparable to that in 2001.

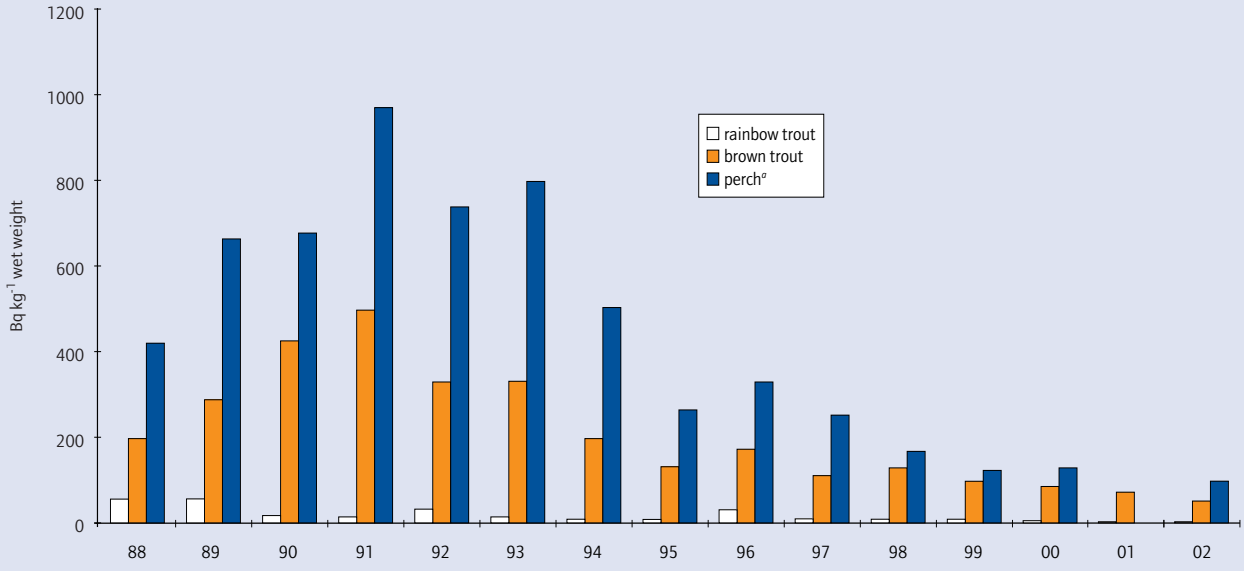
114 Since generation ceased at Berkeley, Hinkley Point A, Hunterston A and Trawsfynydd, aerial discharges have fallen by over an order of magnitude, so terrestrial environmental monitoring specific to the decommissioning

Table 34. Mean gamma dose rates measured in air in intertidal areas in the vicinity of Magnox stations

Station	Sediment type	Mean dose rate (μGy h^{-1})
Bradwell	mud	0.062[b]
Chapelcross	pipeline[a] mud saltmarsh	0.18 0.088 0.094
Dungeness A	mud silt/sand sand shingle	0.078 0.062 0.058 0.060
Hinkley Point A	silt silt/sand sand	0.076 0.077 0.063
Hunterston A	sand	0.088
Oldbury and Berkeley	silt/sand	0.066
Sizewell A	mud sand	0.045 0.047
Wylfa	silt silt/sand sand	0.067 0.063 0.066

a. Gamma dose rate in air, measured 2 m from the above ground sections of the discharge pipeline.
b. See paragraph 107.

Figure 1. Concentrations of caesium-137 in fish from Trawsfynydd Lake



a No samples were available in 2001.

sites has been greatly reduced, or assimilated into monitoring programmes for nearby operating stations. Monitoring of the milk from farms in the vicinity of Trawsfynydd has ceased altogether, although samples of grass are still analysed for carbon-14.

115 Results for monitoring of grass (vegetables at Chapelcross) are shown in table 38. Results from the sampling location nearest to the site are shown, in addition to bulked samples from the farms that also provide milk samples. Generally, levels of radioactivity are elevated near to the site. Results for monitoring in milk are given in table 39.
Results were very similar to those reported for 2001. Iodine-131 was below the limit of detection in milk and vegetation.
Strontium-90 levels were similar to those of recent years. Carbon-14 levels in samples from farms did not differ significantly from the natural background level of 250 Bq kg^{-1} carbon.

Direct radiation

116 Two types of monitoring are carried out, the purpose in each case being to detect any differences from naturally occurring background radiation levels and to assess the radiation exposure to members of the public.

117 Environmental gamma dose rates are measured by a portable instrument at selected locations in the landward area surrounding each station. Measurement locations are distributed at approximately 30° intervals in inner (approximately 1 km) and outer (approximately 10 km) rings. Measurements are repeated over pasture at intervals of no more than three months.

As the impact of Berkeley has diminished, the joint programme (paragraph 104) has become more focused on Oldbury, with the remaining Berkeley locations incorporated in the Oldbury outer ring.

118 The results are summarised in table 40. Data are summarised separately for the inner and outer rings. In general, dose rates are similar in the outer and inner rings around each station. The most notable exception is at Dungeness A, where the dose rate in the inner ring is significantly lower than that in the outer ring. This is due to

Table 35. Radioactivity in fish[a] and water from Trawsfynydd Lake

Radionuclide	Mean radionuclide concentration (Bq kg^{-1} wet weight for fish, Bq m^{-3} for water)				
	Brown trout[b]	Rainbow trout[b]	Perch[c]	Hot lagoon water	Main lagoon water
Cobalt-60	<0.3	<0.2	-	-	-
Strontium-90	3.0	3.6	-	-	-
Ruthenium-106	<5	4.8	-	-	-
Antimony-125	<1	<0.7	-	-	-
Caesium-134	<0.5	<0.4	<3	<4	<4
Caesium-137	53	1.9	97	23	21
Cerium-144	<4	<2	-	-	-
Europium-155	<0.8	<0.6	-	-	-
Plutonium-238	<0.003	<0.0002	-	-	-
Plutonium-239+240	0.00088	0.010	-	-	-
Americium-241	0.030	0.048	-	-	-
Curium-242	<0.02	<0.07	-	-	-
Curium-243+244	<0.002	<0.0009	-	-	-

a. Edible parts only.
b. Data other than those for caesium-134 and caesium-137 are from samples taken in the last quarter of 2001 (paragraph 109). *c. See paragraph 109.*

Table 36. Radioactivity in sediment and moss from Trawsfynydd Lake

Location	Sample	Mean radionuclide concentration[a] (Bq kg^{-1} dry weight for sediment, Bq kg^{-1} wet weight for moss)					
		^{60}Co	^{125}Sb	^{134}Cs	^{137}Cs	^{154}Eu	^{241}Am
Hot lagoon	sediment grab	9	29	6	830	11	36
	core 0-3 cm	14	74	10	1400	18	49
	core 3-20 cm	27	76	7	4100	22	210
Fish farm	core 0-3 cm	7	13	8	1300	5	13
	core 3-21 cm	6	11	6	700	14	16
Bailey bridge	core 0-3 cm	19	22	4	1100	8	27
	core 3-21 cm	13	31	7	1200	12	30
Footbridge	core 0-3 cm	4	10	3	490	4	6
	core 3-14 cm	3	10	3	570	5	10
Cae Adda	core 0-3 cm	9	6	2	300	3	8
	core 3-21 cm	2	7	3	76	4	5
Gwylan stream	moss	3	3	<1	51	<2	4
Prysor stream	moss	1	<2	<1	6	<1	2

a. Analyses of chromium-51, manganese-54, niobium-95, zirconium-95, ruthenium-106 and cerium-144 are also reported but not shown above because, through radioactive decay, their activities have fallen below minimum detectable levels.

a change of ground type (which affects the behaviour and fate of deposited radionuclides) from the inner ring, where the ground is shingle, to the outer ring, where the ground is soil. The results are similar to previous years, although comparison with 2001 is difficult because the national foot and mouth disease crisis prevented collection of much of the data during that year.

119 Thermoluminescence dose meters (TLDs) are deployed on the perimeter fence and further afield around some sites in order to obtain a cumulative measurement of direct gamma radiation (integrated gamma radiation dose). They are changed every three months. Doses to members of the public at the critical location are assessed from these measurements (see paragraph 136).

120 The results are given in table 41. Data were summed across the year at each monitoring location, so that the range shows the total annual values for the least and most exposed locations at the site fence. The mean value is the annual average across all monitoring locations at the site fence. The measurements include the local background together with any external gamma dose contribution from aerial discharges. Background is the average figure calculated from TLDs exposed in the environment around the site. In addition to cosmic background, there is a significant contribution from terrestrial gamma radiation, which varies according to local geology[2]. Therefore, although TLDs are exposed typically up to 30 km around each site, only those within 2.5 km have been used to assess the local background to minimise use of TLDs exposed over a different geology.

Table 37. Gamma dose rates around Trawsfynydd Lake

Location	Substrate	Mean dose rate (μGy h^{-1})
Fish farm	tarmac	0.074
Bailey bridge	grass/rock	0.11
Footbridge	grass/rock	0.086
Cae Adda	grass/rock	0.078

121 In last year's report, the local background measured by TLD was used for the first time to correct measurements taken at the site fence prior to assessing public dose from direct radiation (previously, measurements made using portable instruments, as shown in table 40, were used). This change of method coincided with the national foot and mouth disease crisis, which interfered with data collection; in most cases continuous exposure was maintained albeit with a reduced frequency of sample change, whereas in a few cases there was a break in the exposure period. Misinterpretation of some of the exposure dates resulted in a significant overestimate of the local background for several stations, so a re-assessment of the background for 2001 is included in table 41. For several stations (e.g. Wylfa) there is little or no change. However, there are significant reductions in the assessed background for other stations, particularly at Hunterston A where the assessed background has fallen threefold, with resultant impacts on the assessment of public dose from direct radiation (paragraph 139). The background measured around Berkeley in 2002 was much lower than that reported for 2001, in contrast to that around Oldbury. Given the proximity of the two sites, this implies that the results around Berkeley are not truly representative of local background.

Table 38. Radioactivity in grass[a] in the vicinity of Magnox stations

Station	Location	Mean radionuclide concentration (Bq kg^{-1} wet weight)				
		^{3}H	^{14}C (Bq kg^{-1} C)	^{35}S	^{90}Sr	^{137}Cs
Bradwell	nearest point	-	250	10	-	-
	outer milk farms	-	210	<1	-	-
Chapelcross	local vegetables	620	250	<0.9	0.38	<0.2
Dungeness A	nearest point	-	490	17	-	-
	inner milk farms	-	270	< 2	-	-
Hinkley Point A	nearest point	-	1100	34	-	-
	inner milk farms	-	340	2.8	-	-
Hunterston A[b]	inner milk farms	-	-	14	-	0.69
	outer milk farms	-	-	25	-	1.5
Oldbury and Berkeley	nearest point Oldbury	-	320	21	-	-
	nearest point Berkeley	-	280	3.4	-	-
	inner milk farms	-	300	5.5		
Sizewell A	nearest point	-	250	6.1	-	-
	inner milk farms	-	230	1.5	-	-
Trawsfynydd	nearest point	-	240	-	-	-
	inner milk farms	-	250	-	-	-
Wylfa	nearest point	-	330	11	-	-
	inner milk farms	-	260	2.1	-	-

a. Vegetables at Chapelcross.
b. Bq kg^{-1} dry weight.

Table 39. Radioactivity in milk in the vicinity of Magnox stations

Station	Location	Mean radionuclide concentration (Bq l^{-1})						
		^{3}H	^{14}C (Bq kg^{-1} C)	^{35}S	^{90}Sr	^{131}I	^{134}Cs	^{137}Cs
Bradwell	outer farms	-	-	<0.4	0.012	<0.2	<0.2	<0.2
	control farms	-	-	<0.4	0.030	<0.2	<0.3	<0.2
Chapelcross	inner farms	66	250	<0.6	0.056	<0.2	<0.04	<0.03
	outer farms	55	250	<0.7	0.030	<0.04	<0.04	<0.04
Dungeness A	outer farms	-	240	<0.4	<0.008	<0.8	-	-
	control farms	-	-	<0.4	0.013	-	-	-
Hinkley Point A	inner farms	-	250	0.48	0.025	<0.8	-	-
	outer farms	-	-	<0.4	-	<0.8	-	-
	control farms	-	-	0.41	0.034	<0.8	-	-
Hunterston A	inner farms	< 20	-	1.2	-	<0.4	-	0.07
	outer farms	< 20	-	0.87	-	<0.4	-	0.15
Oldbury and Berkeley	inner farms	-	-	0.84	-	<0.4	<0.09	<0.2
	outer farms	-	-	0.54	-	-	<0.2	<0.2
	control farms	-	-	-	-	<0.5	-	<0.6
Sizewell A	inner farms	-	-	<0.5	0.022	<0.2	<0.09	<0.2
	outer farms	-	-	<0.4	<0.02	<0.1	<0.2	<0.2
Wylfa	inner farms	-	-	<0.5	0.033	-	<0.2	<0.2
	outer farms	-	-	<0.5	0.053	-	<0.2	<0.2

Table 40. Mean gamma dose rates measured in air over pastureland in the vicinity of Magnox stations (μGy h^{-1}) [a]

Station	Mean gamma dose rate	
	Inner Ring	Outer Ring
Bradwell	0.073	0.078
Dungeness A	0.051	0.081
Hinkley Point A	0.087	0.080
Hunterston A	0.088	0.089
Oldbury and Berkeley	0.070	0.065
Sizewell A	0.046	0.049
Trawsfynydd	0.093	0.097
Wylfa	0.083	0.086

a. Including background

Table 41. Integrated gamma radiation doses measured around Magnox stations (μSv y^{-1})

Station	Site Fence [a]		Background	
	Range	Mean	2001 [b]	2002
Berkeley	710 - 1100	860	780	560
Bradwell	1300 - 5300	3300	770	970
Chapelcross	350 - 4800	2300	-	-
Dungeness A	930 – 2300	1500	410	460
Hinkley Point A	400 - 1100	680	620	610
Hunterston A	670 - 2100	1100	700	690
Oldbury	320 - 720	590	700	820
Sizewell A	1100 - 4700	2700	480	845
Trawsfynydd	760 - 2900	1300	880	880
Wylfa	800 - 1200	930	810	820

a. Including background. b. Revision to data reported last year (paragraph 121).

Radiological impact of Magnox operations

Critical group doses

122 Doses to critical groups presented in this chapter are not always solely attributable to the Magnox stations, but include contributions from other sources, which may be of greater significance than the contribution from the Magnox station itself. In particular, doses from aquatic pathways around Chapelcross, Hunterston A and Wylfa are dominated by discharges from Sellafield. Thus, Sellafield's discharges account for over 99% of the dose from aquatic pathways at Chapelcross and also contribute to doses around Hinkley Point A, Oldbury and Berkeley. Similarly, discharges from the French reprocessing plant at Cap de la Hague contributes to doses around Dungeness A, Bradwell and Sizewell A. There are also small contributions to doses from aquatic pathways from discharges from the British Energy sites adjacent to Dungeness A, Hinkley Point A, Hunterston A and Sizewell A. The contribution to doses from terrestrial pathways may be more significant from these British Energy sites, especially at Hunterston and Hinkley Point where discharges of sulphur-35 from the Magnox stations are no longer detectable. However, doses due to direct radiation from British Energy stations are negligible[3], so the doses due to direct radiation reported in this chapter can be attributed primarily to the Magnox stations.

123 Doses from food consumption are presented in one of three ways, depending on the results of radionuclide measurements in the relevant food. Where all radionuclides are measurable, the dose from consumption of that food is presented as a single positive number. Where some radionuclides are measurable, but others are below the limit of detection, the dose from consumption of that food is presented as a range. The lower bound is determined assuming that measurements below the limit of detection are zero, the upper bound is determined assuming that they are equal to the limit of detection. Where all measurements are less than the limit of detection, the lower bound is zero, so the dose from consumption of that food is reported as below the upper bound.

Aquatic pathways

124 Critical group doses from consumption of seafood have been assessed from the measured concentrations of radionuclides in relevant foodstuffs (table 31), the results of site-specific habit surveys published by the Food Standards Agency and SEPA[1] and the most recent dose coefficients in ICRP Publication 72[4]. No samples of crustaceans from the area around Bradwell or crustaceans and molluscs from the area around Berkeley and Oldbury were available to either the company or the Food Standards Agency[1] so doses from consumption of these food types have not been calculated.

Table 42. Consumption and occupancy data for aquatic critical groups in the vicinity of Magnox stations [1]

Station[a]	Consumption, kg y^{-1}			Exposure over sediments	
	Fish	Crustaceans	Molluscs	h y^{-1}	Substrate
Bradwell	44	3.1	6.5	2900	Mud
Chapelcross *(A)*	16 (salmonids) 4 (others)	12 (shrimp)	3.0 (mussel)	1000	Mud & sand
Chapelcross *(B)*	-	-	-	500	Salt marsh
Dungeness A	59	17	15	1500	Mud & sand
Hinkley Point A	43	9.8 (shrimp & prawn)	1.8 (whelk)	960	Mud
Hunterston A *(A)*	29	22 (*Nephrops* & squat lobster)	2 (queen scallop)	-	-
Hunterston A *(B)*	-	-	-	1200	Mud & sand
Oldbury and Berkeley	18	2.3 (shrimp)	-	520	Mud
Sizewell A	40	8.4 (crab & lobster)	6.4 (Pacific oyster & mussel)	1000	Mud
Trawsfynydd	1.8 (brown trout) 22 (rainbow trout) 0.93 (perch)	-	-	1000	Lake shore
Wylfa	94	23 (crab)	1.8	370	Sand

a. Where there is more than one critical group, separate groups are denoted (A), (B) etc.

Table 43. Critical group (adult) doses from consumption of sea foods in the vicinity of Magnox stations by pathway (μSv)

Station	Fish	Crustaceans	Molluscs	Other pathways	Total
Bradwell	1.0 – 4.2	-	0.45	0.47	1.5 – 5.1
Chapelcross	0.75 - 0.81	0.76 - 0.78	-	0.16	1.7 - 1.8
Dungeness A	0.59 – 2.9	0.29 – 1.1	0.27 – 0.43	0.45	1.2 – 4.9
Hinkley Point A	1.8 – 2.3	0.08 – 0.19	0.056 – 0.14	0.26	1.9 – 2.8
Hunterston A	0.47 – 2.8	0.75	0.056 – 0.14	0.37	1.3 – 4.0
Oldbury and Berkeley	0.12 – 0.86	< 0.001	-	0.086	0.13 – 0.95
Sizewell A	0.34 – 2.1	0.0047 – 0.14	< 0.2	0.24	0.34 – 2.6
Wylfa	1.1 – 4.8	0.64 – 0.77	0.014 – 0.10	0.57	1.7 – 6.2

The data for americium-241 measured in seafood (table 31) were determined by stations using a gamma-screening method, because use of the more sensitive alpha spectrometry method is not cost-effective for the low doses from consumption of seafood around Magnox sites. However, the gamma method often yields results below the limit of detection that give unrealistically high assessments of doses from consumption of seafood, so doses have been assessed using data inferred from the Food Standards Agency and SEPA. As results for 2002 were not available at the time of writing, the average concentration over the last 5 years has been used[1]. These estimates of concentration are included in table 31.

125 Consumption and occupancy data for aquatic pathways are summarised in table 42. Where consumption data are species specific, the relevant species data from table 31 have been used, if available, in dose calculations. Otherwise, data for closely related species have been used, or if those are also unavailable, data have been averaged across the groups 'fish', 'crustaceans' and 'molluscs', as appropriate. It has been assumed that consumption of non-critical foods generally add about a further 10% of dose to the dose from consumption of critical foods[5]. Relevant dose coefficients for ingestion are summarised in the Appendix to this report.

126 Tables 43 and 44 presents contributions to critical group doses by pathway and radionuclide respectively. Even using the inferred data, doses from ingestion are frequently dominated by the upper bound concentration of americium-241. Otherwise, doses are dominated by ingestion of caesium-137. Results are similar to those of recent years.

127 Data for the radionuclide concentrations in the fish species sampled from Trawsfynydd Lake (table 35) have been used with site-specific consumption data[1] (table 42) and the most recent dose coefficients[4] (Appendix) to assess the dose from consumption of fish from the lake (table 45). As only caesium data are available for perch, the "Others" category includes an estimate of the dose from ingestion of the other

Table 44. Critical group (adult) doses from consumption of sea foods in the vicinity of Magnox stations by radionuclide (μSv)

Station	^{60}Co	^{65}Zn	^{90}Sr	^{99}Tc	^{110m}Ag	^{134}Cs	^{137}Cs	^{241}Am
Bradwell	0.19	0.027 – 0.54	-	-	< 0.3	0.048 – 0.88	1.0	0.22 – 1.8
Chapelcross	-	-	0.14	0.058 – 0.072	-	<0.07	1.3	-
Dungeness A	0.027 – 0.13	< 0.3	-	-	-	< 0.6	1.1	0.066 – 2.4
Hinkley Point A	< 0.08	< 0.1	-	-	-	< 0.5	0.46	1.5
Hunterston A	< 0.2	< 0.2	-	-	< 0.09	< 0.6	0.47 – 0.50	0.8 – 2.3
Oldbury and Berkeley	< 0.03	< 0.05	-	-	-	< 0.09	0.12	0.0007 - 0.58
Sizewell A	< 0.07	< 0.2	-	-	-	< 0.4	0.34 – 0.39	0.0047 – 1.4
Wylfa	0.048 – 0.15	< 0.3	-	-	-	< 0.4	1.2	0.46 – 3.7

Table 45. Critical group (adult) doses to consumers of fish from Trawsfynydd Lake (μSv)

Foodstuff	^{60}Co	^{90}Sr	^{134}Cs	^{137}Cs	^{238}Pu	^{239}Pu	^{241}Am	Others	Total
brown trout	<0.002	0.15	<0.02	1.2	<0.002	0.00040	0.017	0.14	1.6
rainbow trout	<0.02	2.2	<0.2	0.54	<0.001	0.055	0.13	0.31	3.4
perch	-	-	<0.06	1.2	-	-	-	0.31[a]	1.5
Total	<0.03	2.4	<0.3	2.9	<0.003	0.055	0.15	0.96	6.5

a. Includes an assessment of dose from cobalt-60, strontium-90 and the actinides (paragraph 127).

radionuclides measured in trout. Doses are dominated by ingestion of caesium-137 and strontium-90 and are similar to those in recent years.

128 Results of dose rates observed above intertidal sediments at coastal sites and the shore area around Trawsfynydd Lake (tables 34 and 37) have been used with site specific occupancy data [1] (table 42) to assess doses to the public from external exposure. However, the dose rate measurements are inclusive of natural background, which should be subtracted prior to determining dose resulting from discharges. Background rates of 0.05 μGy h^{-1} over sand, 0.07 μGy h^{-1} over mud or salt marsh, and 0.06 μGy h^{-1} over other substrates are often cited, e.g. by Food Standards Agency[1]. However, these relate to background rates on the Cumbrian coast and are therefore inapplicable in regions of lower background such as south-east England. Therefore, regional background rates (table 46) were derived from those cited above, using the results of gamma dose rate measurements over land. Measurements around Trawsfynydd Lake were made over terrestrial substrates, not intertidal substrates, so the gamma dose rate measurements reported in table 40 were used directly for background correction.

129 Doses from external exposure are shown in table 47. Where appropriate, they have been added to the doses from consumption of fish and seafood to yield the doses summarised in table 1. Where a range of doses is reported for consumption the upper bound figure has been used for table 1.

Airborne and terrestrial pathways

130 Critical group doses from consumption of terrestrial foods have been assessed from the observed concentrations of

Table 46. Regional background dose rates in intertidal areas in the vicinity of Magnox stations (μGy h^{-1})[a]

Region	Stations	Substrate	Dose rate
Northwest	Chapelcross, Hunterston A and Wylfa	sand sand/silt mud/saltmarsh	0.050 0.060 0.070
Southwest	Berkeley, Hinkley Point A and Oldbury	sand sand/silt mud/saltmarsh	0.046 0.053 0.061
Southeast	Bradwell, Dungeness A and Sizewell A	sand sand/silt mud/saltmarsh	0.042 0.047 0.053
Inland[b]	Trawsfynydd	all	0.095

a. See paragraph 128.
b. Lakeside (not intertidal) area.

radionuclides in grass and milk (tables 38 and 39), national consumption data for the UK[1], and the most recent dose coefficients[4]. Monitoring of terrestrial foodstuffs required in the Statutory Environmental Monitoring Programme extends only to milk, although the sampling of grass is also required. Therefore, data for radionuclides in milk have been used directly, whereas it has been assumed that data for grass (table 38) may be applied to green vegetables and legumes.

131 In general, BNFL has adopted the approach used by the Food Standards Agency[6] to determine doses from consumption of terrestrial foods, whereby the two foodstuffs contributing most to the critical group dose are assigned critical consumption rates and national average consumption rates are assumed for other foods. However, this approach requires several foodstuffs to be monitored,

but the monitoring of only milk is required of Magnox stations by the Environment Agency although the concentration of radionuclides in some other foods is inferred from data on grass (paragraph 130). Therefore, critical consumption rates[1] have been assigned to milk, green vegetables and legumes (table 48) and it has been assumed that consumption of non-critical foods generally add about a further 10% of dose to the dose from consumption of critical foods[5]. Relevant dose coefficients are summarised in the Appendix to this report.

132 Doses to adults, showing the contribution from individual pathways, are given in table 49. As the same concentration data were applied to higher rate consumption of both green vegetables and legumes, the results for these two categories are grouped together as 'Vegetables'. Contributions to the critical group doses by individual radionuclides are shown in table 50. Equivalent data for children and infants are given in tables 51 to 54. Doses are dominated by ingestion of iodine-131 in milk. As these results are mainly upper bound figures, the actual ingestion doses may be lower. Doses are broadly similar to last year.

133 External radiation and inhalation dose per unit activity discharged have been assessed for a range of radionuclides at each site using a Gaussian plume model for the dispersion, using the methodology[7] based on the recommendations of the NRPB[8]. The resultant concentrations in air have been applied with occupancy data, discharge data and either dose per unit intake data for inhalation[4] to estimate inhalation dose or mean gamma decay energies to calculate direct radiation dose from the discharge plume. Beta particulate is dominated by cobalt-60 at most stations. Therefore, cobalt-60 has been considered to be representative of beta particulate.

134 Exposure has been assessed for occupancy at the critical habitation for each site, together with any other candidate group that may have been identified. Occupancy inside and outside is given in hours per year for each group in table 55. For critical habitations, BNFL default assumptions for occupancy have been adopted for all Magnox sites, i.e. the fraction of time spent indoors is 50% for farmers and 90% for the general population. No allowance is made for time spent away from home. Actual occupancy data (where available) show these assumptions to be reasonably pessimistic. Where time is spent indoors, a shielding factor of 0.2 is applied to calculate the dose from direct gamma radiation by the discharge plume. Relevant dose coefficients for inhalation are summarised in the Appendix to this report.

135 Inhalation and external doses for each station (assessed from the dispersion model) are presented in table 56. For all generating stations (even those without shield cooling air) dose from the plume is dominated by argon-41. The relevant pathway is external radiation from the plume itself.

Table 47. Critical group doses in the vicinity of Magnox stations from external exposure associated with aquatic discharges (μSv)

Station	Dose
Bradwell	24
Chapelcross (*A*)[a]	20
Chapelcross (*B*)[a]	11
Chapelcross (pipeline)[a,b]	9
Dungeness A	20
Hinkley Point A	12
Hunterston A (*B*)[a]	29
Oldbury and Berkeley	2.4
Sizewell A	BG[c]
Trawsfynydd	BG[c]
Wylfa	5.0

a. See table 42.
b. Critical group walking near the discharge pipeline.
c. Indistinguishable from local background.

Table 48. Consumption data for terrestrial critical groups in the vicinity of Magnox stations[1]

Foodstuff	Consumption (kg y^{-1})		
	Adult	Child	Infant
Milk	240	240	320
Legumes[b]	50	25	10
Green vegetables	45	20	10

a. Consumption of legumes not included for Chapelcross.

Table 49. Summary of doses to terrestrial critical groups (adult) in the vicinity of Magnox stations from the consumption of milk and vegetables (by pathway) (μSv)

Station	Milk	Vegetables	Other pathways	Total
Bradwell	0.14 - 3.0	< 0.02	0.30	0.14 - 3.3
Chapelcross	0.76 - 1.7	1.1 - 1.3	0.30	1.9 - 3.3
Dungeness A	0.27 - 4.5	0.063 - 0.088	0.46	0.33 - 5.1
Hinkley Point A	1.1 - 5.3	0.32	0.57	1.1 - 6.2
Hunterston A	2.1 - 2.2	1.0	0.33	2.1 - 3.6
Oldbury and Berkeley	0.52 - 4.6	0.23	0.48	0.52 - 5.3
Sizewell A	0.14 - 2.2	0.019	0.23	0.14 - 2.5
Trawsfynydd[a]	BG	BG	BG	BG
Wylfa	0.39 - 1.9	0.057	0.20	0.39 - 2.2

a. Results for Trawsfynydd were indistinguishable from natural background.

Table 50. Summary of doses to terrestrial critical groups (adult) in the vicinity of Magnox stations from the consumption of milk and vegetables (by radionuclide) (μSv)

Station	^{3}H	^{14}C	^{35}S	^{90}Sr	^{131}I	^{134}Cs	^{137}Cs
Bradwell	-	BG[a]	< 0.03	0.14	< 2	< 2	< 0.7
Chapelcross	0.96	0.052	< 0.2	0.85	< 0.6	< 0.2	< 0.2
Dungeness A	-	0.26	< 0.04	0.071	< 5	-	-
Hinkley Point A	-	1.2	0.048	0.20	< 5	-	-
Hunterston A	< 0.09	-	0.21	-	< 3	-	0.85
Oldbury and Berkeley	-	0.66	0.089	-	< 3	< 0.7	< 1
Sizewell A	-	BG[a]	0.019 - 0.033	0.14	< 0.8	< 0.7	< 0.7
Trawsfynydd	-	BG[a]	-	-	-	-	-
Wylfa	-	0.13	0.026 - 0.042	0.29	-	< 1	< 0.7

a. Indistinguishable from natural background.

Table 51. Summary of doses to terrestrial critical groups (child) in the vicinity of Magnox stations from the consumption of milk and vegetables (by pathway) (μSv)

Station	Milk	Vegetables	Other pathways	Total
Bradwell	0.30 - 4.1	< 0.02	0.42	0.30 - 4.6
Chapelcross	1.3 - 3.1	0.81 - 0.91	0.4	2.1 - 4.1
Dungeness A	0.43 - 10	0.041 - 0.066	1.1	0.47 - 12
Hinkley Point A	1.7 - 12	0.22	1.2	1.7 - 13
Hunterston A	0.078 - 5.2	0.48	0.57	0.078 - 6.2
Oldbury and Berkeley	0.74 - 7.6	0.17	0.78	0.74 - 8.6
Sizewell A	0.30 - 3.2	0.018	0.32	0.30 - 3.5
Trawsfynydd[a]	BG	BG	BG	BG
Wylfa	0.76 - 1.9	0.046	0.20	0.76 - 2.2

a. Results for Trawsfynydd were indistinguishable from natural background.

Table 52. Summary of doses to terrestrial critical groups (child) in the vicinity of Magnox stations from the consumption of milk and vegetables (by radionuclide) (μSv)

Station	^{3}H	^{14}C	^{35}S	^{90}Sr	^{131}I	^{134}Cs	^{137}Cs
Bradwell	-	BG[a]	< 0.04	0.30	< 3	< 0.9	< 0.5
Chapelcross	0.79	0.066	< 0.3	1.3	< 2	< 0.2	< 0.1
Dungeness A	-	0.32	< 0.05	0.15	< 10	-	-
Hinkley Point A	-	1.4	0.062	0.42	< 10	-	-
Hunterston A	< 0.2	-	0.25	-	< 5	-	0.31
Oldbury and Berkeley	-	0.79	0.11	-	< 6	< 0.5	< 0.8
Sizewell A	-	BG[a]	0.018 - 0.047	0.30	< 2	< 0.5	< 0.5
Trawsfynydd	-	BG[a]					
Wylfa	-	0.16	0.026 - 0.058	0.62	-	< 0.7	< 0.5

a. Indistinguishable from natural background.

For other radionuclides, the dominant pathway is inhalation, except for beta particulate (cobalt-60) which is dominated by external radiation from activity deposited from the plume on to the ground (ground gamma). For decommissioning stations, doses are attributable mainly to tritium (inhalation) and beta particulate (ground gamma). Doses are much lower those reported in 2001 as the latter were based on occupancy at generic reference points used for prospective dose assessments. A significant additional factor for Bradwell is the cessation of discharges of argon-41 after March. Doses to adults from consumption (table 49) have been added to those from the plume to determine which age group's dose is summarised in table 2 (which excludes doses from argon-41 where these are included in the measurement of direct radiation).

Direct radiation

136 The doses to the most exposed members of the public were determined from the perimeter fence dose rate at the nearest monitoring point to the critical location at each site, corrected for the background figure presented in table 41. A shielding factor of 0.2 has been applied to a dwelling for direct gamma radiation. Occupancy data are the same as those used to assess dose from direct radiation from the discharge plume (table 55).

Table 53. Summary of doses to terrestrial critical groups (infant) in the vicinity of Magnox stations from the consumption of milk and vegetables (by pathway) (μSv)

Station	Milk	Vegetables	Other pathways	Total
Bradwell	0.48 - 14	< 0.02	1.4	0.48 - 16
Chapelcross	2.7 - 10	0.65 - 0.78	1.1	3.4 - 12
Dungeness A	0.98 - 47	0.037 - 0.071	4.7	1.0 - 52
Hinkley Point A	4.1 - 50	0.21	5.0	4.1 - 55
Hunterston A	0.33 - 24	0.41	2.4	0.33 - 26
Oldbury and Berkeley	2.0 - 30	0.19	3.0	2.0 - 33
Sizewell A	0.48 - 11	0.026	1.1	0.48 - 12
Trawsfynydd[a]	BG	BG	BG	BG
Wylfa	1.4 - 3.3	0.055	0.33	1.4 - 3.7

a. Results for Trawsfynydd were indistinguishable from natural background.

Table 54. Summary of doses to terrestrial critical groups (infant) in the vicinity of Magnox stations from the consumption of milk and vegetables (by radionuclide) (μSv)

Station	^{3}H	^{14}C	^{35}S	^{90}Sr	^{131}I	^{134}Cs	^{137}Cs
Bradwell	-	BG[a]	< 0.2	0.48	< 12	< 2	< 0.8
Chapelcross	1.6	0.17	< 2	1.6	< 7	< 0.3	< 0.2
Dungeness A	-	0.77	< 0.2	0.24	< 46	-	-
Hinkley Point A	-	3.5	0.17	0.68	< 46	-	-
Hunterston A	< 0.3	-	0.58	-	< 23	-	0.17
Oldbury and Berkeley	-	1.9	0.29	-	< 26	< 0.8	< 2
Sizewell A	-	BG[a]	0.026 - 0.15	0.48	< 9	< 0.8	< 0.8
Trawsfynydd	-	BG[a]	-	-	-	-	-
Wylfa	-	0.39	0.037 - 0.18	0.99	-	< 1	< 0.8

a. Indistinguishable from natural background.

137 The exceptions to the above are Bradwell, Chapelcross and Dungeness A. In these cases, the critical dwelling is very close to the site fence, so measurements have been taken inside the critical dwelling to determine precisely the relationship between direct radiation dose and the radiation source. The empirical model for Bradwell was applied for the period January to March, when generation ceased, after which the generic method was applied (paragraph 136). At Dungeness A, neutrons contribute nearly 30% to the dose at the critical dwelling (this dose has been minimised by fitting a layer of polythene cladding to the duct cell roofs). Neutron radiation from the uranium store accounts for 18% of the direct radiation dose at Chapelcross. At all other sites, only gamma dose is significant.

138 The assessment of direct radiation dose (including neutron dose) to the critical group and any other candidate group that may have been identified is shown in table 57. Measurement of direct radiation includes the effects of gamma dose, mainly from argon-41 in the gaseous discharge plume, which has been assessed independently via a pessimistic Gaussian plume model (table 56, paragraphs 133 to 135) and any gamma-emitting radionuclides deposited from the plume in the vicinity of the detectors. No attempt has been made to correct for these effects in the assessment of direct radiation dose.

Table 55. Occupancy data for terrestrial critical groups in the vicinity of Magnox stations

Station[a]	Occupancy[b,c], h y^{-1}	
	Inside	Outside
Berkeley	4380	4380
Bradwell	7884	876
Chapelcross	4148	1458
Dungeness A	7884	876
Hinkley Point A	4380	4380
Hunterston A	4380	4380
Oldbury	4380	4380
Sizewell A *(A)*	7884	876
Sizewell A *(B)*	-	3650
Sizewell A *(C)*	-	250
Sizewell A *(D)*	-	90
Trawsfynydd	4380	4380
Wylfa	7884	876

a. Where there is more than one critical group, separate groups are denoted (A), (B) etc
b. Occupancy data also apply to assessment of critical group dose from direct radiation.
c. Occupancy data apply to critical habitation, except for Sizewell A where (B) applies to fishermen, (C) to anglers and (D) to dog walkers.

Table 56. Summary of inhalation and external doses to adult terrestrial critical groups from discharges to air (μSv)

Station	Group	Tritium	Carbon-14	Sulphur-35	Argon-41	Beta particulate	Total
Berkeley	Critical habitation	0.000045	0.000091	-	-	0.00015	0.00029
Bradwell		0.0046	0.037	0.0029	1.8	0.015	1.8
Chapelcross		1.4	0.042	0.0026	7.9	-	9.4
Dungeness A		0.0046	1.1	0.0033	22	< 0.05	23
Hinkley Point A		0.000050	0.00012	-	-	0.00012	0.00028
Hunterston A		0.00000089[b]	0.0000020[b]	-	-	0.000037	0.000040
Oldbury		0.020	0.36	0.0077	9.4	0.0091	9.8
Sizewell A *(A)*		0.0086	0.12	0.0035	12	0.0094	13
Sizewell A *(B)*[a]	Fishermen	0.0030	0.044	0.0012	16	0.013	16
Sizewell A *(C)*[a]	Anglers	0.0014	0.021	0.00058	5.8	0.0055	5.8
Sizewell A *(D)*	Dog walkers	0.0017	0.026	0.00071	5.9	0.0048	5.9
Trawsfynydd	Critical habitation	0.00024	0.00015	-	-	0.000078	0.00047
Wylfa		0.015	0.19	0.0065	0.47	0.0017	0.69

a. Additive to dose from consumption of seafoods.
b. Includes assessment from passive exchange with atmosphere (paragraph 86).

Table 57. Direct radiation doses to the most exposed members of the public at Magnox power stations (μSv)

Station	Group	2001			2002		
		Gamma dose	Neutron dose	Total	Gamma dose	Neutron dose	Total
Berkeley	Critical habitation	BG[b]	-	BG[b]	23[d]	-	23[d]
Bradwell		430	-	430	220	-	220
Chapelcross		90	20	110	90	20	110
Dungeness A[a]		290	110	390	400	160	560
Hinkley Point A		BG[b]	-	BG[b]	BG[b]	-	BG[b]
Hunterston A[a]		65	-	65	43	-	43
Oldbury[a]		2.5	-	2.5	BG[b]	-	BG[b]
Sizewell A *(A)*		22	-	22	28	-	28
Sizewell A *(B)*[a,c]	Fishermen	24	-	24	28	-	28
Sizewell A *(C)*[c]	Anglers	20	-	20	17	-	17
Sizewell A *(D)*	Dog walkers	20	-	20	16	-	16
Trawsfynydd	Critical habitation	BG[b]	-	BG[b]	10	-	10
Wylfa[a]		4.5	-	4.5	5.1	-	5.1

a. Revised assessment resulting from re-assessment of background dose (paragraph 139). b. Indistinguishable from local background.
c. Additive to dose from consumption of seafoods. d. Using local background results for Oldbury (paragraph 139).

139 The assessments of direct radiation dose for 2001 presented in table 57 are revisions to those presented in last year's report. This is to accommodate the revision to the assessment of background dose shown in table 41 (paragraph 121). In addition, the empirical model developed for Dungeness A has been reviewed, with the result that a small reduction in local background dose rates has been applied, resulting in a small increase in the assessed dose to the critical group. The dose from direct radiation for Dungeness A is presented exclusive of external radiation from the plume. Doses for 2002 are similar to those for 2001, with the exception of a reduced dose at Bradwell due to the cessation of generation. As Berkeley and Oldbury are so close, similar backgrounds are usually observed (see revised results for 2001 in table 41). Therefore, the dose to the critical group at Berkeley was assessed using the background for Oldbury, as the anomalously low background measured around Berkeley would have implied a dose to the critical group of almost 100 μSv, despite no change in activities on site. Where the dose at the site fence nearest to the critical exposure location was below the local background (table 41), then the result is presented as 'BG' in table 57. The most exposed group from each site represents the critical group for direct radiation, summarised in table 3.

140 There is a significant difference in direct radiation dose between reactor types. The highest doses are associated with the older reactors fitted with steel pressure vessels. The doses associated with Oldbury and Wylfa, which are equipped with concrete pressure vessels, are much lower. This is because concrete pressure vessels encapsulate the complete gas circuit, whereas the boilers and gas ducting are outside the concrete biological shield at the older stations, so are not shielded to the same degree.

Table 58. Collective dose commitments from discharges from Magnox stations (man Sv)

Station	Aerial discharges			Liquid discharges		
	UK	Europe	World	UK	Europe	World
Berkeley	0.00012	0.00075	0.0047	0.0000013	0.0000061	0.0000065
Bradwell	0.12	0.59	3.1	0.0048	0.020	0.023
Chapelcross	0.94	2.4	7.1	0.00039	0.00094	0.0011
Dungeness A	1.2	11	67	0.0027	0.015	0.017
Hinkley Point A	0.0011	0.0072	0.049	0.0012	0.0063	0.0067
Hunterston A	0.0000054	0.000036	0.00028	0.00025	0.00067	0.00083
Oldbury	1.3	7.5	49	0.0018	0.0086	0.0091
Sizewell A	0.67	3.8	23	0.0065	0.032	0.037
Trawsfynydd	0.00031	0.0023	0.017	0.000042	0.00011	0.00013
Wylfa	0.48	3.8	28	0.00059	0.0015	0.0019

Summary of critical group doses

141 Doses to members of the public from discharges to water, discharges to air and from direct radiation have been considered separately above. The most exposed group of the public local to each site in 2002 constitutes the critical group for that year. Depending on the additivity of the impact of each of these operations, the critical group could be represented by a group of people exposed through a single operation (e.g. discharges of liquid wastes) or through a combination of different operations (e.g. direct radiation and discharges of radioactivity to air). Where fishermen are exposed to the gaseous discharge plume or direct radiation, the resultant dose is added to the dose due to liquid discharges, rather than the dose due to gaseous discharges via consumption. Critical group doses for the stations are summarised in table 4. Where necessary, summary doses for 2001 have been revised to account for the change in dose due to direct radiation (paragraph 139) consequent on the revision of background dose (paragraph 121). Critical group doses are broadly similar to those in 2001, except for Bradwell due to the cessation of generation in March.

Collective doses

142 Collective doses resulting from discharges from Magnox stations, shown in table 58, have been calculated in accordance with paragraphs 27-29 and 36 of the Introduction and amplified in the Appendix. The inclusion of the daughters of antimony-125 and plutonium-241 in the assessments, as discussed in the Appendix, has had a negligible affect. The collective dose to the population of the UK from operation of the Magnox fleet was 4.8 man Sv (67% from discharges of carbon-14, 16% from discharges of tritium and 11% from discharges of argon-41). That to the population of Europe was 29 man Sv (89% from discharges of carbon-14 and 6% from discharges of tritium) and that to the world population was 180 man Sv (98% from discharges of carbon-14). The collective dose commitments from generating stations are dominated by the dose from aerial discharges of carbon-14 because of its long radioactive half-life (5760 years) and its incorporation into the global carbon cycle. In contrast, collective dose commitments from liquid discharges are negligible. However, because the discharges of carbon-14 from decommissioning stations are several orders of magnitude lower than those from generating stations, dose commitments from liquid discharges are comparable to those from aerial discharges. Collective doses were generally similar to those reported last year except for much lower doses reported for Bradwell, where discharges of carbon-14 were significantly reduced following the cessation of generation (see table 16).

Non-radioactive discharges and disposals

143 Non-radioactive discharges from Magnox stations are subject to authorisations and consents which are listed in the annex to this chapter. Several sites also hold water abstraction licences under the Water Resources Act 1991, although these are not included in the annex tables, as they have no impact on discharges. Maentwrog holds only a water abstraction licence, so there is no entry for that station in the Annex.

Discharges under the terms of Prescribed Process authorisations

144 Magnox stations operate a range of non-nuclear plant which require authorisation under the EPA 1990 because of size and potential to emit prescribed substances. The plants include the incinerators used to dispose of combustible low level waste at Dungeness A and Wylfa, the gas turbines installed at Wylfa as standby generation plant, and Auxiliary Boiler 4 at Wylfa (boilers 1-3 fall below capacity requiring authorisation).

145 The authorisation covering the incinerators at Dungeness A and Wylfa require monitoring of discharges to demonstrate compliance with limits on peak concentration of a range of chemical species (table 59). Other incinerators in use at Magnox stations fall below the capacity requiring authorisation under the EPA 1990.

146 The authorisations covering the gas turbines and auxiliary boiler at Wylfa require annual declaration of the quantities

of sulphur dioxide and oxides of nitrogen discharged, which in 2002 were respectively 681 kg and 5052 kg, representing 19% and 42% of the respective limits.

147 There were no non-compliances with Prescribed Process Authorisations during 2002.

Discharges made under the terms of consents

148 Operating power stations draw large volumes of water from the sea to cool their condensers. This cooling water is discharged to sea in accordance with consents issued under the Water Resources Act 1991 and Control of Pollution Act 1974, which impose limits on temperature, volume, pH and residual anti-fouling biocides. Other sources of waste water include:

- Turbine condenser cooling water overflow.
- Waste water from the demineralisation plant.
- Boiler water from reactor heat exchangers.
- Site surface drainage.

149 Discharges to water of oxidising species, where data are available, are shown in table 60. Discharges of non-radioactive substances from Chapelcross are shown in table 61.

150 The following events in 2002 were not compliant with consents or were of general environmental significance.

Calder Hall

151 In January, the station exceeded its limit on outfall temperature (30°C) by 5°C when blowdown water was discharged to the Calder interceptor sewer while the cooling towers were out of service. The River Ehen was diverted to provide dilution flow, preventing a recurrence. The station had previously advised the Environment Agency that the sampling point was inappropriate and it was recognised that this event was related to that issue, so no enforcement action was taken.

Oldbury

152 In March, the Environment Agency measured suspended solids at about 2% above the consent limit, probably caused by routine maintenance of the sewage plant. The level of solids quickly settled back to normal, and the Environment Agency took no further action.

153 In October, the Environment Agency measured suspended solids over 50% above the consent limit in a sample of water discharged from Number 3 Silt Lagoon. However, subsequent measurements taken by Environment Agency were well within the limit. The unusual level is thought to be associated with disturbance caused by heavy rain. The Environment Agency has accepted the remedial actions taken to prevent a recurrence.

Table 59. Non-radioactive discharges to air from incinerators

Substance	Peak concentration (mg m^{-3})			
	Dungeness A		Wylfa	
	Discharge	Limit	Discharge	Limit
Carbon monoxide	41	100	15	100
Organic compounds (excluding particulate matter)	2.4	20	1.9	20
Total particulate matter	61	200	22	200
Heavy metals	1.1	5	0.45	5
Chlorine (as hydrogen chloride)	44	250	110	250
Sulphur dioxide	180	300	97	300

Ozone depleting substances

154 One of the environmental objectives for the Company is to minimise the use of ozone depleting substances. These are used in refrigerant circuits associated with the bulk storage of liquid carbon dioxide and irradiated fuel storage pond water cooling systems. Discharges can arise during system maintenance work and from accidental leakage. All stations have a programme in place to phase out and replace ozone depleting substances in accordance with the Environmental Protection (Controls on Ozone Depleting Substances) Regulations 2002/528. However, where replacement of any ozone depleting substance would compromise safety systems, exemptions from these regulations are sought.

Table 60. Discharges of oxidant to water

Station[b]	Discharge[a]	
	Total residual oxidant (mg l^{-1} max)	Sodium hypochlorite equivalent (15%) (te)
Wylfa	<0.3	2028

a Data available only for the financial year.
b There were no discharges of oxidant from Bradwell and Hinkley Point A.

Table 61. Non-radioactive liquid effluent discharges from Chapelcross

Substance	Discharge (te)
Copper	0.5
Zinc	0.1
Cadmium	<0.0004
Mercury	<0.001
Lead	<0.001
Suspended solids	39

Carbon dioxide and other greenhouse gases

155 The carbon dioxide used to cool reactor cores (paragraph 6) used to be extracted from the atmosphere, but is now produced as an industrial by-product of fertiliser production. During normal operation and planned depressurisations of the reactor cooling circuit, it is released to the atmosphere (table 62). However, if it were not used in the Magnox reactors, the carbon dioxide would be discharged directly to atmosphere during the production of fertiliser, so its use in Magnox reactors does not contribute directly to global warming. There are small adventitious discharges to atmosphere of methane and carbon monoxide from the reactor gas circuit.

156 Because there is no discharge of greenhouse gases associated with the generation of electricity by non-fossil fuels (including nuclear and hydro-electric plant such as Maentwrog), additional carbon dioxide would be discharged if the electricity was generated by coal, oil or natural gas. In 2000, the UK generated 263 TWh by fossil fuels (coal, oil and gas), resulting in 42 million tonnes of carbon discharged, primarily as carbon dioxide[9]. This implies a discharge of 0.58 MTe CO_2 per TWh generated. In 2002 BNFL and Magnox Electric together supplied 18.2 TWh electricity to the grid (table 5). Assuming no change in discharge of carbon dioxide per unit fossil fuel generation in the UK, the discharge of 10.6 million tonnes of carbon dioxide was thereby averted.

Off-site disposals of wastes

157 Solid wastes are reused or recycled, where practicable, or sold as scrap. Specialist waste contractors currently collect special wastes and directive waste, both a form of controlled waste, for disposal at licensed waste disposal sites. Controlled wastes arise in offices, general workshops and from other plants on site and may also be collected for disposal by local council waste disposal contractors. Details of the quantities of special waste, recycled waste and directive waste sent to landfill are shown in table 63 (where data are available). The amount of waste disposed from sites depends on activities giving rise to the waste; a major refurbishment or decommissioning activity produces more waste than is produced by normal operations.

158 On one occasion, Oldbury despatched a consignment of waste oil to the waste management contractor without the correct paperwork. This non-compliance with the Special Waste Regulations (1996) was corrected without recourse to enforcement action.

Table 62. Discharges of carbon dioxide from reactor circuits

Station	Discharge (te)
Bradwell	1800
Chapelcross	3500
Dungeness A	3300
Oldbury	6200
Sizewell A	2700
Wylfa	5100

Table 63. Disposals of non-radioactive solid wastes

Station[a,b]	Quantity (te)	
	Directive waste to landfill	Special waste
Berkeley Site	210	-
Bradwell	105	18
Chapelcross	195	200
Dungeness A	150	14
Hinkley Point A	84	0
Oldbury[c]	230	-
Sizewell A	470	32
Trawsfynydd	410	-
Wylfa	490	94
Maentwrog	7	0

a. Data unavailable for Hunterston A, as the quantities cannot be distinguished from other disposal.
b. Data available only for financial year.
c. Data not available for special waste.

Acknowledgements

This chapter was written by Laurence Austin of Magnox Generation's Environment, Health, Safety and Quality Unit, EHSQU at Berkeley, assisted by Jodie Price-Williams of the same unit, Hema Patel of BNFL Environmental Services at Berkeley and Bob Millard at Chapelcross. Colleagues at Magnox stations collected samples, made radiological analyses and measured environmental dose rates. Thanks are also due to British Energy staff who carried out these duties at Dungeness, Hinkley Point and Hunterston. Analyses requiring radiochemical separation were carried out by the Central Radiochemical Laboratory at Berkeley. Members of the public who co-operated in collecting samples and making measurements are especially thanked.

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Annex: Authorisations and consents effective in 2002

Table number	Station
A1	Berkeley
A2	Bradwell
A3	Chapelcross
A4	Dungeness A

Table number	Station
A5	Hinkley Point A
A6	Hunterston A
A7	Littlebrook
A8	Oldbury

Table number	Station
A9	Sizewell A
A10	Trawsfynydd
A11	Wylfa

Table A1. Authorisations and consents for Berkeley

Relevant legislation	Description	Effective Date
Radioactive Substances Act	Disposal of waste gases, mists and dusts to atmosphere	1 May 1991
	Disposal of liquid waste to the Severn estuary	1 May 1991
	Disposal of low level waste to Drigg from Berkeley Power Station Variation to above	1 Jan 1992 19 Aug 1996
	Disposal of low level waste to Drigg from Berkeley Centre Variation to above	1 Jan 1992 19 Aug 1996
	Disposal of low level waste to UKAEA Winfrith from Berkeley Power Station	1 Feb 1993
	Disposal of low level waste to UKAEA Winfrith from Berkeley Centre	1 Feb 1993
	Disposal of combustible wastes by incineration on site	8 Nov 1965
	Disposal of combustible wastes by transfer to Hinkley Point (held jointly with Oldbury)	1 Mar 1978
	Revocation of all above authorisations in name of Magnox Electric	31 Jul 2003
	Disposal of radioactive waste in name of BNFL (multi-media) authorising: Disposal of gaseous waste to the environment Disposal of aqueous waste to the environment Disposal of combustible wastes by incineration on site Disposal of low level waste to Drigg Transfer of organic liquid waste to Shanks at Hythe for incineration	18 Dec 2002
Water Resources Act	Discharge of site drainage to the Conigre Pill (012108)	25 May 1993
	Discharge of sewage effluent and site drainage to the Severn Estuary (012411)	6 May 1994
	Discharge of trade effluent and site drainage from laboratories to the Conigre Pill (012412)	6 May 1994
	Discharge of trade effluent to the Severn Estuary (100293)	11 Jul 1997

Table A2. Authorisations and consents for Bradwell

Relevant legislation	Description	Effective Date
Radioactive Substances Act	Disposal of waste gases, mists and dusts to atmosphere Variation to above	1 Jan 1993 1 Aug 1994
	Disposal of liquid waste to the Blackwater Estuary	1 Jan 1993
	Disposal of low level waste to Drigg Variation to above	1 Jan 1992 1 Oct 1995
	Disposal of low level waste to UKAEA Winfrith	1 Feb 1993
	Disposal of waste oil to Littlebrook	11 May 1981
	Revocation of all above authorisations	18 Dec 2002
	Disposal of radioactive waste (multi-media) authorising: Disposal of gaseous waste to the environment Disposal of aqueous waste to the environment Disposal of organic liquid by incineration on site Disposal of low level waste to Drigg	18 Dec 2002
	District survey laboratory: Disposal and accumulation of radioactive waste	3 Jun 1964
Environmental Protection Act	Operation of Evans Universal solid waste incinerator (AJ3352) Variation to above (AJ3352/AO5140)	12 Nov 1993 14 Sep 1994
	Revocation of AJ3352	13 Mar 2002
Water Resources Act	Discharge of cooling water, trade effluent, fully treated sewage effluent and surface water to the River Blackwater Estuary Variation to above Variation to the above (PR2TSE107/60(B))	21 Dec 1960 4 Mar 1993 2 Aug 1993
	Discharge of sewage effluent, cooling water, trade effluent and surface water to the Delph Ditch (PR/E/N/F/8529)	12 Aug 1993
	Discharge of sewage effluent in an emergency, cooling water and surface water to the Delph Ditch (PR2TSE012/57A)	4 Mar 1993

Table A3. Authorisations and consents for Chapelcross

Relevant legislation	Description	Effective Date
Radioactive Substances Act	Discharge of gaseous radioactive wastes to atmosphere	1 Apr 1986
	Discharge of liquid radioactive waste to the Solway	1 Apr 1986
	Transfer and disposal of solid radioactive waste to Drigg	1 Nov 1995
	Transfer of combustible liquid waste to authorised industrial contractor	1 Jan 1990
Control of Pollution Act	Discharge of cooling water and trade effluent to the Solway	6 May 1979
	Discharge of site surface water drainage to Gullielands Burn	21 Feb 1996

Table A4. Authorisations and consents for Dungeness A

Relevant legislation	Description	Effective Date
Radioactive Substances Act	Disposal of waste gases, mists and dusts to atmosphere Variation to above	1 Jul 1994 1 Oct 1997
	Disposal of liquid waste to the English Channel	1 Jul 1994
	Disposal of low level waste to Drigg Variation to above	1 Jan 1992 1 Apr 1997
	Disposal of low level waste to UKAEA Winfrith	1 Feb 1993
	Disposal of combustible waste by incineration on site	1 Jan 1996
	Revocation of all above authorisations	18 Dec 2002
	Disposal of radioactive waste (multi-media) authorising: Disposal of gaseous waste to the environment Disposal of aqueous waste to the environment Disposal of low level waste and organic liquid by incineration on site Disposal of low level waste to Drigg	18 Dec 2002
Environmental Protection Act	Operation of Evans Universal solid waste incinerator (AK1363)	21 Jan 1994
Water Resources Act	Discharge of trade effluent (cooling water, water treatment plant effluent, active plant effluent, magnesium dissolution waste waters and surface waters) Variation to above (P231/K/85)	29 Jan 1986 27 Apr 1995

Table A5. Authorisations and consents for Hinkley Point A

Relevant legislation	Description	Effective Date
Radioactive Substances Act	Disposal of waste gases, mists and dusts to atmosphere	1 Jul 1991
	Disposal of liquid waste to the Bristol Channel	1 Nov 1990
	Disposal of low level waste to Drigg Variation to above	1 Jan 1992 31 Mar 1996
	Disposal of low level waste to UKAEA Winfrith	1 Feb 1993
	Disposal of combustible waste to Hinkley Point B	31 Mar 1996
	Revocation of all above authorisations	18 Dec 2002
	Disposal of radioactive waste (multi-media) authorising: Disposal of gaseous waste to the environment Disposal of aqueous waste to the environment Disposal of low level waste to Drigg Disposal of low level waste and organic liquid by transfer to Hinkley Point B for incineration	18 Dec 2002
Water Resources Act	Discharge of trade effluent (water treatment plant) (013338)	Draft consents replacing deemed consents 27 Apr 1995
	Discharge of trade effluent (R2 auxiliary cooling water) (013339)	
	Discharge of trade effluent (R1 auxiliary cooling water) (013340)	
	Discharge of trade effluent (main cooling water) (013342)	

Table A6. Authorisations and consents for Hunterston A

Relevant legislation[a]	Description	Effective Date
Radioactive Substances Act	Disposal of gaseous radioactive waste to atmosphere	3 Aug 2000
	Disposal of liquid waste to the Firth of Clyde	3 Aug 2000
	Disposal of low level waste to Drigg	3 Aug 2000

a. Consents under the Control of Pollution Act are held by British Energy with respect to Hunterston B.

Table A7. Authorisations and consents for Littlebrook

Relevant legislation	Description	Effective Date
Radioactive Substances Act	Accumulation and disposal of radioactive waste	11 Jan 2001

Table A8. Authorisations, consents and waste disposal licences for Oldbury

Relevant legislation	Description	Effective Date
Radioactive Substances Act	Disposal of waste gases, mists and dusts to atmosphere	1 Oct 1991
	Disposal of liquid waste to the Severn estuary	1 Oct 1991
	Disposal of low level waste to Drigg Variation to above	1 Jan 1992 13 May 1996
	Disposal of low level waste to UKAEA Winfrith	1 Feb 1993
	Disposal of combustible waste by incineration on site	1 Oct 1991
	Combustible radioactive waste to Berkeley and Bradwell	1 Feb 1967
	Disposal of combustible waste by transfer to Hinkley Point B (held jointly with Berkeley)	1 Mar 1978
	Revocation of all above authorisations	18 Dec 2002
	Disposal of radioactive waste (multi-media) authorising: Disposal of gaseous waste to the environment Disposal of aqueous waste to the environment Disposal of low level waste and organic liquid by incineration on site Disposal of low level waste to Drigg	18 Dec 2002
Environmental Protection Act	Deposit of silt (lagoon no. 2) (L/NA/T/127)[a]	14 Sep 1982
	Deposit of silt (lagoon no. 3) (L/NA/T/260)[a]	8 Jan 1993
Water Resources Act (and it's predecessors)	Discharge of silt from lagoon no. 3 (011900)	11 Nov 1992
	Discharge of condenser cooling water and active effluent (021558)	26 Apr 1983
	Discharge of surface water, treated sewage effluent, etc (021559)	26 Apr 1983
	Discharge of effluent from main water treatment plant (021221)	7 Sep 1984

a. Waste disposal licence.

Table A9. Authorisations and consents for Sizewell A

Relevant legislation	Description	Effective Date
Radioactive Substances Act	Disposal of waste gases, mists and dusts to atmosphere	22 May 1994
	Disposal of liquid waste to the North Sea	22 May 1994
	Disposal of low level waste to Drigg Variation to above	1 Jan 1992 1 Apr 1997
	Disposal of oil waste to Littlebrook	11 May 1981
	Disposal of combustible wastes by incineration on site	27 Jan 1971
	Revocation of all above authorisations	18 Dec 2002
	Disposal of radioactive waste (multi-media) authorising: Disposal of gaseous waste to the environment Disposal of aqueous waste to the environment Disposal of low level waste and organic liquid by incineration on site Disposal of low level waste to Drigg Disposal of organic liquid by transfer to Sizewell B for incineration	18 Dec 2002
	District survey laboratory: Accumulation and disposal of radioactive waste	3 Nov 1991
Water Resources Act	Discharge of trade effluent/sewage effluent/cooling water/surface water and other trade effluents (PR4CS/1516A)	10 Jan 1994

Table A10. Authorisations and consents for Trawsfynydd

Relevant legislation	Description	Effective Date
Radioactive Substances Act	Disposal of waste gases, mists and dusts to atmosphere	1 Nov 1991
	Disposal of liquid waste to Trawsfynydd Lake	1 Nov 1991
	Disposal of low level waste to Drigg Variation to above	1 Jan 1992 1 Apr 1995
	Disposal of low level waste to UKAEA Winfrith	1 Feb 1993
	Disposal of low level waste to Hinkley Point B	11 Dec 1995
	Revocation of all above authorisations in name of Magnox Electric	31 Jul 2003
	Disposal of radioactive waste in name of BNFL (multi-media) authorising: Disposal of gaseous waste to the environment Disposal of aqueous waste to the environment Disposal of low level waste to Drigg Transfer of organic liquid waste to Shanks at Hythe for incineration	18 Dec 2002
Water Resources Act (and it's predecessors)	Discharge of cooling water and sewage plant effluent (CG00881-01)	1 Mar 1974
	Discharge of storm water via the Diversion Culvert (CG00877-01)	1 Mar 1974
	Discharge of sewage effluent (CG03149-01)	17 May 1991

Table A11. Authorisations and consents for Wylfa

Relevant legislation	Description	Effective Date
Radioactive Substances Act	Disposal of waste gases, mists and dusts to atmosphere	1 Aug 1992
	Disposal of liquid waste to the sea	1 Aug 1992
	Disposal of low level waste to Drigg Variation to above	1 Jan 1992 1 Apr 1995
	Disposal of low level waste to UKAEA Winfrith	1 Feb 1993
	Disposal of combustible waste by incineration on site	1 Mar 1995
	Revocation of all above authorisations	18 Dec 2002
	Disposal of radioactive waste (multi-media) authorising: Disposal of gaseous waste to the environment Disposal of aqueous waste to the environment Disposal of low level waste and organic liquid by incineration on site Disposal of low level waste to Drigg Transfer of organic liquid waste to Shanks at Hythe for incineration	18 Dec 2002
	District survey laboratory: Accumulation and disposal of radioactive waste	25 Jan 1993
Environmental Protection Act	Operation of combustion plant (gas turbines) (AF6626) Variation to above Temporary variation to the above	26 Oct 1992 25 Nov 1998 25 Oct 2000
	Incineration (AH6210)	1 Oct 1993
Water Resources Act	Discharge of trade effluent (cooling water) (CG0336501)	25 Apr 1995
	Discharge of sewage effluent (CG0336502)	25 Apr 1995
	Discharge of trade effluent (emergency cooling and site drainage) (CG0336503)	25 Apr 1995
	Discharge of trade effluent (site drainage) (CG0336504)	25 Apr 1995
	Discharge of trade effluent (site drainage) (CG0336505)	25 Apr 1995

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appendix

Values for individual dose per unit intake and collective dose per unit discharge

Individual doses

1 Radionuclides taken into the body, either by ingestion or by inhalation, cause exposure both to the local tissue and to the whole body. For the purposes of dosimetry, monitoring and control, it is the whole-body exposure which is often of prime concern. The actual exposure will depend on many factors, such as the solubility of the radionuclide and its characteristic retention time in the body.

2 The dose coefficients in tables 1 and 2 reflect the most recent advice of the International Commission on Radiological Protection (ICRP)[1]. They represent the lifetime dose to the whole body, i.e. the 'committed effective dose' (CED), which would be incurred by an individual following the intake of a unit amount of a radionuclide. Since biokinetic behaviour (and hence dose incurred) may change with age, differing values are presented depending on the age of the individual at the time of intake.

3 In determining the dose arising from ingestion of material containing radioactivity, it is necessary to consider the fraction of the radioactivity which is likely to be absorbed across the wall of the gastro-intestinal tract. Such absorption is referred to as the gut uptake factor (f_1) and varies with the physical and chemical form of the radionuclide and with the metabolism and physiology of the individual. In general, young infants absorb some molecular species more readily than older children or adults and f_1 values tend to be correspondingly larger for infants in a number of cases. However, little conclusive data exists for neonates (infants at ages below three months) and their dosimetry is not considered here. In general, more soluble elements, such as caesium or tritium, tend to be absorbed more readily than less soluble elements, such as plutonium, across all age ranges.

4 With respect to intakes of radionuclides by ingestion, a number of studies[2,3,4] have established more appropriate gut uptake values for the actinides present in winkles and other molluscs in the Sellafield area, for use in critical group studies. For winkles, these values have been endorsed by the NRPB[5] and supported by other studies[6]. These values are presented here and are used in this report to estimate doses arising from consuming winkles from the West Cumbrian coast. For seafoods other than winkles close to Sellafield, the NRPB considers that using a gut transfer factor of 0.0005 for both plutonium and americium will not lead to underestimates of critical group doses[4,7]. Additionally, recent studies by CEFAS[8] have suggested that a gut uptake factor for technetium-99 in lobster lies in the range 0.046 to 0.3 compared to the value of 0.5 recommended by the ICRP[9]. A value of 0.1 (leading to a revised dose factor of 4.5E-10 for adults)[10] is used in this report for calculating the dose to the Sellafield critical group.

5 Dose per unit intake values for the inhalation of radionuclides are derived from the most recent recommendations of ICRP[1,11]. The dose following intake of radionuclides by inhalation depends upon a number of factors in addition to the radioactive properties of the nuclide(s) involved - in particular, on the particle size of the inhaled material (which influences the extent and distribution of deposition within the respiratory tract) and the rate at which deposited material can be absorbed into body fluids within the respiratory tract, and subsequently enter general systemic circulation. A significant proportion of particulate material deposited in the respiratory tract is cleared directly via the gastro-intestinal tract in swallowed mucus, so the proportion of this swallowed material which is absorbed across the gut wall also influences the dose. Regarding particle size, ICRP recommends the calculation of doses to members of the public assuming an activity median aerodynamic diameter of 1 micron (10^{-6} m) for the inhaled material[11]. For most nuclides, this maximises the resulting dose by maximising deposition in the alveolar region of the respiratory tract.

6 ICRP has derived a standard classification for inhaled material (the 'lung absorption type') based on the rate of absorption of different chemical forms of radionuclides into body fluids. These absorption types are denoted as V, F, M and S with type V being the most rapidly absorbed and type S the slowest. For each absorption type ICRP recommends an appropriate factor (the 'f_1 value') for the fraction of swallowed material which is absorbed through the gut wall.

7 ICRP has provided calculated values for the committed effective dose to members of the public of different ages, for inhalation of airborne particles with a median diameter of 1 micron, for all the radionuclides of relevance to this report[11]. Several values are generally cited for each radionuclide, reflecting the range of absorption types which may be encountered. However, for most radionuclides, ICRP recommends a default absorption type which may be assumed in the absence of specific information about absorption behaviour; in most cases the dose per unit intake values corresponding to those default absorption types are used in the dose assessments in this report. For some radionuclides, ICRP does not specify a default absorption type and in these instances the absorption type producing the highest value of dose per unit intake is assumed for dose assessments. Finally, for some discharges of uranium to atmosphere from Company sites, specific information on chemical composition and lung absorption type is available. In these instances, the dose per unit intake corresponding to the actual lung absorption type is used for dose assessment.

8 BNFL are currently considering the advice in ICRP Publication 88[12], which provides dose coefficients for the embryo and foetus after intakes of radionuclides by the mother, but does not advise on dose limitation or dose constraints for the embryo[13]. The NRPB has recently published a draft consultation document on the calculation and interpretation of foetal doses and the Company is

(Continued on page 140)

Table 1. Committed effective doses per unit intake for ingestion

Radionuclide	f_1[a]	Dose per unit intake (Sv Bq^{-1})		
		1y	10y	Adult
H-3 oxide	1E+00	4.8E-11	2.3E-11	1.8E-11
H-3 organic	1E+00	1.2E-10	5.7E-11	4.2E-11
C-14	1E+00	1.6E-09	8.0E-10	5.8E-10
S-35	1E+00	8.7E-10	2.7E-10	1.3E-10
S-35 organic	1E+00	5.4E-09	1.6E-09	7.7E-10
Mn-54	1E-01	3.1E-09	1.3E-09	7.1E-10
Fe-55	1E-01	2.4E-09	1.1E-09	3.3E-10
Co-60	1E-01	2.7E-08	1.1E-08	3.4E-09
Ni-63	5E-02	8.4E-10	2.8E-10	1.5E-10
Zn-65	5E-01	1.6E-08	6.4E-09	3.9E-09
Sr-89	3E-01	1.8E-08	5.8E-09	2.6E-09
Sr-90	3E-01	7.3E-08	6.0E-08	2.8E-08
Zr-95	1E-02	5.6E-09	1.9E-09	9.5E-10
Nb-95	1E-02	3.2E-09	1.1E-09	5.8E-10
Tc-99	5E-01	4.8E-09	1.3E-09	6.4E-10
Ru-103	5E-02	4.6E-09	1.5E-09	7.3E-10
Ru-106	5E-02	4.9E-08	1.5E-08	7.0E-09
Ag-110m	5E-02	1.4E-08	5.2E-09	2.8E-09
Sb-125	1E-01	6.1E-09	2.1E-09	1.1E-09
I-129	1E+00	2.2E-07	1.9E-07	1.1E-07
I-131	1E+00	1.8E-07	5.2E-08	2.2E-08
Cs-134	1E+00	1.6E-08	1.4E-08	1.9E-08
Cs-137	1E+00	1.2E-08	1.0E-08	1.3E-08
Ce-144	5E-04	3.9E-08	1.1E-08	5.2E-09
Pm-147	5E-04	1.9E-09	5.7E-10	2.6E-10
Eu-152	5E-04	7.4E-09	2.6E-09	1.4E-09
Eu-154	5E-04	1.2E-08	4.1E-09	2.0E-09
Eu-155	5E-04	2.2E-09	6.8E-10	3.2E-10
Ra-226	2E-01	9.6E-07	8.0E-07	2.8E-07
Th-228	5E-04	3.7E-07	1.5E-07	7.2E-08
Th-230	5E-04	4.1E-07	2.4E-07	2.1E-07
Th-232	5E-04	4.5E-07	2.9E-07	2.3E-07
Th-234	5E-04	2.5E-08	7.4E-09	3.4E-09
U-234	2E-02	1.3E-07	7.4E-08	4.9E-08
U-235	2E-02	1.3E-07	7.1E-08	4.7E-08
U-238	2E-02	1.2E-07	6.8E-08	4.5E-08
Np-237	5E-04	2.1E-07	1.1E-07	1.1E-07
Pu-238	5E-04	4.0E-07	2.4E-07	2.3E-07
Pu-239	5E-04	4.2E-07	2.7E-07	2.5E-07
Pu-240	5E-04	4.2E-07	2.7E-07	2.5E-07
Pu-241	5E-04	5.7E-09	5.1E-09	4.8E-09
Am-241	5E-04	3.7E-07	2.2E-07	2.0E-07
Cm-242	5E-04	7.6E-08	2.4E-08	1.2E-08
Cm-243	5E-04	3.3E-07	1.6E-07	1.5E-07
Cm-244	5E-04	2.9E-07	1.4E-07	1.2E-07
Plutonium and americium values for application to the consumption of Cumbrian winkles:				
Pu-238	2E-04	1.6E-07	1.0E-07	9.2E-08
Pu-239	2E-04	1.7E-07	1.1E-07	1.0E-07
Pu-240	2E-04	1.7E-07	1.1E-07	1.0E-07
Pu-241	2E-04	2.3E-09	2.0E-09	1.9E-09
Am-241	2E-04	1.5E-07	8.8E-08	8.4E-08
Technetium values for application to the consumption of Cumbrian lobsters:				
Tc-99	1E-01	-	-	4.5E-10

a. The gastro-intestinal absorption fraction does not apply to neonates or infants aged below about one year.

Table 2. Committed effective doses per unit intake by inhalation

Radionuclide	Lung absorption type	f_1[a]	Dose per unit intake, Sv Bq^{-1}			Basis for choice of lung absorption type
			1y	10y	Adult	
H-3 oxide	V	1E+00	4.8E-11	2.3E-11	1.8E-11	Water vapour
H-3 organic	V	1E+00	1.1E-10	5.5E-11	4.1E-11	Organically bound tritium
C-14	M	1E-01	6.6E-09	2.8E-09	2.0E-09	ICRP recommended default
S-35	M	1E-01	4.5E-09	2.0E-09	1.4E-09	ICRP recommended default
S-35 (as SO_2)	F	8E-01	6.6E-10	2.1E-10	1.1E-10	ICRP recommended default
Mn-54	M	1E-01	6.2E-09	2.4E-09	1.5E-09	ICRP recommended default
Co-60	M	1E-01	3.4E-08	1.5E-08	1.0E-08	ICRP recommended default
Ni-63	M	5E-02	1.9E-09	7.0E-10	4.8E-10	ICRP recommended default
Zn-65	M	1E-01	6.5E-09	2.4E-09	1.6E-09	ICRP recommended default
Sr-89	M	1E-01	2.4E-08	9.1E-09	6.1E-09	ICRP recommended default
Sr-90	M	1E-01	1.1E-07	5.1E-08	3.6E-08	ICRP recommended default
Zr-95	M	2E-03	1.6E-08	6.8E-09	4.8E-09	ICRP recommended default
Nb-95	M	1E-02	5.2E-09	2.2E-09	1.5E-09	ICRP recommended default
Tc-99	M	1E-01	1.3E-08	5.7E-09	4.0E-09	ICRP recommended default
Ru-103	M	5E-02	8.4E-09	3.5E-09	2.4E-09	ICRP recommended default
Ru-106	M	5E-02	1.1E-07	4.1E-08	2.8E-08	ICRP recommended default
Ag-110 m	M	5E-02	2.8E-08	1.2E-08	7.6E-09	ICRP recommended default
Sb-125	M	1E-02	1.6E-08	6.8E-08	4.8E-08	ICRP recommended default
I-129	F	1E+00	8.6E-08	6.7E-08	3.6E-08	ICRP recommended default
I-131	F	1E+00	7.2E-08	1.9E-08	7.4E-09	ICRP recommended default
Cs-134	F	1E+00	7.3E-09	5.3E-09	6.6E-09	ICRP recommended default
Cs-137	F	1E+00	5.4E-09	3.7E-09	4.6E-09	ICRP recommended default
Ce-144	M	5E-04	1.6E-07	5.5E-08	3.6E-08	ICRP recommended default
Pm-147	M	5E-04	1.8E-08	7.0E-09	5.0E-09	Most restrictive[b]
Eu-152	M	5E-04	1.0E-07	4.9E-08	4.2E-08	Most restrictive[b]
Eu-154	M	5E-04	1.5E-07	6.5E-08	5.3E-08	Most restrictive[b]
Eu-155	M	5E-04	2.3E-08	9.2E-09	6.9E-09	Most restrictive[b]
Ra-226	M	1E-01	1.1E-05	4.9E-06	3.5E-06	ICRP recommended default
Th-228	S	5E-04	1.3E-04	5.5E-05	4.0E-05	ICRP recommended default
Th-230	F	5E-04	2.0E-04	1.1E-04	1.0E-04	Depends on source[c]
Th-230	S	5E-04	3.5E-05	1.6E-05	1.4E-05	ICRP recommended default
Th-232	F	5E-04	2.2E-04	1.3E-04	1.1E-04	Depends on source[c]
Th-232	S	5E-04	5.0E-05	2.6E-05	2.5E-05	ICRP recommended default
U-234	S	2E-03	2.9E-05	1.2E-05	9.4E-06	Depends on source[c]
U-234	M	2E-02	1.1E-05	4.8E-06	3.5E-06	ICRP recommended default
U-235	S	2E-03	2.6E-05	1.1E-05	8.5E-06	Depends on source[c]
U-235	M	2E-02	1.0E-05	4.3E-06	3.1E-06	ICRP recommended default
U-235	F	2E-02	1.3E-06	7.5E-07	5.2E-07	Depends on source[c]
U-236	S	2E-03	2.7E-05	1.1E-05	8.7E-06	Depends on source[c]
U-236	M	2E-02	1.0E-05	4.5E-06	3.2E-06	ICRP recommended default
U-236	F	2E-02	1.3E-06	7.5E-07	5.3E-07	Depends on source[c]
U-238	S	2E-03	2.5E-05	1.0E-05	8.0E-06	Depends on source[c]
U-238	M	2E-02	9.4E-06	4.0E-06	2.9E-06	ICRP recommended default
U-238	F	2E-02	1.3E-06	7.3E-07	5.0E-07	Depends on source[c]
Np-237	M	5E-04	4.0E-05	2.2E-05	2.3E-05	ICRP recommended default
Np-239	M	5E-04	4.2E-09	1.4E-09	9.3E-10	ICRP recommended default
Pu-238	M	5E-04	7.4E-05	4.4E-05	4.6E-05	ICRP recommended default
Pu-239	M	5E-04	7.7E-05	4.8E-05	5.0E-05	ICRP recommended default
Pu-240	M	5E-04	7.7E-05	4.8E-05	5.0E-05	ICRP recommended default
Pu-241	M	5E-04	9.7E-07	8.3E-07	9.0E-07	ICRP recommended default
Am-241	M	5E-04	6.9E-05	4.0E-05	4.2E-05	ICRP recommended default
Cm-242	M	5E-04	1.8E-05	7.3E-06	5.2E-06	ICRP recommended default
Cm-243	M	5E-04	6.1E-05	3.1E-05	3.1E-05	ICRP recommended default
Cm-244	M	5E-04	5.7E-05	2.7E-05	2.7E-05	ICRP recommended default

a. The gastro-intestinal absorption fraction does not apply to neonates or infants aged below about one year.
b. No default inhalation class recommended - most restrictive value cited by ICRP used.
c. Value used where site specific information about source characteristics is available.

Table 3. Collective dose commitment from BNFL sites (man Sv per Bq discharged, integrated to 500 years): atmospheric discharges

Radionuclide	Sellafield			Drigg			Capenhurst[b]			Springfields[b]		
	UK	EU[a]	World	UK	EU[a]	World	UK	EU[a]	World	UK	EU[a]	World
H-3	6.9E-16	1.6E-15	1.9E-15	1.4E-15	3.0E-15	3.3E-15	2.4E-15	3.7E-15	4.0E-15			
C-14	2.2E-13	2.0E-12	1.8E-11	3.4E-13	2.6E-12	1.9E-11						
S-35	2.8E-13	8.4E-13	8.4E-13									
Ar-41	7.7E-17	7.7E-17	7.7E-17									
Co-60	4.8E-12	7.1E-12	7.1E-12									
Kr-85	5.0E-18	2.7E-17	2.8E-16									
Sr-90	2.1E-12	1.0E-11	1.0E-11									
Zr-95	1.7E-13	2.4E-13	2.4E-13									
Nb-95	4.8E-14	6.9E-14	6.9E-14									
Ru-106	2.8E-13	4.2E-13	4.2E-13									
Sb-125	5.6E-13	7.9E-13	7.9E-13									
I-129	4.4E-11	2.1E-10	3.0E-10									
I-131	8.7E-13	8.7E-13	8.7E-13									
Cs-134	3.0E-12	8.8E-12	8.8E-12									
Cs-137	4.1E-12	9.7E-12	9.7E-12									
Ce-144	1.3E-13	2.2E-13	2.2E-13									
U-234							1.3E-10	1.5E-10	1.5E-10	4.0E-11	5.6E-11	5.6E-11
U-235							1.2E-10	1.4E-10	1.4E-10	3.9E-11	5.5E-11	5.5E-11
U-238							1.1E-10	1.3E-10	1.3E-10	3.4E-11	4.9E-11	4.9E-11
Pu-239 } Pu-240	1.5E-10	2.4E-10	2.4E-10									
Pu-241	2.6E-12	4.3E-12	4.3E-12									
Am-241	1.2E-10	2.0E-10	2.0E-10									

a. EU is defined as the population of the member states of the European Union, including the UK.
b. Data reflects actual chemical compounds discharged by Capenhurst and Springfields.

Table 4. Collective dose commitment from BNFL sites (man Sv per Bq discharged, integrated to 500 years): liquid discharges[a]

Radionuclide	Sellafield			Drigg			Capenhurst			Springfields		
	UK	EU[b]	World	UK	EU[b]	World	UK	EU[b]	World	UK	EU[b]	World
H-3	5.0E-19	2.2E-18	4.4E-17	5.0E-19	2.2E-18	4.4E-17	5.2E-19	2.2E-18	4.4E-17			
C-14	2.4E-13	8.9E-13	1.2E-11									
S-35	3.8E-18	7.4E-18	7.5E-18									
Mn-54	1.3E-15	1.3E-15	1.3E-15									
Fe-55	2.1E-15	3.6E-15	3.6E-15									
Co-60	1.5E-14	1.6E-14	1.6E-14	1.5E-14	1.6E-14	1.6E-14						
Ni-63	9.9E-17	1.9E-16	2.0E-16									
Zn-65	1.1E-13	1.7E-13	1.7E-13									
Sr-89	6.7E-18	1.3E-17	1.3E-17									
Sr-90	7.7E-16	2.0E-15	2.2E-15	7.7E-16	2.0E-15	2.2E-15						
Zr-95	5.3E-16	5.4E-16	5.4E-16									
Nb-95	1.4E-16	1.4E-16	1.4E-16									
Tc-99	1.9E-15	5.0E-15	5.3E-15				2.5E-15	6.1E-15	6.5E-15	4.3E-15	7.9E-15	8.3E-15
Ru-103	3.8E-16	5.7E-16	5.7E-16									
Ru-106	1.0E-14	2.0E-14	2.0E-14	1.0E-14	2.0E-14	2.0E-14						
Ag-110m	3.4E-14	6.2E-14	6.3E-14	3.4E-14	6.2E-14	6.3E-14						
Sb-125	1.0E-14	2.5E-14	2.7E-14									
I-129	2.2E-14	7.0E-14	2.9E-13									
Cs-134	1.3E-14	3.0E-14	3.2E-14									
Cs-137	1.5E-14	3.7E-14	4.2E-14	1.5E-14	3.7E-14	4.2E-14						
Ce-144	2.1E-16	2.4E-16	2.4E-16									
Pm-147	8.2E-18	1.0E-17	1.0E-17									
Eu-152	9.6E-15	9.7E-15	9.7E-15									
Eu-154	8.9E-15	9.0E-15	9.0E-15									
Eu-155	3.7E-16	3.8E-16	3.8E-16									
Th-228	5.5E-15	5.9E-15	5.9E-15							5.4E-15	6.3E-15	6.3E-15
Th-230	5.3E-15	9.6E-15	1.1E-14				6.6E-15	1.5E-14	1.6E-14	7.8E-15	1.6E-14	1.7E-14
Th-232	3.4E-13	8.1E-13	8.8E-13							5.5E-13	1.3E-12	1.4E-12
Th-234	2.9E-16	3.0E-16	3.0E-16	2.9E-16	3.0E-16	3.0E-16	1.6E-16	1.9E-16	1.9E-16	2.4E-16	2.6E-16	2.7E-16
U-234	2.8E-15	7.9E-15	8.9E-15	2.8E-15	7.7E-15	8.4E-15	3.5E-15	9.2E-15	1.0E-14	5.5E-15	1.1E-14	1.2E-14
U-235	2.9E-15	7.7E-15	8.6E-15				3.6E-15	9.0E-15	9.9E-15	5.6E-15	1.1E-14	1.2E-14
U-238	2.6E-15	7.1E-15	7.8E-15	2.6E-15	7.1E-15	7.8E-15	3.2E-15	8.3E-15	8.9E-15	5.1E-15	1.0E-14	1.1E-14
Np-237	5.6E-14	1.5E-13	1.6E-13				6.5E-14	1.6E-13	1.7E-13	9.6E-14	1.9E-13	2.0E-13
Pu-238	7.6E-14	1.2E-13	1.2E-13	7.7E-14	1.2E-13	1.2E-13						
Pu-239 + Pu-240	8.6E-14	1.4E-13	1.5E-13	8.6E-14	1.4E-13	1.5E-13						
Pu-241	1.6E-15	2.6E-15	2.6E-15	1.6E-15	2.6E-15	2.6E-15						
Am-241	2.1E-14	2.6E-14	2.6E-14	2.1E-14	2.6E-14	2.6E-14						
Cm-242	1.6E-15	1.9E-15	1.9E-15									
Cm-243 + Cm-244	2.3E-14	2.8E-14	2.8E-14									

a. The collective dose factors include the contribution from the first decay product where appropriate. *b. EU is defined as the population of the member states of the European Union, including the UK.*

Table 5. Collective dose commitment from BNFL Magnox stations (man Sv per Bq discharged, integrated to 500 years): atmospheric discharges

Radionuclide	Chapelcross			Wylfa			Oldbury			Dungeness A			Bradwell		
	UK	EU[a]	World	UK	EU[a]	World	UK	EU[a]	World	UK	EU[a]	World	UK	EU[a]	World
H-3	1.0E-15	2.2E-15	2.5E-15	9.9E-16	2.4E-15	2.7E-15	1.7E-15	3.2E-15	3.5E-15	9.2E-16	3.4E-15	3.7E-15	1.3E-15	3.7E-15	4.0E-15
C-14	2.8E-13	2.3E-12	1.8E-11	2.8E-13	2.4E-12	1.8E-11	4.0E-13	2.7E-12	1.9E-11	3.1E-13	3.0E-12	1.9E-11	4.5E-13	3.1E-12	1.9E-11
S-35	4.4E-13	1.2E-12	1.2E-12	2.6E-13	8.0E-13	8.0E-13	6.3E-13	1.9E-12	1.9E-12	1.6E-13	8.7E-13	8.7E-13	2.0E-13	8.6E-13	8.6E-13
Ar-41	8.2E-17	9.3E-17	9.3E-17	5.2E-17	5.2E-17	5.2E-17	3.0E-16	3.4E-16	3.4E-16	1.1E-16	1.2E-16	1.2E-16	2.8E-16	3.0E-16	3.0E-16
Co-60	-	-	-	4.4E-12	7.3E-12	7.3E-12	1.2E-11	1.6E-11	1.6E-11	7.1E-12	1.4E-11	1.4E-11	1.2E-11	1.8E-11	1.8E-11

Radionuclide	Sizewell A			Hinkley Point A			Berkeley			Hunterston A			Trawsfynydd		
	UK	EU[a]	World	UK	EU[a]	World	UK	EU[a]	World	UK	EU[a]	World	UK	EU[a]	World
H-3	1.0E-15	3.4E-15	3.7E-15	1.5E-15	3.0E-15	3.3E-15	1.8E-15	3.4E-15	3.7E-15	8.3E-16	2.1E-15	2.4E-15	9.9E-16	2.4E-15	2.7E-15
C-14	3.8E-13	2.9E-12	1.9E-11	3.7E-13	2.7E-12	1.9E-11	4.3E-13	2.9E-12	1.9E-11	2.4E-13	2.2E-12	1.8E-11	2.8E-13	2.4E-12	1.8E-11
S-35	1.6E-13	8.2E-13	8.2E-13	5.6E-13	1.7E-12	1.7E-12	6.6E-13	2.0E-12	2.0E-12	2.5E-13	7.7E-13	7.7E-13	2.6E-13	8.0E-13	8.0E-13
Ar-41	9.5E-17	1.1E-16	1.1E-16	1.7E-16	1.8E-16	1.8E-16	3.1E-16	3.5E-16	3.5E-16	1.6E-16	1.8E-16	1.8E-16	5.2E-17	5.2E-17	5.2E-17
Co-60	6.0E-12	1.2E-11	1.2E-11	8.2E-12	1.2E-11	1.2E-11	1.2E-11	1.7E-11	1.7E-11	5.8E-12	8.6E-12	8.6E-12	4.4E-12	7.3E-12	7.3E-12

a. EU is defined as the population of the member states of the European Union including the UK.

Table 6. Collective dose commitment from BNFL Magnox stations (man Sv per Bq discharged, integrated to 500 years): liquid discharges[a]

Radionuclide	Chapelcross			Wylfa			Oldbury			Dungeness A			Bradwell		
	UK	EU[b]	World	UK	EU[b]	World	UK	EU[b]	World	UK	EU[b]	World	UK	EU[b]	World
H-3	5.0E-19	2.1E-18	4.4E-17	4.7E-19	2.1E-18	4.4E-17	2.9E-19	1.7E-18	4.3E-17	3.3E-19	2.0E-18	4.4E-17	5.1E-19	2.3E-18	4.4E-17
S-35	4.0E-18	7.5E-18	7.7E-18	3.3E-18	6.2E-18	6.4E-18	3.2E-18	6.6E-18	6.6E-18	1.7E-18	1.3E-17	1.3E-17	2.2E-17	3.4E-17	3.4E-17
Co-60	1.5E-14	1.6E-14	1.6E-14	1.0E-14	1.5E-14	1.5E-14	5.7E-15	2.3E-14	2.3E-14	8.4E-15	6.7E-14	6.8E-14	1.9E-14	7.1E-14	7.3E-14
Zn-65	1.2E-13	2.0E-13	2.0E-13	9.6E-14	1.6E-13	1.6E-13	4.0E-14	8.1E-14	8.1E-14	4.0E-14	4.1E-13	4.1E-13	2.9E-13	5.9E-13	6.0E-13
Sr-90	7.7E-16	2.0E-15	2.2E-15	7.3E-16	1.9E-15	2.2E-15	1.3E-16	5.6E-16	6.1E-16	2.8E-16	1.6E-15	1.8E-15	6.1E-16	2.4E-15	2.8E-15
Ru-106	1.0E-14	2.0E-14	2.0E-14	5.7E-15	1.1E-14	1.1E-14	1.2E-14	1.4E-14	1.4E-14	2.9E-15	3.5E-14	3.5E-14	9.9E-14	1.3E-13	1.3E-13
Sb-125	1.0E-14	2.5E-14	2.7E-14	9.5E-15	2.4E-14	2.7E-14	1.4E-15	6.3E-15	6.4E-15	3.6E-15	1.9E-14	2.1E-14	7.1E-15	2.9E-14	3.1E-14
Cs-134	1.3E-14	3.1E-14	3.3E-14	1.4E-14	3.3E-14	3.5E-14	2.7E-15	1.3E-14	1.3E-14	6.2E-15	3.5E-14	3.7E-14	1.1E-14	4.9E-14	5.2E-14
Cs-137	1.5E-14	3.7E-14	4.3E-14	1.5E-14	3.9E-14	4.5E-14	2.5E-15	1.2E-14	1.3E-14	6.3E-15	3.4E-14	3.9E-14	1.1E-14	4.9E-14	5.8E-14
Ce-144	2.3E-16	2.9E-16	2.9E-16	2.4E-16	3.5E-16	3.5E-16	5.4E-16	1.5E-15	1.5E-15	5.1E-16	4.9E-15	5.0E-15	2.0E-15	5.3E-15	5.4E-15
Pm-147	1.2E-17	1.7E-17	1.8E-17	3.3E-17	6.6E-17	6.9E-17	6.0E-17	2.8E-16	2.8E-16	6.6E-17	5.6E-16	5.7E-16	1.6E-16	5.4E-16	5.7E-16
Eu-154	8.8E-15	9.0E-15	9.0E-15	5.4E-15	6.3E-15	6.4E-15	2.4E-15	6.0E-15	6.1E-15	2.1E-15	1.7E-14	1.7E-14	6.3E-15	1.8E-14	1.9E-14
Pu-238	1.0E-13	1.9E-13	1.9E-13	1.3E-13	3.4E-13	3.5E-13	1.2E-13	4.5E-13	4.8E-13	1.6E-13	1.9E-12	1.9E-12	8.4E-13	2.3E-12	2.4E-12
Pu-239 + Pu-240	1.2E-13	2.3E-13	2.3E-13	1.5E-13	4.4E-13	4.7E-13	1.5E-13	8.4E-13	9.2E-13	1.9E-13	2.2E-12	2.3E-12	9.6E-13	2.8E-12	2.9E-12
Pu-241	2.1E-15	4.0E-15	4.1E-15	2.7E-15	7.8E-15	8.1E-15	2.8E-15	1.6E-14	1.7E-14	3.5E-15	4.3E-14	4.4E-14	1.8E-14	5.3E-14	5.5E-14
Am-241	2.9E-14	4.3E-14	4.3E-14	4.4E-14	1.1E-13	1.1E-13	1.5E-13	7.1E-13	7.4E-13	1.3E-13	1.6E-12	1.7E-12	4.9E-13	1.5E-12	1.5E-12

Radionuclide	Sizewell A			Hinkley Point A			Berkeley			Hunterston A			Trawsfynydd		
	UK	EU[b]	World	UK	EU[b]	World	UK	EU[b]	World	UK	EU[b]	World	UK	EU[b]	World
H-3	4.2E-19	2.2E-18	4.4E-17	2.7E-19	1.7E-18	4.3E-17	2.9E-19	1.7E-18	4.3E-17	4.4E-19	2.0E-18	4.4E-17	4.7E-19	2.1E-18	4.4E-17
S-35	1.1E-17	2.3E-17	2.3E-17	1.2E-18	4.5E-18	4.6E-18	3.2E-18	6.6E-18	6.6E-18	3.7E-18	7.2E-18	7.8E-18	-	-	-
Co-60	1.9E-14	7.1E-14	7.3E-14	5.2E-15	2.3E-14	2.3E-14	5.7E-15	2.3E-14	2.3E-14	5.7E-15	1.2E-14	1.3E-14	1.0E-14	1.5E-14	1.5E-14
Zn-65	2.5E-13	5.5E-13	5.6E-13	1.7E-14	5.9E-14	5.9E-14	4.0E-14	8.1E-14	8.1E-14	6.0E-14	9.7E-14	1.0E-13	9.6E-14	1.6E-13	1.6E-13
Sr-90	4.9E-16	2.2E-15	2.7E-15	1.0E-16	5.4E-16	5.8E-16	1.3E-16	5.6E-16	6.1E-16	6.5E-16	1.7E-15	2.2E-15	7.3E-16	1.9E-15	2.2E-15
Ru-106	4.7E-14	7.6E-14	7.6E-14	2.5E-15	5.1E-15	5.1E-15	1.2E-14	1.4E-14	1.4E-14	1.4E-15	2.8E-15	2.9E-15	5.7E-15	1.1E-14	1.1E-14
Sb-125	6.0E-15	2.7E-14	3.0E-14	1.2E-15	6.1E-15	6.2E-15	1.4E-15	6.3E-15	6.4E-15	8.2E-15	2.1E-14	2.4E-14	9.5E-15	2.4E-14	2.7E-14
Cs-134	9.9E-15	4.8E-14	5.1E-14	2.4E-15	1.3E-14	1.3E-14	2.7E-15	1.3E-14	1.3E-14	1.5E-14	3.5E-14	3.9E-14	1.4E-14	3.3E-14	3.5E-14
Cs-137	9.7E-15	4.8E-14	5.7E-14	2.3E-15	1.2E-14	1.3E-14	2.5E-15	1.2E-14	1.3E-14	1.5E-14	3.9E-14	4.9E-14	1.5E-14	3.9E-14	4.5E-14
Ce-144	2.0E-15	5.4E-15	5.4E-15	4.9E-16	1.5E-15	1.5E-15	5.4E-16	1.5E-15	1.5E-15	1.3E-16	2.1E-16	2.2E-16	2.4E-16	3.5E-16	3.5E-16
Pm-147	1.6E-16	5.4E-16	5.7E-16	5.8E-17	2.8E-16	2.8E-16	6.0E-17	2.8E-16	2.8E-16	3.4E-16	7,.3E-16	8.1E-16	3.3E-17	6.6E-17	6.9E-17
Eu-154	6.2E-15	1.8E-14	1.9E-14	2.1E-15	5.8E-15	5.9E-15	2.4E-15	6.0E-15	6.1E-15	2.0E-15	3.7E-15	4.2E-15	5.4E-15	6.3E-15	6.4E-15
Pu-238	8.1E-13	2.3E-12	2.4E-12	9.3E-14	4.3E-13	4.5E-13	1.2E-13	4.5E-13	4.8E-13	1.5E-13	4.5E-13	5.2E-13	1.3E-13	3.4E-13	3.5E-13
Pu-239 + Pu-240	9.2E-13	2.8E-12	2.9E-12	1.3E-13	8.1E-13	9.0E-13	1.5E-13	8.4E-13	9.2E-13	1.9E-13	7.2E-13	8.6E-13	1.5E-13	4.4E-13	4.7E-13
Pu-241	1.7E-14	5.2E-14	5.4E-14	2.3E-15	1.6E-14	1.6E-14	2.8E-15	1.6E-14	1.7E-14	3.3E-15	1.3E-14	1.6E-14	2.7E-15	7.8E-15	8.1E-15
Am-241	4.8E-13	1.5E-12	1.5E-12	1.5E-13	7.0E-13	7.2E-13	1.5E-13	7.1E-13	7.4E-13	9.5E-14	3.5E-13	4.0E-13	4.4E-14	1.1E-13	1.1E-13

a. The collective dose factors include the contribution from the first decay product where appropriate.
b. EU is defined as the population of the member states of the European Union including the UK.

considering this guidance with a view to calculating foetal doses during the next year.

9 Only radionuclides which are known to be present in BNFL discharges, and are listed in the discharge authorisations, are included here. In two specific cases, argon-41 and krypton-85, which are present in aerial discharges, no dose per unit intake value is presented since exposure for these nuclides is determined by external rather than internal dosimetry.

Collective doses

10 The collective committed effective dose estimates resulting from discharges from the BNFL sites covered in this annual report have been calculated using the 1998 upgrade of the NRPB model PC CREAM [14], which is based on a methodology for assessing the radiological consequences of routine releases to the environment published by the European Commission [15]. The NRPB has recently recommended [16] that the calculation of marine collective dose coefficients using PC CREAM should be amended to include the contributions of daughter radionuclides, and this recommendation has been followed in this report. The collective dose coefficients have been recalculated for all relevant radionuclides in the liquid discharges. The effects of these recalculations on collective doses are nearly all negligible. The only significantly increased collective doses arise at Springfields from the Ra-228 daughter of Th-232 which results in an increase of approximately 25% in the very small total collective dose from liquid discharges; and a small increase (< 10%) in the collective dose from Sellafield arising from the Te-125m daughter of Sb125.

11 Generally, the PC CREAM default dose per unit intake values have been applied. Where required, the pulmonary retention classes for nuclides have been modified on a site-specific basis. For example, site-specific ratios of the chemical forms of uranium in aerial discharges from the Springfields and Capenhurst sites have been used to identify the most appropriate pulmonary retention half times. The dose per unit discharge factors have been derived accordingly.

12 The collective effective dose has units of man-sieverts (man Sv) and can be defined as the sum of all the exposures from a given source to a defined group of people.

13 For this report, the collective committed dose follows the current NRPB advice [17,18] of a 500 year integration period and the doses are calculated to the populations of the UK, Europe and the world. Europe is defined as the population of the member states of the European Union, including the UK.

14 The values presented in tables 3 and 4 for Sellafield, Drigg, Capenhurst and Springfields, and in tables 5 and 6 for Magnox stations, are site specific and are given as man sieverts per becquerel discharged. In general, only radionuclides which are known to be present in BNFL discharges, and are listed in the discharge authorisations, are included here. No atmospheric discharges are detectable at Drigg and the collective dose factors in table 3 have been included for hypothetical purposes only.

15 PC CREAM currently does not include facilities to model liquid discharges to a lake. Collective dose factors for liquid discharges from Trawsfynydd have been derived assuming that discharges occur directly to the sea. This approach is justified on the basis that radioactivity in the lake affects only a small number of individuals and most of the radionuclides concerned can be expected to reach the sea relatively quickly in comparison with the 500 year integration time.

Acknowledgements

This appendix was written, and its tables compiled, by members of the Environmental Assessments Group of Westlakes Scientific Consulting.

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glossary

Glossary of terms and abbreviations

Absorbed radiation dose Quantity of energy imparted by ionising radiation to unit mass of matter such as tissue. The unit is the Gray (Gy). 1 Gy = I joule per kilogram.

Activation products Radionuclides produced by the interaction of neutrons with stable nuclides.

Activity See ***radioactivity***

Alpha activity Radionuclides that decay by emitting an alpha particle. The latter consists of two protons and two neutrons.

ALARA (As Low as Reasonably Achievable) Radiological doses from a source of exposure are ALARA when they are consistent with the relevant dose or target standard and have been reduced to a level that represents a balance between radiological and other factors, including social and economic factors. The level of protection may then be said to be optimised.

Authorisation Permission given by regulatory authority under the ***Radioactive Substances Act*** or ***Environmental Protection Act*** to dispose of respectively ***radioactive*** and non-radioactive waste, subject to conditions.

Basic Safety Standards Directive (BSS) European Community Directive 80/836/Euratom, Basic Safety Standards for the Health Protection of the General public and Workers against the Dangers of Ionising Radiation. These standards were adopted as European Law in 1980. A revised Directive 96/29/Euratom was adopted in May 1996 for implementation in Member States by May 2000. The Radioactive Substances (Basic Safety Standards) Direction 2000 is the means by which the BSS Directive has been implemented in England and Wales, and in Scotland, with respect to the ***Radioactive Substances Act 1993***. Other provisions of the BSS Directive were implemented through the ***Ionising Radiation Regulations 1999***.

Becquerel The SI unit of ***radioactivity*** equal to one transformation per second.

BATNEEC (Best Available Technique Not Entailing Excessive Costs) The best available technique (BAT) is the most effective process in preventing, minimising or rendering harmless polluting emissions taking into account availability and whether the costs are not out of proportion to the benefit. (See ***IPC***.)

BPEO (Best Practicable Environmental Option) A concept developed by the Royal commission on Environmental Pollution. It implies that decisions on waste management have been based on an assessment of alternative options evaluated on the basis of factors such as the occupational and environmental impacts, the costs and social implications. (See ***IPC***.)

BPM (Best Practicable Means) Within a particular waste management option, the BPM is that level of management and engineering control that minimises as far as practicable, the release of radioactivity to the environment whilst taking account of a wider range of factors including cost-effectiveness, technological status, operational safety, and social and environmental factors.

Beta activity Radionuclides that decay by emitting a beta particle as an electron.

CEFAS The Centre for Environment, Fisheries and Aquaculture Science is a scientific research and advisory centre for fisheries management and environmental protection. It is an Agency of the UK Government's ***Department for Environment, Food and Rural Affairs (defra)***. It was formed in 1997 from the Fisheries Research Laboratory of MAFF and its Lowestoft laboratory carries out habit surveys and monitoring of radioactivity in the environment on behalf of the ***Food Standards Agency***.

Collective dose See ***dose***.

Committed effective dose See ***dose***.

Consent Discharges to controlled waters of sewage or trade effluent, from processes not subject to Environmental Protection Act authorisations, are regulated through consents under the Water Resources Act (1991) or the Water Industries Act 1991 (in England and Wales) and Control of Pollution Act 1974 or Sewerage Scotland Act 1968 (in Scotland).

Critical group A group of members of the public whose radiation exposure is reasonably homogeneous and is typical of the people receiving the highest ***dose*** from a radiation source. The critical group dose is calculated as the mean effective dose to members of the group.

defra (Department for Environment, Food and Rural Affairs) Formed in 2001 from ***MAFF*** and the environmental section of the Department of Environment, Transport and the Regions (DETR). It is the sponsoring department for the EA, and is responsible *inter alia* for environmental policy in England, including that for the management and disposal of radioactive wastes.

Direct radiation Term used to refer to radiation direct from a nuclear site as distinct from the radiation emitted from discharged radioactive wastes.

Dose A measure of radiation received. Various forms of dose are commonly referred to and are defined below. In this document it is used primarily to mean the 'effective dose' received by members of critical groups.

- **Absorbed dose** The mean energy imparted by ionising radiation to matter in a given volume divided by the mass of the matter. Normally used in the context of the dose averaged over an organ or tissue. The unit is the Gray (Gy) (see inside front cover).
- **Equivalent dose** The ***absorbed dose*** in a tissue or organ weighted by the radiation weighting factor (e.g. alpha particles = 20, beta particles = 1, gamma rays = 1) which allows for the different effectiveness of various types of ionising radiations in causing harm to tissues. The unit is the Sievert (Sv) (see inside front cover).
- **Effective dose** The sum of the ***equivalent doses*** in all tissues and organs of the body from internal and external radiation multiplied by the tissue weighting factor (e.g. skin = 0.01, thyroid = 0.05, red bone marrow = 0.12, gonads = 0.20). It allows the various equivalent doses in the body to be represented by a single number giving a broad indication of the detriment to the health of an individual from exposure to ionising radiation, regardless of the energy and type of radiation. For comparison with dose limits, the term takes on a specific meaning (see below).
- **Committed effective dose** The time integral of the ***effective dose*** from ingested and inhaled radioactivity delivered over 50 years (adults, who are cautiously assumed to be 20 years old at the time of intake) or to age 70 years (children). It is a function of biokinetic behaviour and radioactive ***half-lives***. For radionuclides with short effective ***half-lives*** in the body (e.g.caesium-137), most of the committed effective dose is delivered in the year in which the intake of activity took place. For others, such as plutonium, the committed dose is delivered over the remaining lifetime of the individual and so the dose in the year of intake is much lower than the committed dose.

Effective dose (definition used for calculation of critical group doses and for comparison with dose limits) The overall annual effective dose is the sum of ***committed effective doses*** from intakes of radionuclides in a given year and the effective dose from external irradiation in that year. It is this quantity that should be compared with the annual limit on effective dose (***dose limit***).

Collective dose The summation of individual effective doses received by the population of a defined geographical area over a defined period of time. A 500 year integration period is used in this report (see paragraph 29 of the Introduction). The unit is the man sievert (man Sv).

Dose constraint A restriction on annual dose to an individual from a single source, applied at the design and planning stage of any activity in order to ensure that when aggregated with doses from all sources, excluding natural background and medical procedures, the ***dose limit*** is not exceeded.

Dose limit For the purpose of discharge authorisations, the UK has (since 1986) applied a dose limit of 1 mSv (1000 μSv) per annum to members of the public from all man-made sources of radiation (other than medical exposure). This limit is now incorporated into UK law (see ***Basic Safety Standards Directive***).

EA (Environment Agency) The leading public body for protecting and improving the environment in England and Wales. (See ***defra***).

Effective dose See ***dose***.

Environment Act 1995 The legislation giving the EA its powers, aims and objectives.

Environmental Protection Act 1990 See ***IPC***

Equivalent dose See ***dose***.

Fission products Nuclear fission is the splitting of a heavy atomic nucleus such as uranium into (usually) two nuclei spontaneously or under the impact of another particle, with resulting increase of energy. The two nuclei are called fission products.

Food Standards Agency Formed in April 2000 from parts of ***MAFF*** and the Department of Health. It is responsible for food safety issues in the UK. Although it is a Government agency it does not report to a specific minister and is free to publish any advice it issues. It is accountable to Parliament through Health Ministers, and to the devolved administrations in Scotland, Wales and Northern Ireland for its activities within their areas. (The abbreviation FSA should only be used for the Financial Services Authority.)

Gray The SI unit of absorbed ***dose***.

Half-life The time for the ***radioactivity*** of a ***radionuclide*** to decrease by radioactive decay to one half of its initial value. Half-lives range from fractions of a second to millions of years. The effective half-life in the human body of a quantity of ingested radioactivity is a function of the radioactive half-life and biokinetic behaviour.

High Level Waste (HLW) Highly active heat-generating radioactive waste that normally continues to generate heat for several centuries. A high level of shielding and heat dissipation is is required during handling, transportation and storage. It is chemically separated from spent nuclear fuel during reprocessing.

Intermediate Level Waste (ILW) Waste with radioactivity levels exceeding the upper boundaries for ***low level waste*** but which does not require heat generation by the waste to be accounted for in the design of disposal or storage facilities.

ICRP International Commission on Radiological Protection. An independent group of experts founded in 1928 which provides guidance on principles and criteria in the field of radiological protection. The recommendations are not legally binding, but are generally followed by the UK in legislation.

IPC (Integrated Pollution Control) A statutory means of controlling industrial pollution set up under the ***EPA 1990***. Thus, discharges from 'Prescribed Processes' are controlled by IPC authorisations (issued by the ***EA*** and ***SEPA***) or by air pollution control authorisations issued by local authorities. These ensure compliance with quality objectives and standards by specifying discharge limits (i.e. to air and water) and other conditions. There is also a 'residual duty' in these authorisations that ***BATNEEC*** will be used to prevent or minimise releases of the most polluting substances and render them harmless. Where releases of a substance may affect more than one environmental medium, the authorisation must have regard to the ***BPEO***. See ***IPPC***.

IPPC (Integrated Pollution Prevention and Control) Prescribed Process (***IPC***) authorisations will be progressively replaced over the next few years by permits issued under the Pollution Prevention and Control Regulations 2000 (PPC). These regulations implement the requirements of the EC Directive on IPPC.

Ionising Radiation Regulations 1999 (IRRs 1999) These regulations under the Health and safety at Work Act 1974 in part implement the European ***Basic Safety Standards Directive*** of 1996.

ISTA Informal abbreviation for 'inter-site transfer authorisation' (Radioactive Substances Act).

Low Level Waste (LLW) Waste containing levels of radioactivity greater than those acceptable for dustbin disposal but not exceeding 4 GBq per tonne of alpha-emitting radionuclides or 12 GBq per tonne of beta-emitting radionuclides.

MAFF (Ministry of Agriculture, Fisheries and Food) Superseded by ***defra***. MAFF's statutory responsibilities for food safety issues in the UK have been passed to the ***Food Standards Agency***.

Magnox A magnesium/aluminium alloy that is used in the manufacture of the canister for uranium fuel metal ('Magnox fuel') used in a type of nuclear reactor ('Magnox reactor').

NII (Nuclear Installations Inspectorate) Part of the Health and Safety Executive. It is responsible for enforcing legislation relating to nuclear safety under the Nuclear installations Act 1965.

NRPB National Radiological Protection Board. An independent statutory body set up by the Radiological Protection Act 1970 to advance the acquisition of knowledge about the protection of mankind from radiation hazards and to provide information and advice on matters relating to radiological protection and radiation hazards.

Notice of Variation The means by which the conditions or limitations of an ***authorisation*** are changed.

OSPAR Convention The Oslo Paris Convention, where contracting parties (including the UK) agreed to take all possible steps to prevent and eliminate pollution, and to take all necessary measures to protect the maritime area against the adverse effects of human activities, so as to safeguard human health and to conserve marine ecosystems and, where practicable, restore marine areas which have been adversely affected. See ***Sintra***.

Quarterly Notification Level (QNL) Quarterly discharge or disposal levels that the ***EA*** may specify in ***RSA*** authorisations They enable the application of ***BPM*** to be monitored by the EA. Exceeding a QNL requires the operator to submit a written justification of the BPM used to limit discharges.

Radioactive Substances Act (RSA) 1960, 1993 Statutory legislation to control the keeping and use of radioactive substances and the accumulation discharge or disposal of ***radioactive waste***.

Radioactive waste Material that contains radioactivity above the appropriate levels specified in the ***Radioactive Substances Act 1993*** and which meets the definition of waste given in the Act.

Radioactivity The spontaneous disintegration of atomic nuclei. Radioactive substances or the radiation they emit (e.g. ***alpha*** particles, ***beta*** particles, gamma rays). The rate of radioactive decay. Measured in the standard international (SI) unit, ***Becquerels*** (Bq) or their multiples or sub-multiples (see inside front cover).

Radionuclide A radioactive isotope of an element.

SEPA Scottish Environment Protection Agency.

Sievert The SI unit of equivalent ***dose***.

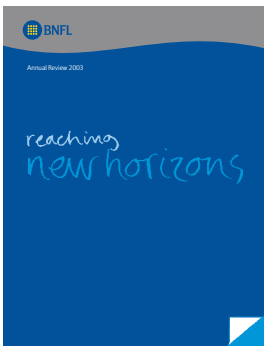
Sintra Agreement An agreement made at a ministerial meeting of the ***Ospar*** Commission in Sintra, Portugal, 22-23 July 1998. The ultimate aim is to achieve concentrations in the environment that are near background levels for naturally occurring radioactive substances and close to zero for artificial radioactive substances.

Thorp (Thermal Oxide Reprocessing Plant) A plant at BNFL Sellafield where oxide fuels from Advanced Gas Cooled Reactors and Light Water Reactors have been reprocessed since 1995.

UKAEA United Kingdom Atomic Energy Authority.

Notes

other publications



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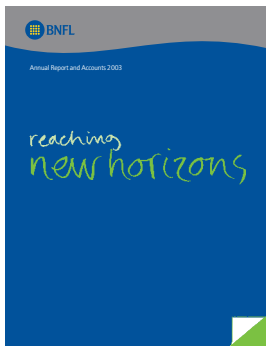

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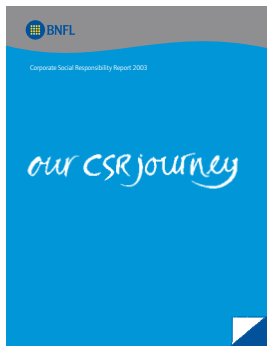

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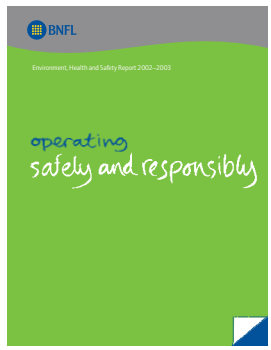

Environment, Health and Safety Report 2002–2003: an in-depth review of our health, safety and environmental performance over the year.

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Compiled and edited on behalf of BNFL by Ralph Atherton Associates Ltd.

Designed by Wilson & Cooke Ltd

Code EDMR2003/1.75k

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