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Foreword

i) At the 1998 Ministerial meeting of the Oslo and Paris (OSPAR) Commission, contracting parties to the 1992 Convention for the Protection of the Marine Environment of the North East Atlantic agreed a Strategy with regard to Radioactive Substances. This is reproduced at Annex 1. The Strategy was endorsed in a Ministerial Declaration, signed by the UK and all other OSPAR contracting parties. The objective of the Strategy is to prevent pollution of the maritime area (as defined under the convention) from ionising radiation, through progressive and substantial reductions of discharges, emissions and losses of radioactive substances. The ultimate aim is to achieve concentrations in the environment near background levels for naturally occurring radioactive substances and close to zero for artificial radioactive substances.

ii) In June 2000, the Government issued a consultation document to seek the views of interested parties on a draft UK strategy for radioactive discharges, covering the period 2001 to 20201. As a result of the responses received to that consultation and decisions announced since the consultation started, the strategy has been modified in the following main respects.

- The aim of reducing the estimated dose to a representative member of a critical group to 0.02 millisieverts (mSv) a year at most, as a result of discharges made from 2020 onwards, is explained more fully. In particular, the strategy makes clear that this level of exposure is seen as a consequence of achieving the Government’s targets for reducing radioactive discharges. It is not the intention to impose a general dose limit of 0.02 mSv from 2020.
- The costs and benefits associated with the strategy have been assessed in a Regulatory Impact Assessment, which forms Annex 2 to the document.
- Some consultees expressed concern over site specific issues, including discharges of technetium-99 (Tc-99) and the timetable for completing the reprocessing of Magnox fuel. Detailed options relating to these concerns are now addressed in the body of the text (Tc-99 at paragraph 7.3.15 onwards and Magnox reprocessing at paragraph 7.3.19).
- The graphs and bar charts showing past and predicted discharges of radioactive substances and past concentrations in the environment have been re-drawn. This was necessary to correct some errors which had inadvertently been introduced at the printing stage; to ensure a common methodology between industry sectors for expressing “total beta” in discharges; and to reflect further work on establishing a matrix of key indicators for environmental radioactivity.
- The opportunity has also been taken to update discharge projections in the light of decisions taken since the consultation, e.g. not to re-start reprocessing at Dounreay and to abandon the development of Magrox fuel on economic grounds.

iii) The strategy shows how the Government and the devolved administrations will implement the OSPAR Strategy with regard to Radioactive Substances and provides a clear policy base for future reviews of discharge authorisations by the regulators and for strategic planning by the nuclear operators. It should be read in conjunction with statutory guidance to the Environment Agency in England and Wales, and the Scottish Environment Protection Agency in Scotland, on the regulation of radioactive discharges into the environment from nuclear licensed sites. This guidance was in preparation at the time of going to press.

iv) This document is also available on the Internet at: www.defra.gov.uk/environment/radioactivity/discharge/strategy/index.htm
# Acronyms and abbreviations

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<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>AGR</td>
<td>Advanced Gas-cooled Reactor</td>
</tr>
<tr>
<td>ALARA</td>
<td>As Low As Reasonably Achievable</td>
</tr>
<tr>
<td>AWE</td>
<td>Atomic Weapons Establishment</td>
</tr>
<tr>
<td>BAT</td>
<td>Best Available Technology</td>
</tr>
<tr>
<td>BEP</td>
<td>Box Encapsulation Plant</td>
</tr>
<tr>
<td>BNFL</td>
<td>British Nuclear Fuels plc</td>
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<tr>
<td>BPEO</td>
<td>Best Practicable Environmental Option</td>
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<td>BPM</td>
<td>Best Practicable Means</td>
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<tr>
<td>Bq</td>
<td>Becquerel</td>
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<tr>
<td>BSS</td>
<td>Basic Safety Standards</td>
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<tr>
<td>COMARE</td>
<td>Committee on Medical Aspects of Radiation in the Environment</td>
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<tr>
<td>COS</td>
<td>Carbonyl Sulphide</td>
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<tr>
<td>EA</td>
<td>Environment Agency</td>
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<tr>
<td>EARP</td>
<td>Enhanced Actinide Removal Plant</td>
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<tr>
<td>EURATOM</td>
<td>European Atomic Energy Community</td>
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<tr>
<td>FSA</td>
<td>Food Standards Agency</td>
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<tr>
<td>GBq</td>
<td>Gigabecquerel</td>
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<tr>
<td>Gy</td>
<td>Gray</td>
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<tr>
<td>HSE</td>
<td>Health and Safety Executive</td>
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<tr>
<td>IAEA</td>
<td>International Atomic Energy Agency</td>
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<tr>
<td>ICRP</td>
<td>International Commission on Radiation Protection</td>
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<tr>
<td>ILW</td>
<td>Intermediate Level Waste</td>
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<td>JET</td>
<td>Joint European Torus</td>
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<tr>
<td>LLW</td>
<td>Low Level Waste</td>
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<tr>
<td>MAC</td>
<td>Medium Active Concentrate</td>
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<tr>
<td>mSv</td>
<td>Millisievert</td>
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<tr>
<td>NEA</td>
<td>Nuclear Energy Agency</td>
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<td>NIA 65</td>
<td>Nuclear Installations Act 1965</td>
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<td>NII</td>
<td>Nuclear Installations Inspectorate</td>
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<tr>
<td>Acronym</td>
<td>Definition</td>
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<tr>
<td>NORM</td>
<td>Naturally Occurring Radioactive Material</td>
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<td>NRPB</td>
<td>National Radiological Protection Board</td>
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<tr>
<td>OBT</td>
<td>Organically Bound Tritium</td>
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<tr>
<td>OECD</td>
<td>Organisation for Economic Co-operation and Development</td>
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<tr>
<td>OSPAR</td>
<td>Oslo and Paris (Convention/Commission)</td>
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<td>PWR</td>
<td>Pressurised Water Reactor</td>
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<td>RIA</td>
<td>Regulatory Impact Assessment</td>
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<td>RSA 93</td>
<td>Radioactive Substances Act 1993</td>
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<td>SDP</td>
<td>Sellafield Drypac Plant</td>
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<td>SEPA</td>
<td>Scottish Environment Protection Agency</td>
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<td>SIXEP</td>
<td>Site Ion Exchange Plant</td>
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<td>SMP</td>
<td>Sellafield Mox Plant</td>
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<td>SSBN</td>
<td>Vanguard Class Trident Ballistic Nuclear Missile Submarine</td>
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<td>SSN</td>
<td>Hunter Killer Submarine</td>
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<td>STP</td>
<td>Solvent Treatment Plant</td>
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<td>Sv</td>
<td>Sievert</td>
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<td>TBq</td>
<td>Terabecquerel</td>
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<tr>
<td>THORP</td>
<td>Thermal Oxide Reprocessing Plant</td>
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<tr>
<td>UKAEA</td>
<td>United Kingdom Atomic Energy Authority</td>
</tr>
<tr>
<td>UNSCEAR</td>
<td>United Nations Scientific Committee on the Effects of Atomic Radiation</td>
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<tr>
<td>UOC</td>
<td>Uranium Ore Concentrate</td>
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Executive summary

1. This strategy for radioactive discharges describes how the UK will implement the agreements reached at the 1998 Ministerial meeting, and subsequent meetings, of the OSPAR Commission, with regard to radioactive substances, as set out in the OSPAR Strategy with regard to Radioactive Substances (reproduced at Annex 1). It also provides a policy base for future reviews of discharge authorisations by the regulatory bodies and for strategic planning by the nuclear operators. The Government is working closely with other OSPAR contracting parties to develop an agreed view of the baseline situation in the OSPAR area, against which progress towards achievement of the OSPAR Strategy will be evaluated.

2. This strategy does not set individual site limits for radioactive discharges, but rather a strategic framework for radioactive discharges from UK installations over the next 20 years. Its aims are:

   ● progressive and substantial reduction of radioactive discharges and discharge limits, to achieve the strategy targets for each sector as set out at paragraph 12 below;

   ● progressive reduction of human exposure to ionising radiation arising from radioactive discharges, as a consequence of reductions in discharges, such that a representative member of a critical group of the general public will be exposed to an estimated mean dose of no more than 0.02 millisieverts (mSv) a year from liquid radioactive discharges to the marine environment made from 2020 onwards*;

   ● progressive reduction of concentrations of radionuclides in the marine environment resulting from radioactive discharges, such that by 2020 they add close to zero to historic levels. (The terms “close to zero” and “historic levels” are not defined in the OSPAR Strategy and the OSPAR Commission is continuing to work on establishing agreed definitions.)

3. It is the Government’s view that the unnecessary introduction of radioactivity into the environment is undesirable, even at levels where the doses to both human and non-human species are low and, on the basis of current knowledge, are unlikely to cause harm. The progressive reduction of discharge limits, and of actual discharges, having regard to the application of Best Practicable Means (BPM) is a central tenet of the way in which radioactive discharges should be controlled and has been a feature of UK policy since 1993.

4. Through the effective application of BPM, radioactive discharges (and particularly discharges of the most radiotoxic radionuclides) in the UK have been reduced very considerably. For instance, total discharges of beta activity from the British Nuclear Fuels plc (BNFL) site at Sellafield have already been reduced to less than 1% of their peak levels in the 1970s and alpha discharges to just 0.06% of peak levels. This strategy represents the next chapter of what has been an increasingly effective policy to minimise discharges, while recognising the benefits of nuclear practices in terms of energy, defence, medical treatments and scientific research.

* This level of exposure, which is less than 1% of natural background, would be the estimated result of achieving the discharge reductions set out in this strategy, subject to a review of the impact of clean-up and decommissioning activities. It is not the Government’s intention to impose it as an annual dose limit or constraint. See section 4.1 for an explanation of radiation exposure and the measurement units used.
5. Application of the “As Low As Reasonably Achievable” (ALARA) principle, is a requirement in UK and European law, whereby radiological doses and risks are kept ALARA and are reduced to a level that represents a balance between radiological and other factors, including social and economic factors. The Government intends to take costs fully into account in determining how to achieve the objective of the OSPAR Strategy*. The Government considers that applying the ALARA principle will reduce discharges sufficiently to achieve that objective. In the unlikely event that it appeared that the application of ALARA/BPM would not deliver the objective of the OSPAR Strategy, the Government would urgently review this strategy.

6. The strategy is guided by the precautionary principle, taking account of the definition of this principle set out in the European Council of Ministers’ Resolution at the Nice summit in December 2000. It is also guided by the polluter pays principle, as set out in the OSPAR Convention. The strategy aims to optimise impact by giving a greater priority to reducing those discharges which have the greatest effect on the environment.

7. In producing this strategy, the Government is concerned not only with further reducing discharges and hence radiation doses to the UK population, but also with the effects on neighbouring countries. A report by the Radiological Protection Institute of Ireland in September 2000 estimated the dose to a heavy consumer of seafood in 1999, from measured artificial radionuclides, to be 0.00133 mSv. This is less than a hundredth of the estimated dose of 0.15 mSv a year to the Sellafield critical group. The same report pointed out that this dose could be put into context by comparing it to the estimated 0.148 mSv a year received by seafood consumers in Ireland from naturally-occurring polonium-210. The impact of the UK’s radioactive discharges further afield is even less than in Ireland. However, the UK recognises that any level of radioactive contamination remains of concern to certain of its neighbours, even if, on the basis of current knowledge, it poses no threat to human health or the environment.

8. The scope of the UK strategy encompasses radioactive discharges from nuclear licensed sites, defence activities and other nuclear and non-nuclear sources of radioactive discharges. Because the OSPAR Strategy is concerned with concentrations in the marine environment, this first UK strategy concentrates on liquid radioactive discharges, as it is assumed that in general liquid discharges will have the largest and most measurable effects in the marine environment. Future issues of the strategy, which will be reviewed about every four years, will also address aerial discharges.

9. The strategy is set in the context of a well-established framework for the control of discharges and radiation exposure, comprising national legislation, policy and regulatory arrangements and international commitments and codes of practice. In parallel with this strategy, the Government and the devolved administrations for Scotland and Wales are issuing statutory guidance to the environmental regulators to help them to take account of radiological principles and environmental policy objectives when determining authorised limits for radioactive discharges from nuclear licensed sites. At the time of going to press, this guidance was in preparation. The statutory guidance will provide the vehicle through which the UK strategy will be implemented. Both the strategy and the statutory guidance incorporate regulatory impact assessments, which evaluate the costs and benefits involved (see Annex 2).

* Detailed requirements for achieving the OSPAR objective are set out in the Programme for the More Detailed Implementation of the OSPAR Strategy with Regard to Radioactive Substances, agreed at the OSPAR Commission meeting in June 2000 at Copenhagen.
10. Trends in discharges of man-made radionuclides over the last 20 years show large and sustained reductions in discharges of the most radiologically significant radionuclides, particularly from the nuclear fuel reprocessing sector. Trends in environmental concentrations and doses over the same period tend to mirror this pattern. However, discharges of some other radionuclides have shown little change or have increased during this period.

11. In particular, concern has been expressed over an increase in technetium (Tc)-99 discharges from the reprocessing sector in 1994 and 1995. This was a consequence of the Enhanced Actinide Removal Plant (EARP) at Sellafield starting to treat a backlog of liquid wastes, which had been temporarily stored pending construction of the treatment plant. Whilst unwelcome, a temporary increase in some discharges is often an unavoidable side effect of making safe old, stored wastes. Although EARP removes the most radiotoxic elements from the wastes, it is unable to remove Tc-99, which has a low level of radiotoxicity. Tc-99 discharges have reduced considerably from 1995 and are set to reduce further. The Environment Agency has carried out a review of Tc-99 discharge authorisations at Sellafield and published its proposed decision in September 2001 to reduce the liquid discharge limit for Tc-99 from 90 terabecquerels (TBq) a year to 10 TBq a year by the end of 2006. At the time this strategy went to press, Ministers were considering whether to accept the Agency’s proposals.

12. Discharges from six sectors are considered: nuclear fuel production and uranium enrichment; nuclear energy production; spent fuel reprocessing; research facilities; defence facilities; and other sources. For each sector, the possibilities for reducing discharges are examined and projected discharge profiles for the period 2001 to 2020 are given for the first five sectors. The following targets have been set for discharge reductions, by sector:

- **Nuclear fuel production and uranium enrichment:** By 2006, production of Magnox fuel and uranium hexafluoride at Springfields are expected to cease, with consequent major reductions in alpha and beta discharges. By 2020, liquid discharges are expected to be reduced from around 120 TBq a year to virtually zero for beta-emitting nuclides and from about 0.25 TBq to less than 0.01 TBq a year for alpha-emitting nuclides.

- **Nuclear energy production:** By 2010, all of the currently operating Magnox power stations are expected to have closed down, with consequent major reductions in discharges following defuelling and post-operational clean-out. By 2020, total beta/gamma discharges (excluding tritium) are expected to be reduced from more than 10 TBq to less than 1.5 TBq a year. Discharges of tritium are expected to be reduced from more than 2800 TBq to about 850 TBq a year.

- **Spent fuel reprocessing:** Tc-99 discharges from reprocessing are expected (if the Environment Agency adopts its proposed Decision) to be reduced from close to 90 TBq a year to below 10 TBq a year as soon as possible and by no later than the end of 2006, and to less than 1 TBq a year by 2020. By around 2012, reprocessing of spent Magnox fuel is expected to cease, with consequent significant reductions in discharges. By 2020, total alpha/beta liquid discharges (excluding tritium) are expected to be reduced from 165 TBq a year to around 50 TBq a year.

- **Research facilities:** by 2020, total alpha/beta discharges (excluding tritium) are expected to be reduced from more than 4 TBq a year to less than 1 TBq a year; tritium discharges are expected to reduce from more than 1000 TBq a year to about 20 TBq a year.
Defence facilities: By 2005, radioactive discharges to the Thames from the Atomic Weapons Establishment (AWE) Aldermaston are expected to cease. By 2020, tritium discharges from the defence sector are expected to be reduced from 0.7 TBq to 0.4 TBq a year and other beta/gamma discharges are expected to be reduced from 0.005 to 0.003 TBq a year.

Other sources of discharges: Due to the diverse nature of other minor sources of radioactive discharges, no discharge profile or target is set for this sector. The presumption is that these discharges will continue to be tightly controlled and reduced wherever practicable.

13. In June 2000, the Government issued a consultation document to seek the views of interested parties on a draft UK strategy for radioactive discharges, covering the period 2001 to 2020\(^1\). The current text discusses, at appropriate points, the major issues raised in response to the consultation. As a result of the consultation responses and decisions announced since the consultation started, the strategy has been modified in the following main respects:

- The aim of reducing the estimated mean dose to a representative member of a critical group to 0.02 mSv a year at most, as a result of discharges made from 2020 onwards, is explained more fully. In particular, the strategy makes clear that this level of estimated critical group exposure is seen as a consequence of achieving the Government’s targets for reducing radioactive discharges. It is not the intention to impose a general dose limit of 0.02 mSv from 2020.

- The costs and benefits associated with the strategy have been assessed in a Regulatory Impact Assessment, which forms Annex 2 to this document.

- The possibilities for reducing discharges of Tc-99 from Sellafield, suggested by some consultees, are discussed in greater depth. These suggestions include the dry storage of spent Magnox fuel and the suspension of operation of the EARP facility, pending the development of abatement techniques for Tc-99 (see paragraphs 7.3.10, 7.3.11 and 7.3.15 to 7.3.17).

- In response to concerns that the B205 Magnox reprocessing plant at Sellafield may not complete the reprocessing of all Magnox spent fuel by the target date of around 2012, the strategy describes contingency plans for meeting the target date for closing B205. These plans include the option of bringing forward the closure dates of some Magnox stations (see paragraph 7.3.19).

- The graphs and bar charts, showing past and predicted discharges of radioactive substances and past concentrations in the environment, have been re-drawn. This was necessary to correct some errors which had inadvertently been introduced at the printing stage; to ensure a common methodology between industry sectors for expressing “total beta” in discharges; and to reflect further work on establishing a matrix of key indicators for environmental radioactivity.

- The opportunity has also been taken to update discharge projections in the light of decisions taken since the consultation, e.g. not to re-start reprocessing at Dounreay and to abandon the development of Magrox fuel on economic grounds.

14. The Government intends to review this strategy, its objectives and discharge profiles, about every four years. This review will take account of developments in Government policy, commercial decisions within the nuclear industry, technological advances and improvements in our knowledge of the impacts of radionuclides in the marine environment.
Chapter 1: Background

1.1 In June 2000, the Government issued a consultation document to seek the views of interested parties on a draft UK strategy for radioactive discharges, covering the period 2001 to 2020. This strategy for radioactive discharges is set in the wider context of environmental protection in the UK. The Government has a leading role in formulating environmental protection policy in the context of the principle of sustainable development. It is UK policy that radioactive wastes should be managed and disposed of in ways that protect the public, the workforce and the environment. This demands that radioactive wastes are not created unnecessarily, and that such wastes as are created are managed safely and disposed of appropriately.

1.2 At the 1998 Ministerial meeting of the Oslo and Paris (OSPAR) Commission, in Sintra, Portugal, contracting parties to the 1992 Convention for the Protection of the Marine Environment of the North East Atlantic agreed a Strategy with regard to Radioactive Substances. This is reproduced at Annex 1. The Strategy was endorsed in a Ministerial Declaration, signed by the UK and all other OSPAR contracting parties (the Sintra Statement). The objective of the Strategy is to prevent pollution of the maritime area, as defined under the convention, from ionising radiation, through progressive and substantial reductions of discharges, emissions and losses of radioactive substances. The ultimate aim is to achieve concentrations in the environment near background levels for naturally occurring radioactive substances and close to zero for artificial radioactive substances.

1.3 The OSPAR Strategy is to be implemented in accordance with the following time frame:

- by the year 2000, the OSPAR Commission will, for the whole maritime area, work towards achieving further substantial reductions or elimination of discharges, emissions and losses of radioactive substances;
- by the year 2020, the OSPAR Commission will ensure that discharges, emissions and losses of radioactive substances are reduced to levels where the additional concentrations in the marine environment above historic levels, resulting from such discharges, emissions and losses, are close to zero.

1.4 The UK’s intentions for implementing the OSPAR Strategy for radioactive substances were submitted to the OSPAR Secretariat in October 1999. At the OSPAR Commission meeting in June 2000, all contracting parties agreed to a Programme for the More Detailed Implementation of the OSPAR Strategy with regard to Radioactive Substances. This requires the production of national plans for achieving the objectives of the OSPAR Strategy. This UK strategy for radioactive discharges comprises the UK’s national plan for the purposes of the Programme and meets the criteria for such national plans to provide forecasts of man-made radioactive discharges, by industry sector or activity and by the regions of the OSPAR maritime area likely to be affected. However, it is the Government’s understanding that the targets set out in the 1998 OSPAR Strategy time frame apply to the maritime area as a whole and to the totality of radioactive discharges from all sources within each country. They are not necessarily taken to apply to each individual source of discharges or to every radionuclide discharged.

* Where the term “the Government” is used in this document, it refers to the UK Government and/or the Devolved Administrations, as appropriate.
1.5 The UK strategy also provides a clear policy base for future reviews of discharge authorisations by the regulators and for strategic planning by the nuclear operators. It should be read in conjunction with statutory guidance to the Environment Agency (EA) in England and Wales, and the Scottish Environment Protection Agency (SEPA) in Scotland, on the regulation of radioactive discharges into the environment from nuclear licensed sites. These documents were in preparation at the time of going to press.

1.6 The statutory guidance will provide the vehicle through which the UK strategy will be implemented. Both the strategy and the statutory guidance incorporate regulatory impact assessments, which evaluate the costs and benefits involved (see Annex 2).
Chapter 2: Principles and aims

2.1 It is a Government policy objective to ensure adequate national and European Union statutory powers, international agreements and other measures to protect the quality of life and the natural environment from harmful levels of radioactivity.

2.2 The OSPAR Strategy introduced the factor of environmental concentrations into a mechanism for controlling radioactive discharges that had previously been driven primarily by considerations of human radiation protection. The challenge in implementing the OSPAR Strategy with regard to Radioactive Substances is to strike an appropriate balance between measures to protect human health (including the health of workers at nuclear installations) and measures to protect the environment, whilst taking account of other legitimate uses of the sea.

- The objective of the UK Strategy for Radioactive Discharges 2001-2020 is to implement the UK’s obligations in respect of the OSPAR Strategy rigorously and transparently.

2.3 Criteria for protection of the environment from the effects of ionising radiation are at present less well developed than those for the protection of people. Some respondents to the consultation document argued for a continued focus on the radiological protection of people and pointed out the difficulties of moving from this tried and tested basis for setting discharge limits, to one which may appear to be more arbitrary. Other respondents, however, took the view that only discharge reductions well beyond those required on the basis of human radiation protection would suffice to meet the OSPAR target for 2020.

2.4 It is the Government’s view that the unnecessary introduction of radioactivity into the environment is undesirable, even at levels where the doses to both human and non-human species are low and, on the basis of current knowledge, are unlikely to cause harm. The progressive reduction of discharge limits and of actual discharges, having regard to the application of Best Practicable Means (BPM), is a central tenet of the way in which radioactive discharges should be controlled and has been a feature of UK policy since 1993.

2.5 Through the effective application of BPM, radioactive discharges (and particularly discharges of the most radiotoxic radionuclides) in the UK have been reduced very considerably. For instance, total discharges of beta activity from Sellafield have already been reduced to less than 1% of their peak levels in the 1970s and alpha discharges to just 0.06% of peak levels. This strategy represents the next chapter of what has been an increasingly effective policy to minimise discharges, while recognising the benefits of nuclear practices in terms of energy, defence, medical treatments and scientific research.

2.6 The UK strategy sets a framework for the progressive reduction of radioactive discharges over the next twenty years, guided by the following principles:

- the precautionary principle, taking account of the definition of this principle set out in the European Council Resolution at Nice in December 2000. This requires that preventive measures are to be taken where the possibility of harmful effects on health or the environment has been identified and preliminary scientific evaluation proves inconclusive for assessing the level of risk. The Council of Ministers considered that risk management measures must be taken by the public authorities responsible on the basis of a political appraisal of the desired level of protection;
● the polluter pays principle, by virtue of which the costs of pollution prevention, control and reduction measures are to be borne by the polluter;

● the ALARA principle, whereby radiological doses and risks are kept as low as reasonably achievable, taking account of other factors, including economic and social factors; this is discussed more fully at paragraph 4.2.3;

● a proportionate approach, whereby priority is given to reducing discharges which have greatest radiological significance or which present most risk of damaging the marine environment, whilst ensuring that the costs of such reductions are not grossly disproportionate to their benefits in line with current Government guidance on better regulation; this is discussed more fully in Chapter 6.

Through applying these principles, the Government intends to take costs fully into account in determining how to achieve the objective of the OSPAR Strategy*. The Government considers that applying the ALARA principle will reduce discharges sufficiently to achieve that objective. In the unlikely event that it appeared that the application of ALARA/BPM would not deliver the objective of the OSPAR Strategy, the Government would urgently review this strategy.

2.7 The aims of the strategy are:

● progressive and substantial reduction of radioactive discharges and discharge limits, to achieve the strategy targets for each sector as set out in Chapter 7;

● progressive reduction of human exposure to ionising radiation arising from radioactive discharges, as a consequence of reductions in discharges, such that a representative member of a critical group of the general public will be exposed to an estimated mean dose of no more than 0.02 mSv a year from liquid radioactive discharges to the marine environment made from 2020 onwards – see Section 4.1 for an explanation of critical groups and the significance of this level of exposure;

● progressive reduction of concentrations of radionuclides in the marine environment resulting from radioactive discharges, such that by 2020 they add close to zero to historic levels. (The terms “close to zero” and “historic levels” are not defined in the OSPAR Strategy and the OSPAR Commission is continuing to work on establishing agreed definitions.)

2.8 The achievement of these aims will be assessed by monitoring authorised radioactive discharges in the UK and concentrations in the marine environment, and by estimating the likely dose consequences to critical groups of members of the public. Mathematical models will also be developed to predict future concentrations in the environment and the extent to which these might differ from historic levels. As they become available, these predictions will be taken into account in setting future limits on radioactive discharges.

* Detailed requirements for achieving the OSPAR objective are set out in the Programme for the More Detailed Implementation of the OSPAR Strategy with Regard to Radioactive Substances3, agreed at the OSPAR Commission meeting in June 2000 at Copenhagen.
Chapter 3: Scope of the UK strategy

3.1 This strategy covers radioactive discharges from:

- nuclear licensed sites operated by the nuclear industry; such discharges may result from nuclear fuel cycle activities, decommissioning and the clean-up of historic wastes;
- defence applications, such as the Atomic Weapons Establishments, the Royal Dockyards and other naval bases;
- other nuclear and non-nuclear industries, medical applications and other “small users”.

3.2 The strategy is based on current policies and practices relating to radioactive waste management. Wider issues, including future policy on the reprocessing of spent nuclear fuel and the future mix of UK energy generating capacity, are outside the scope of this strategy. Future issues of the strategy will take account of any changes in Government policy that are announced.

3.3 The OSPAR Strategy objective makes a distinction between naturally-occurring radioactive substances and artificial radioactive substances. Power production from fossil fuels results in the release to the environment of naturally-occurring radioactive material (NORM), mostly isotopes of radon and thorium. The Environment Agency has undertaken a study of aerial emissions of radioactivity from coal fired power stations, the results of which were published in its “Radioactivity in the Environment” report for 2005.

3.4 The Environment Agency’s study showed that measured concentration levels indicate that emissions of isotopes of uranium, thorium, radium, polonium and lead are below the relevant limit in Schedule 1 of the Radioactive Substances Act 1993 (RSA 93) and so do not require authorisation under the Act. Total alpha/beta emissions from coal fired power stations in the UK amount to 10-15 GBq per year. Doses to individual members of the public have been calculated as less than 0.001 mSv, far below the site dose constraint of 0.3 mSv. These releases and the resulting doses are much smaller than those from the nuclear industry and below the internationally accepted criterion for exemption from regulatory requirements of the order of 0.01 mSv a year or less for individual doses, as set out in Annex 1 of the Basic Safety Standards Directive 96/29 Euratom. In accordance with a proportionate approach, they are not, therefore, considered further in this strategy.

3.5 NORM in discharges to sea of sludges and macerated scale deposits from offshore oil and gas platforms, although also low in total activity (about 0.016 TBq alpha activity in 2000), are subject to authorisation under RSA 93. Discharges of NORM to sea, particularly in produced water from the oil and gas sector, are subject to greater uncertainties than discharges from nuclear industries. Initial findings from the Marina II study, carried out by the European Commission, indicate that discharges of alpha activity to sea from produced water from the oil and gas sector could be an important source of overall discharges of alpha activity. Details of these and other discharges of NORM are covered in Section 7.6 of this strategy but no forward profile of NORM discharges has been compiled for this first edition.

3.6 The focus of this initial strategy is on liquid discharges to sea from coastal nuclear installations, on the assumption that, in general, these will have the largest and most measurable effects in the marine environment. Consequently, the discharge profiles in this document are for liquid discharges only. Monitoring of river water has shown that discharges to inland waters and “wash out” of radionuclides from airborne discharges are unlikely to contribute significantly to concentrations in the marine environment.
3.7 However, airborne discharges can potentially be important contributors to public exposure and the OSPAR Strategy does not specify discharge routes. Future issues of the UK strategy will examine both liquid and airborne discharges, from nuclear and non-nuclear activities.

3.8 The disposal of solid radioactive wastes to dedicated burial sites, landfill or incineration, may also give rise to discharges and emissions that have pathways to the marine environment. No assessment of these has been attempted in the current strategy, but it is intended that the possible contribution of such discharges to concentrations in the marine environment should be evaluated in future issues.

3.9 The reduction of liquid discharges might, in some cases, only be achieved at the expense of increasing the activity in airborne discharges or the volume of solid waste arisings. The transfer of radioactivity between environmental compartments in this way may have undesirable implications for estimated doses to workers or critical groups (see paragraph 4.1.3 for an explanation of critical groups). Determining the balance between discharges and solid wastes usually involves an assessment of the Best Practicable Environmental Option (BPEO) and the implications for occupational, public and environmental radiation exposures, and risks to future generations, need to be balanced. As a general principle, reductions in liquid discharges proposed in this strategy will be achieved in ways that have no unacceptable implications for doses to workers or the general public, or for terrestrial or freshwater ecosystems, now or in the future.
Chapter 4: Control of radiation exposure and radioactive discharges

4.1 Sources of radiation exposure

4.1.1 We are all exposed to ionising radiation, most of which is of natural origin. Natural background sources of radiation include cosmic rays from outer space, gamma radiation from the rocks and soils of the earth’s crust, and radionuclides (e.g. polonium-210 and potassium-40) in foods. The background radiation doses which people receive depend on where they live, their habits and their diet. Some 85% of the average amount of radiation to which the UK population is exposed each year occurs naturally, largely as a result of radon gas. A further 14% comes from medical exposure and most of the remaining 1% is from weapons test fallout, occupational and miscellaneous exposure.

4.1.2 For the population as a whole, discharges from nuclear installations contribute less than 0.1% to the annual average dose of 2.6 mSv. (See the box for an explanation of dose units.) Even typical members of the public living in the vicinity of nuclear installations generally receive less than 0.006 mSv a year as a result of radioactive discharges. To put this into perspective, a person taking one return flight between London and the Canary Islands would receive about five times that exposure (i.e. 0.03 mSv), from cosmic radiation.

4.1.3 However, some members of the public close to nuclear installations are assumed to receive higher doses, due to their higher than average consumption of certain foodstuffs (as established by surveys), frequenting certain areas or living in close proximity to the site. In predicting radiological impacts to man, the concept of the critical group is used. For a given source of radioactive discharges, this is the small number of members of the public who are likely to receive the highest radiation dose as a result of that source. By ensuring that the critical group is not exposed to unacceptable levels of radiation as a result of discharges, the wider population is also protected. The highest estimated dose from discharges from nuclear sites to a representative member of a critical group in the UK was 0.15 mSv a year in 2000, as a result of current and historic discharges from Sellafield.

4.1.4 Although the critical group approach is accepted by the International Commission on Radiation Protection (ICRP) and the UK’s National Radiological Protection Board (NRPB), some responses to the consultation document gave the view that it is wrong to assume that the most exposed individual will experience the greatest health detriment. Whilst critical group methodology recognises the differing vulnerability of adults, children and infants, some consultees felt that this does not adequately address degrees of vulnerability within each category or the vulnerability of the unborn child.

4.1.5 The question of individuals with differing vulnerabilities to radiation has been addressed by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), ICRP and NRPB. To date it has only proved possible to provide evidence of genetically increased radiation risk in rare cancer-prone individuals exposed to high radiation doses received during cancer therapy. In such individuals, the increased risk due to additional low dose radiation exposure from, for example, discharges of radionuclides would not be detectable because of their high risk of developing cancer spontaneously. Ongoing research is addressing the possibility of more common genetic determinants of radiation response but, at present, there is no meaningful way in which the complex interaction between
radiation and genetic factors can be included in the system of radiological protection. Turning to the vulnerability of the foetus, ICRP Publication 88 on 'Doses to the Embryo and Foetus from Intakes of Radionuclides by the Mother' has recently been issued. A comparison of doses to the mother and her offspring has also been given in a paper by NRPB staff and others. It may be concluded that application of dose limits and constraints to the assessed dose to the mother will, in the majority of cases, ensure corresponding protection of the foetus. NRPB is developing advice for circumstances where this may not be the case. This advice will be taken into account in the strategy when it becomes available.

Estimation of radiation doses

Ionising radiation (usually referred to simply as “radiation”) consists of various types of particles or rays, all of which have the potential to damage living cells or to alter their DNA. Humans may be exposed to radiation by a number of different routes or pathways, such as ingestion, inhalation and external radiation. To estimate radiation dose, assumptions must first be made about habits, diet etc. of the group of people in question. The amount of radiation absorbed by the body via the various pathways is expressed in terms of the energy it deposits in the tissues. This is the absorbed dose and is measured in grays (Gy).

The degree of damage this causes depends not only on the amount, but also on the kind of radiation. Alpha particles, because of their high mass and charge, are more damaging and so are accorded a “radiation weighting factor” of 20. Beta particles (which have low mass and charge) and gamma rays and X-rays (no mass or charge) have a weighting factor of 1. Applying these factors gives the equivalent dose, measured in sieverts (Sv). Account is taken of the varying sensitivity of body tissues and organs to radiation, by multiplying the equivalent dose by “tissue weighting factors”, to give the effective dose (also measured in sieverts).

When radioactive material is incorporated into the body, the dose is delivered to the tissues over a period of time. For some radionuclides, this period will extend for the rest of life. In practice, this continuing dose is accounted for in the year in which the intake of radioactive material occurs and is referred to as the committed effective dose. When the term “dose” is used in this document, it refers to the sum of committed effective dose and effective dose.

Current dose assessment methodologies are designed to be conservative – that is, to assume the worst case. They assume discharges at the authorised limits rather than actual amounts discharged, which may be much lower. Assumptions regarding behaviour and diet are also deliberately extreme. This means that doses, whilst consistent within the methodology used, could easily be overestimated by a factor of ten.

The international system of units (SI) is used for measuring radioactivity and its effects. Common multiples and sub-units used include mega-, M (1 million); kilo-, k (one thousand); milli-, m (1 thousandth) and micro-, µ (1 millionth). In this document, doses are given in millisieverts (mSv). The international annual dose limit for members of the public from man-made sources of radioactivity is 1 mSv.
4.2 Controls on radiation exposure

4.2.1 UK policy on the control of radiation exposure has long been based upon acceptance of the recommendations of the appropriate international bodies. The ICRP has recommended a system of radiological protection based on the principles of justification of practices, optimisation of protection, and dose limitation. Further recommendations have built on this system and have introduced the use of dose constraints and risk constraints.

4.2.2 European Council Directive 96/29 Euratom requires Member States of the European Union to ensure that all new classes or types of practice resulting in exposure to ionising radiation are justified, in advance of being first adopted or first approved, by their economic, social or other benefits, in relation to the health detriment they may cause.

4.2.3 It has also long been Government policy to adhere to the ICRP principle that radiological doses and risks from a source of exposure are kept as low as reasonably achievable in that 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 ALARA principle). When ALARA is being applied, the level of protection may be said to be optimised. The application of ALARA in UK law flows from a requirement in Directive 96/29 Euratom (Article 6.3(a)).

4.2.4 Dose limits are intended to ensure that no individual is exposed to radiation risks that are judged to be unacceptable in any normal circumstances. In 1993, the UK adopted, on the advice of the NRPB, the ICRP recommended dose limit for members of the public of 1 mSv a year. This was confirmed as UK policy in 1995. Several international bodies have used ICRP recommendations as a basis for guidance for national regulatory authorities and operators. For European Union Member States, the European Atomic Energy Community (EURATOM) is the only international body with powers to set and enforce basic radiation standards, by virtue of the 1957 EURATOM Treaty. The Basic Safety Standards (BSS) Directive, 96/29/Euratom, sets a dose limit for members of the public of 1mSv a year, in line with recommendations made in ICRP Publication 60. This applies to all artificial sources covered by the EURATOM Treaty, including historic disposals of radioactive waste, but excludes doses from medical and diagnostic procedures.

4.2.5 In 2000, the Secretary of State for the Environment, Transport and the Regions issued a Direction, extending to England and Wales, implementing elements of the BSS Directive. This requires the Environment Agency to ensure, wherever applicable, that:

- all public radiation exposures from radioactive waste disposal are kept ALARA;
- the sum of such exposures does not exceed the dose limit of 1 mSv a year;
- the dose received from any new source does not exceed 0.3 mSv a year;
- the dose received from any single site does not exceed 0.5 mSv a year.

4.2.6 In Scotland, SEPA is subject to a similar, but separate, Direction (The Radioactive Substances (Basic Safety Standards) Scotland Direction 2000), which has the same remit in relation to the four points listed above. Regulations to implement the BSS Directive are currently being made in Northern Ireland.

4.2.7 The UK has consistently applied the radiological protection principles described above to reduce the levels of radioactive discharges and the doses of ionising radiation to humans, and in so doing has reduced concentrations in the wider environment. This is ensured by the system of authorisation and control described below.
4.3 Controls on discharges

Legislation

4.3.1 The Radioactive Substances Act 1993 (RSA 93), as amended by the Environment Act 1995 and by legislation implementing the BSS Directive, is the formal basis of control of radioactive discharges, and other aspects of the control of radioactive materials in the UK. It provides a framework for the standards, practices and objectives in the field of radioactive waste management articulated in Government policy statements. The Act sets out requirements for registration (relating to the use of radioactive material) and authorisation (for the disposal and accumulation of radioactive waste). It prohibits any disposal of radioactive waste other than in accordance with the conditions of an authorisation granted by the appropriate regulatory body. Radioactive discharges and emissions to the environment are considered to be disposals of radioactive waste under RSA 93.

4.3.2 Certain categories of activities are specified in exemption orders under the Act and are not subject to its requirements, although most of the exemption orders have conditions attached. These activities include the handling and disposal of certain phosphatic and other substances that contain naturally occurring radionuclides, and the medical uses of radioactive substances in hospitals etc. Although such activities are minor contributors to the national picture of radioactive discharges, they are still expected to use best practice to reduce radioactive discharges wherever practicable.

4.3.3 Ministry of Defence sites are excluded from statutory regulation under RSA 93, although the Environment Agency exercises an equivalent system of controls by administrative means in England and Wales. Administrative arrangements also exist for SEPA in Scotland to deal with discharges from Ministry of Defence sites. Statutory regulation is, however, applied to the licensed sites at the Atomic Weapons Establishments at Aldermaston and Burghfield and to the Royal Dockyards at Devonport and Rosyth, which are operated by civilian contractors.

4.3.4 The Nuclear Installations Act 1965 (NIA 65) requires nuclear sites to be licensed by the Health and Safety Executive (HSE). The Nuclear Installations Inspectorate (NII) of the HSE regulates the storage of radioactive waste on these nuclear licensed sites. Occupational exposure to ionising radiation and any direct exposure to other persons arising from a work activity is regulated by the HSE under the Health and Safety at Work Act 1974 and the Ionising Radiations Regulations 1999. Similar Regulations are enforced by the Health and Safety Executive, Northern Ireland.

4.3.5 The effects of nuclear operations on the environment are also regulated under the Town and Country Planning Act and legislation implementing the EU Environmental Impact Directive, 97/11/EC.

Regulation

4.3.6 It is not the function of this strategy to prescribe individual site limits for radioactive discharges, but rather to indicate the strategic direction. The regulatory authorities described at paragraph 4.5.4 of this strategy have responsibility for issuing authorisations for radioactive discharges under RSA 93 and for varying existing authorisations. In considering applications for discharge authorisations, or variations to existing authorisations, they must take account of Government policy and of the requirements of European law, including the principles of justification, optimisation and dose. (Following Directive 96/29 Euratom coming into force, decisions on justification under Article 6.1 and 6.2 will be taken by the
The Statutory Guidance to the Environment Agency in England, which is in the process of being finalised, is intended to set out a clear framework within which the Environment Agency will operate when authorising the discharge of radioactivity into the environment from licensed nuclear sites.

4.3.7 The dose estimates used by the regulatory authorities in setting limits on the discharge of specific radionuclides assume that discharges would be maintained at the limits for all radionuclides specified. Since this is unlikely to happen in practice, the doses resulting from actual discharges from the site will be lower than these estimates.

4.3.8 In addition to placing numerical limits on the levels of radioactivity discharged, authorisations under RSA 93 require operators to use BPM to minimise the activity of waste discharged. BPM, which is within the control of operators, is the mechanism whereby dose to the public, which is normally outwith the control of operators, is kept ALARA.

4.3.9 Authorisations under RSA 93 also impose requirements on the operator to carry out monitoring of levels of discharged radionuclides in the surrounding environment. In accordance with the polluter pays principle, both these monitoring programmes and independent monitoring carried out by, or on behalf of, the environmental regulatory bodies and the Food Standards Agency (FSA) are funded by the nuclear operators.

4.3.10 All authorisations for the disposal of radioactive waste are kept under review. The Environment Agency will continue to review site discharge authorisations every four years. SEPA currently carries out such reviews at five-yearly intervals but will move to four-yearly reviews if this requirement is included in statutory guidance from Ministers to SEPA. Discharge authorisations are placed on public registers where they are open to inspection and discharge limits are published in various documents, for instance the annual FSA/SEPA report on Radioactivity in Food and the Environment and the Environment Agency Report on Radioactivity in the Environment.

4.3.11 The regulatory bodies carry out checks on the actual discharges made, in terms of activity and radionuclide composition, and have powers of prosecution under RSA 93 if the terms of authorisations are breached. The system of discharge authorisations, and their regular review, is an important mechanism to ensure effective control over radioactive discharges.

4.4 International context

4.4.1 Mention has already been made of the radiological principles expounded by the ICRP and the BSS Directive. The Euratom Treaty also requires compliance with measures to monitor radioactivity in the European environment (Articles 35 and 36) and to prevent radioactive discharges or waste disposal in one Member State resulting in the contamination of the environment of another Member State (Article 37). In this context, the European Commission decides whether any plan for the disposal of radioactive waste would result in contamination that is “significant from the health point of view”.

4.4.2 Further international controls on radioactive wastes, including discharges, are provided by the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, to which the UK is a contracting party. This convention, which entered into force in June 2001, provides for a system of regular peer reviews of the policies and practices of radioactive waste management in each Contracting Party. The UK must provide its first national report under the convention by May 2003. In addition, the International Atomic Energy Agency (IAEA) Radioactive Waste Safety Standards system
provides a hierarchy of documents, from broad principles to detailed guidance, on all aspects of radioactive waste management.

4.4.3 The UK also has obligations under other international conventions. The Convention on the Prevention of Marine Pollution by Dumping of Wastes and other Matter 1972 (the London Convention) regulates dumping at sea. A 1993 Resolution under this convention banned the sea disposal of low-level radioactive waste and, together with earlier resolutions, effectively imposed a complete ban on the sea dumping of all radioactive waste. The UK took a decision in 1982 to discontinue sea disposal operations. Operational discharges to sea from land-based installations and offshore platforms are not covered by the London Convention and are controlled in the UK within strict authorised limits, set under RSA 93.

4.4.4 The United Nations Convention on the Law of the Sea, 1982 (UNCLOS) requires contracting parties to take necessary measures to ensure effective protection of the marine environment from harmful effects that may arise from exploration for or exploitation of resources on or under the seabed. It also requires ships carrying nuclear cargoes through the territorial sea to carry documents and observe special precautionary measures established in international agreements regarding such transports.

4.4.5 As stated earlier, the UK is also a Contracting Party to the OSPAR Convention. As a general obligation, OSPAR contracting parties shall, in accordance with the provisions of the convention, take all possible steps to prevent and eliminate pollution and shall take the necessary measures to protect the maritime environment against the adverse effects of human activities. The OSPAR Strategy for radioactive substances sets objectives and targets for radioactive discharges, which are set out in paragraphs 1.2 and 1.3 of this strategy. In addition, in the Sintra Statement, Ministers undertook to pay particular attention to the safety of workers in nuclear installations.

4.5 National arrangements

4.5.1 Since July 1999, the devolved administrations have had responsibility for issues arising relative to the provisions of the Radioactive Substances Act 1993. Although the UK as a single unitary state retains ultimate responsibility for compliance with international conventions and European Union legislation, the devolved administrations are responsible for detailed implementation and compliance in their respective countries, so far as these relate to devolved matters.

4.5.2 In the UK, there is a comprehensive system of protection of the workforce, the population and the environment in respect of ionising radiation. In England, Scotland and Wales, the NII of the HSE has regulatory responsibility for the safety of operation of nuclear sites and for the regulation of doses to workers. In Northern Ireland, the HSE in the Department of Enterprise, Trade and Investment regulates doses to workers. There are no nuclear installations in Northern Ireland.

4.5.3 The responsibility for radioactive waste management in the UK is devolved. Certain aspects of radioactive waste management are the responsibility of the regulators and the producers of the waste, but the Government decides on overall policy. The relevant Departments are the Department for Environment, Food and Rural Affairs (in England); the National Assembly for Wales; the Scottish Executive; and the Department of the Environment, Northern Ireland.
4.5.4 The relevant regulatory authorities ensure that Government policy is implemented. These authorities are: the EA in England and Wales, SEPA in Scotland, the Environment and Heritage Service of the Department of the Environment, Northern Ireland and the NII (which regulates the management of radioactive waste on nuclear sites throughout the UK in respect of its production, treatment and storage). The FSA has responsibility for all aspects of food safety and is consulted on the setting of authorisations. It also has a substantial role in monitoring the marine and terrestrial environment. The authorisations set by the environmental regulators will also influence the processes that give rise to radioactive waste, and how it is treated, on nuclear sites. The main tool of regulation for the environmental regulators is RSA 93, under which authorisations for discharge of waste are issued. Environmental regulators have powers to shut down any operation that is causing unacceptable levels of pollution.

4.5.5 The NII and the relevant environmental regulators work together, but with different aims. For instance, the environmental regulators aim to protect the public and the environment by reducing radioactive discharges, while the NII aims to protect workers and the public by reducing the hazard from radioactive wastes held on site. Since a consequence of reducing discharges may be that more wastes will need to be stored on site, a balance often needs to be struck, giving due regard to the BPEO for managing the waste.

4.5.6 Producers of radioactive waste must manage it in ways that meet the regulatory requirements. The producers and owners of radioactive waste are also responsible for bearing the costs of management and disposal of waste, including the costs of regulation and those of related research undertaken by both themselves and the regulatory bodies.
Chapter 5: Trends in discharges, doses and concentrations

5.1 Discharges

5.1.1 An analysis of historic trends in liquid radioactive discharges, by industry sector, has been carried out for the period 1979 to 2000. Discharges of principal radionuclides were examined for the following sectors:

- nuclear fuel production and uranium enrichment;
- nuclear energy production;
- nuclear fuel reprocessing;
- research facilities and
- defence facilities.

5.1.2 The results of this analysis are presented in the form of line graphs. Figures 1.1 to 1.5 show liquid radioactive discharges from each of the above sectors. Note that the amount of activity in terabecquerels (TBq) is shown on a logarithmic scale in most cases, in order to accommodate large differences in activity between the different radionuclides discharged. See the box for an explanation of these measurement units. Data were taken largely from monitoring reported by the Ministry of Agriculture, Fisheries and Food (responsibility for this has now passed to the FSA) for England and Wales, and by SEPA for Scotland. Some measurements are from monitoring reported by the Environment Agency and other bodies.

5.1.3 These line graphs show liquid discharges only, since this initial strategy focuses on the need to reduce liquid discharges from coastal nuclear installations to the marine environment. Both liquid and aerial discharges will be addressed in the next issue of the strategy, due to be published at the end of 2005.

Measurement of radioactivity concentrations

Radiation is produced by the disintegration of atoms of radioactive isotopes of elements, or radionuclides. The activity of a given amount of a radionuclide is expressed by the rate at which these disintegrations occur, measured in becquerels (Bq). One becquerel equals one atomic disintegration every second. Radioactivity in liquid or airborne discharges is expressed in terms of becquerels. Measurements of radioactivity in air, water, sediment and biological media are expressed in becquerels per cubic metre (Bq/m3), per litre (Bq/l), per kilogram (Bq/kg) etc., as appropriate. These are known as activity concentrations.

The international system of units (SI) is used for measuring activities and activity concentrations. Common multiples and sub-units used include tera-, T (1 million million); giga-, G (1 thousand million); mega-, M (1 million) and kilo-, k (one thousand). Discharge authorisations for large nuclear installations are often given in GBq or TBq a year, for individual radionuclides or groups of radionuclides.
5.1.4 It should be recognised that, while the UK has always complied with international guidance when setting discharge authorisations, levels of discharge and public exposure that were considered acceptable in the past are not necessarily acceptable today. It is right to expect that improvements in technology will continue to deliver lower levels of radioactive discharges.

5.1.5 There have been some significant reductions in the discharges of some radionuclides over the period studied. In particular, there have been large and sustained reductions in discharges of the most radiologically significant nuclides from the reprocessing sector, caesium (Cs)-137, plutonium (Pu)-241 and ruthenium (Ru)-106, mainly due to new treatment plants such as the Site Ion Exchange Plant (SIXEP) and the Enhanced Actinide Removal Plant (EARP). There have also been substantial reductions in discharges of Cs-137 and Ru-106 from research facilities and of cobalt (Co)-60 discharges from defence facilities.

5.1.6 Discharges of some other radionuclides, however, have shown little change or have increased. A rapid rise in Tc-99 discharges from the reprocessing sector in 1994 and 1995 was a consequence of the operation of EARP. In 1994, this plant started to treat a backlog of liquid wastes, which had been temporarily stored pending construction of the treatment plant. Although it was known at the time EARP was designed that it would not remove Tc-99 from discharges and that this radionuclide was liable to bioaccumulate in some biota, the resulting doses were judged to be acceptable.

5.1.7 There have also been gradual increases in discharges of tritium (a radioactive isotope of hydrogen with the symbol H-3) and sulphur (S)-35, from the nuclear power sector, and of tritium and carbon (C)-14 from reprocessing. Tritium and C-14 are naturally occurring radionuclides that form a small proportion of the hydrogen in water and the carbon in carbon dioxide. Nuclear operations also produce tritium and C-14, so adding to the amounts present, although they remain comparatively small (e.g. for a typical nuclear power station, in the region of 7 grams of tritiated water in 200 tonnes of ordinary water a year). Efforts should be made to minimise the release of tritium and C-14 to the environment where possible.

5.1.8 In its inorganic form, tritium is generally of low radiological toxicity. However, opportunities for reducing tritium discharges will be pursued by nuclear operators wherever possible. Although in many cases it may not be technically possible at present to remove tritium from liquid discharges, the prospects for tritium abatement will be kept under review, including possibilities for changing the chemical form of discharges so that the impact is less.

5.2 Doses

5.2.1 Man is exposed to radiation from radioactive discharges by various pathways. In general, because most UK nuclear installations are on coastal sites, the primary exposure pathway is through consumption of fish and shellfish. In this case, dose is dependent on dietary habits as well as on the concentrations and the radiotoxicity of radionuclides in the foods concerned. Because liquid discharges contribute far more to concentrations in the marine environment than do airborne discharges, changes in estimated doses by this pathway usually mirror changes in liquid discharges of the most radiologically significant radionuclides, provided assumptions about dietary habits remain constant.

5.2.2 However, radionuclides differ in their behaviour in the marine environment. Some are taken up readily by organisms that contribute to the human food chain. Some are held in sediments and released slowly over a long period whilst others are highly mobile and
disperse rapidly. In some cases, and most notably around Sellafield, a significant part of the estimated dose to the critical group is due to the legacy of past discharges.

5.2.3 For 2000, the highest estimated doses from nuclear sites to the UK general public by the ingestion pathway were due to discharges from the Sellafield site. The critical group of high consumers of locally caught fish and shellfish for this site were calculated to have received some 0.15 mSv a year. This is 7.5% of the estimated dose to the same critical group in 1981. The estimated dose includes a contribution due to external exposure. Most of this estimated dose, from the consumption of seafood and external radiation due to Sellafield, resulted from historic discharges, mainly plutonium and americium. Recent and current discharges of Tc-99 contributed about 13% of the dose to Sellafield seafood consumers. Estimated dose to the critical group of fish and seafood eaters between 1971 and 2000, resulting from Sellafield’s discharges, is shown at Figure 2 (data from BNFL).

5.2.4 Table 1, reproduced from the Joint FSA and SEPA report “Radioactivity in Food and the Environment, 2000”, shows estimated radiation doses from discharges of radioactive waste in the UK in 2000. It should be noted that these figures include far field effects of Sellafield discharges, which account for the majority of exposure at some sites.

5.3 Concentrations

5.3.1 Environmental monitoring of radionuclide concentrations has been carried out in the UK for many years and a good time series of data is available for locations around several nuclear sites. However, because the sampling media and radionuclides measured may vary between these sites and sometimes also with time, it is not easy to tease out the more general trends for the UK as a whole, from the many thousands of data records available.

5.3.2 In an attempt to provide a meaningful yet concise indication of the situation, a review of the published monitoring data was carried out, for the period 1979 to 2000, using a set of eight radionuclides, in six sample types, at eight locations around the UK. The following criteria were used:


Sample types: fish, crustaceans, molluscs, Fucus sp. (seaweed), sediment, seawater.

Locations: Sellafield, Northern Ireland, Wylfa, Severn Estuary (Cardiff), Channel Islands, Sizewell, Hartlepool, Dounreay.

In addition, data are given for Fucus seaweed on the Scilly Isles, which has been monitored since 1987. This represents the nearest approximation of a UK “background” situation, relatively unaffected by discharges from UK installations, although historic data are only available for Co-60, Tc-99 and Cs-137. The locations for all sites are shown on Map 2 and details of the key indicators and suggested locations for future monitoring are given in Table 2 (Appendix 2).

5.3.3 The aim of this study was to provide an indication of general trends in the marine environment, without seeking to analyse the totality of available monitoring data. The results are shown in Figures 10.1 to 18.6 (Appendix 2). The graphs need to be interpreted with care. For instance, most measurements of activity concentrations are made to pre-set minimum reporting levels. If the actual concentration is below this limit, the limit itself is shown on the graph as the measured value. Minimum reporting levels may be changed due
to resource constraints, since it is more expensive to accurately measure smaller concentrations. Raising a minimum reporting level could therefore result in an apparent rise in concentration, where none has actually occurred. To aid interpretation, different symbols are used on the graphs for “less than reporting level” results and for measurements extrapolated from offshore concentration contours.

5.3.4 Although there are still some gaps in this database, a number of general trends are evident. Concentrations of Cs-137 have shown consistent reductions, for all locations and datatypes. With a few exceptions, trends for Co-60, Sr-90, plutonium (Pu-239/240) and americium (Am-241) are also generally downward. The picture for H-3 and C-14 is rather less clear. The rise in Tc-99 levels after 1994, as a result of increased discharges from Sellafield, shows up at Sellafield, Northern Ireland, Wylfa, Dounreay, Hartlepool and Sizewell. This is as expected, as a result of its dispersion by prevailing currents.

5.3.5 The intention is to build on this database in future years, by ensuring the continuity of data collection and supplementing monitoring programmes where necessary. The development of predictive modelling based on discharge data, supported by appropriate measurements, will help to demonstrate how the UK is meeting the OSPAR target for 2020. Work is currently under way to develop robust methodologies for this purpose. The OSPAR Commission, the European Commission and other international fora are carrying out further work on radioactivity in the marine environment. The UK will seek to ensure, as far as possible, consistency and comparability in national and international monitoring programmes for the marine environment, in terms of sampling, analytical methodology, quality assurance and data interpretation.
Chapter 6: Considerations for further reducing discharges

6.1 Achieving a balance

6.1.1 It is important that decisions relating to radioactive waste management should be based on the best scientific information and analysis of risks. This should include consideration of risks to human health (to members of the general public and to workers), and, where sufficient information is available, risks to non-human species and the wider environment. Pressures to reduce these risks should be seen alongside issues such as the technological feasibility and cost of introducing measures to reduce discharges.

6.1.2 Balancing and prioritising these and other considerations (e.g. international legislation and agreements, sustainable development, the precautionary principle) is a matter of fine judgement. Arguments were put forward by some respondents to the consultation paper in favour of giving a heavy weighting to the risk-based system of radiological protection of humans. Keeping estimated doses to critical groups ALARA through the application of BPM has driven much of the reduction in discharges over the last 20 years, and will continue to be a major factor in setting discharge limits. The Government considers that applying ALARA/BPM will reduce discharges sufficiently to achieve the objective of the OSPAR Strategy. Other respondents, however, took the view that only discharge reductions well beyond those required on the basis of human radiation protection would suffice to meet the OSPAR target for 2020.

6.1.3 Since 1993, the progressive reduction of discharge limits, and of actual discharges, has been a central tenet of the way in which radioactive discharges from any given site are controlled in the UK. However, this strategy recognises that, within the policy of progressive reduction, some flexibility will need to be maintained to safeguard other key Government objectives, in particular the safe and timely decommissioning of redundant facilities, the clean-up of the historic legacy of radioactive wastes, security of energy supply, the expected growth in the use of radionuclides in medicine and the operational capabilities of the armed forces.

6.1.4 The other considerations, discussed in more detail below, provide the context in which progressive reduction is applied. They ensure that decisions about discharge reductions are made in ways that afford maximum protection for people and, where appropriate information is available, non-human biota, whilst recognising that considerations of cost, societal detriment or practicality may apply in specific situations.

6.2 Considerations of risk and exposure

6.2.1 The perception of risk attached to exposure to ionising radiation from radioactive discharges, and the degree of risk that is considered to be acceptable, vary between individuals. The internationally accepted upper limit for tolerability of risk is reflected in the dose limit for members of the public of 1 mSv a year (see paragraph 4.2.4). At the other end of the scale is a level of risk that is generally considered as negligible in comparison with other risks that form a part of daily life.
6.2.2 Work carried out by HSE on the acceptability and tolerability of risks has shown that an annual risk of death of around one in a million or less is broadly acceptable. It represents about one hundredth of the risk of dying in a traffic accident. This level of risk, whilst not entirely negligible, does not cause most people to alter their everyday behaviour. In terms of the risks associated with radioactive discharges, an exposure of 0.03 mSv a year would equate to a risk of one in a million.

6.2.3 Although the risk-based approach to radiological protection is internationally accepted, its validity was questioned by some respondents to the consultation, who argued that the models being applied are defective or not relevant to the situation for which they are used. A working group of the Committee on Medical Aspects of Radiation in the Environment (COMARE), a Government Advisory Committee, is re-examining the robustness of current risk models for radiation and health that apply to exposure to radiation from internal radionuclides and is due to report in 2003.

6.2.4 The NRPB believes that even the lowest dose of ionising radiation, whether natural or man-made, has a chance of causing cancer and the ICRP has stated “it must be presumed that even small exposures to radiation may be deleterious to health”. For the present, though, the risks from radiation exposures at very low levels remain theoretical and there is no established link between such low doses and cancer death rates. For instance, natural background radiation in Cornwall gives an average dose to residents of 7.6 mSv a year, around three times the UK average, but there is no discernible difference in cancer deaths.

6.2.5 By 2020, the discharge reductions set out in this strategy are expected to reduce the estimated mean dose to a representative member of a critical group (see explanation at paragraph 4.1.3), due to ongoing authorised liquid discharges to the marine environment, to 0.02 mSv a year (or less if technology allows). This is just 2% of the international dose limit for members of the public and less than 1% of natural background. It can be compared with the dose of 0.03 mSv received by a person taking one return flight between London and the Canary Islands, from cosmic radiation (see paragraph 4.1.2).

6.2.6 Consultation responses showed that there was some misunderstanding over this figure of 0.02 mSv a year. It is not the intention to impose it as an annual dose limit or constraint. Neither is it a threshold below which the OSPAR target of “close to zero” concentrations will be assumed to have been reached. Rather, if the discharge reductions set out in this strategy are achieved as expected, this would lead by 2020 to estimated critical group doses of 0.02 mSv or less from ongoing routine discharges. This will be one of a number of indicative targets, relating to radioactive discharges and their effects, that the Government will be setting and vigorously pursuing in the period to 2020.

6.2.7 Similarly, it is expected that the dose impact in neighbouring countries will reduce further, from the current very low levels. A report by the Radiological Protection Institute of Ireland in September 2000 estimated the dose to a heavy consumer of seafood in 1999, from measured artificial radionuclides, to be 0.00133 mSv. This is less than a hundredth of the estimated dose of 0.15 mSv a year to the Sellafield critical group. The same report pointed out that this dose could be put into context by comparing it to the estimated 0.148 mSv a year received by seafood consumers in Ireland from naturally-occurring polonium-210. The impact of the UK’s radioactive discharges further afield is even less than in Ireland.

However, the UK recognises that any level of radioactive contamination remains of concern to certain of its neighbours, even if, on the basis of current knowledge, it poses no threat to human health or the environment.
6.3 Environmental considerations

6.3.1 Prior to agreement of the OSPAR Convention in 1992, the effects of radioactive discharges were considered almost exclusively in terms of doses to man. The current system of radiological protection for man, as developed by the ICRP, has in the past been assumed to be sufficient in itself to protect the environment. The ICRP has previously stated that “the standard of environmental control needed to protect man to the degree currently thought desirable will ensure that other species are not put at risk”\textsuperscript{12}. However, there is now a growing recognition that protection of the environment merits attention in its own right, as evidenced by international initiatives being led by the ICRP and the Nuclear Energy Agency (NEA) of the Organisation for Economic Co-operation and Development (OECD). The OSPAR Strategy with Regard to Radioactive Substances is primarily concerned with reducing concentrations of radionuclides in the marine environment, with dose to man as a significant supporting consideration.

6.3.2 There is no current evidence that exposure to anthropogenic radiation is causing damage to wildlife in the UK. The OSPAR Quality Status Report 2000 for the Celtic Seas examines the impact of radioactivity in that part of the UK marine environment where man-made radionuclide concentrations are generally at their highest. It states: \textit{“Reviews of available data on the effects of chronic radiation exposure on aquatic organisms indicate that the estimated dose rates to organisms in the north-eastern Irish Sea and elsewhere in Region III [the Celtic Seas], are unlikely to produce adverse effects at the population level. This applies even to historical dose rates that are likely to have been more than an order of magnitude greater than at present.”}\textsuperscript{17}

6.3.3 Concern has been expressed in some consultation responses that exposure to levels significantly higher than natural background may occur and that risks to wildlife are not explicitly considered in human dose assessment methodology. At present, it is recognised that a radiological protection framework for species other than humans is at a relatively early stage of development, internationally. The UK, other countries and international organisations are funding research projects on radiological effects on non-human species. Guideline values have been developed for exposure levels below which effects on populations of various groups of biota are thought unlikely to occur. As part of the OSPAR Strategy, the OSPAR Commission is developing environmental quality criteria for the protection of the marine environment from adverse effects of radioactive substances, and is to report on progress by the year 2003.

6.3.4 Targets for concentrations of radionuclides in environmental media cannot be set with confidence at present. They will be developed in the light of work to be carried out by the OSPAR Commission, and in the light of further monitoring and modelling of environmental concentrations of radionuclides around the UK coastline. The UK will aim to ensure compatibility between the set of radionuclides and data types used as indicators of the situation in the UK marine environment, those used more generally by OSPAR contracting parties, and the work being carried out internationally on radiological effects on non-human species.
6.4 Technological considerations

6.4.1 The development of new or modified operational processes, abatement techniques and waste management approaches holds promise for further reductions of radioactive discharges to the environment. Any such technological options should avoid increasing risks to workers, be practicable, entail costs which are proportionate with the benefit they bring, ensure wastes are maintained in a safe and passive form and not create other problems, such as increased risk or spread of contamination. The balance between the costs and benefits of technological options is discussed further at Section 6.6.

6.4.2 Modification of operational processes, in order to reduce discharge arisings at source or to enable their diversion into extended storage, is a long term option. It may take several years to develop and construct new or modified processes and to go through the necessary regulatory procedures involved. Abatement is essentially the provision of an add-on system to transfer radioactivity in a gaseous or liquid form into a solid form for long term storage and/or disposal. Waste management options could include simply storing liquid wastes on site while abatement technology is developed (as was done with medium active concentrates at Sellafield while EARP was being planned and constructed). Alternative approaches might involve the routing of some liquid waste streams to high level waste storage, where this is possible, or the conversion of a waste stream to a chemical form that has less impact on the environment.

6.5 Health and safety considerations

6.5.1 Retaining on site radioactivity that would otherwise be discharged to the environment reduces the dose to members of the general public from such discharges. However, progressive reduction in discharges should not take precedence over the risk to workers unless tangible net benefits can be demonstrated. Equally, it will be important to ensure that discharge reductions are not achieved at the expense of increased accident risk, due, for instance, to storage of greater quantities of waste on site, for a longer time, in unsatisfactory conditions. The systems of control for nuclear safety and nuclear waste management in the UK would not, in any case, allow the risks from such factors to increase unacceptably.

6.5.2 A well-developed system of occupational radiation protection ensures that doses to workers are regularly assessed and do not exceed statutory limits. However, in some situations, radioactivity discharged to the environment may increase the exposure of particular members of the public as a result of their occupation, even though such exposure is not normally considered to be “occupational”. For instance, fishermen in the vicinity of Sellafield were estimated to receive a skin dose (not effective dose) of around 0.12 mSv in 2000 from handling nets and fishing gear, due to radioactivity adsorbed onto particles of sediment from historic discharges. An Environment Agency study suggests that, albeit in unlikely circumstances, some workers in sewage treatment plants could potentially be exposed to estimated effective doses up to 0.238 mSv a year. This would be largely as a result of excreta from cancer patients receiving radiotherapy and assumes all discharges to be made at the authorised limits applying at the time of the study. These kinds of exposure of members of the public are also taken into account by the regulatory authorities when setting discharge limits.

6.6 Cost effectiveness

6.6.1 In considering options to reduce radioactive discharges, having regard to the application of BPM, costs and benefits need to be made clear, to ensure that the most cost-effective option is
adopted and that costs are not grossly disproportionate to the benefits obtained. The UK Strategy on Sustainable Development\textsuperscript{19} requires account to be taken of costs and benefits, including those which cannot be valued in monetary terms, in a decision matrix that includes public values, risks and uncertainties. The Government intends to take costs fully into account in determining how to achieve the objective of the OSPAR Strategy. The Government considers that applying the ALARA principle will reduce discharges sufficiently to achieve that objective. In the unlikely event that it appeared that the application of ALARA/BPM would not deliver the objective of the OSPAR Strategy, the Government would urgently review this strategy.

6.6.2 Benefits of reducing radioactive discharges include reducing the risk to non-human species and to the environment, as well as reducing doses and risks to humans. Benefits in terms of public perception and confidence, both in the UK and abroad, have an economic value for fishing and shellfish industries, tourism and trade, and should be taken into account. Public values and attitudes to risks must also be recognised as relevant factors in decisions about radioactive discharges.

6.6.3 Costs of discharge reduction must be taken to include wider economic and societal detriment, as well as monetary expenditure. Increased industry expenditure is likely to be passed on to customers and/or taxpayers. If plants become uneconomic, they may close, with consequent job losses. In some cases, where closure of the plant is already foreseen, it may not be appropriate to expend great amounts of resource to reduce discharges if they would in any case cease within an acceptable timescale. Similarly, the lead time needed for technological improvements to be put in place needs to be viewed in terms of the planned life of the process. We believe that this strategy will meet the OSPAR objective and that it is fully in line with Government policy on better regulation\textsuperscript{20}, that the cost of reducing discharges should not be grossly disproportionate to the benefits.

6.6.4 The Government recognises that organisations in the nuclear and non-nuclear industry sectors, and those involved in the medical and health science uses of radioactivity, have concerns about the cost effectiveness of the proposals in this strategy. A Regulatory Impact Assessment, which is a formal requirement for policy documents of this kind, is at Annex 2. Its main conclusions are as follows:

- There is a lack of information on tangible benefits to be derived from the strategy. Some notional gains may be seen in pollution-related health, and in activities in areas benefiting from a cleaner environment, such as tourism and fishing, especially around the Irish Sea coasts of Britain. In addition, there is the intangible benefit of improvements in international relations with neighbouring countries.

- The base case scenario is likely to cost the UK as a whole some £23 - 50 million a year, to 2020. Implementing the discharges strategy is likely to cost a similar amount, up to perhaps £59 million/year.

- The incremental cost of implementing the strategy, over the base case, is therefore relatively small at between 0 and £9 million a year, to 2020. Considerable uncertainty surrounds the base data, so the margin of error is potentially high.

- The key costs will be felt within BNFL, both through loss of generating revenue and some costs brought forward for Magnox decommissioning. There are also external societal costs associated with job losses in local economies.

- Going substantially beyond the discharge reductions set out in the strategy would result in very much higher costs, of the order of hundreds of millions of pounds a year.
Chapter 7: Proposals for discharge reductions 2001-2020

7.1 Nuclear fuel production and uranium enrichment

Springfields

7.1.1 The UK imports uranium ore concentrate (UOC) as the raw material for the production of nuclear fuel. At its site in Springfields, Lancashire, British Nuclear Fuels plc (BNFL) manufactures fuel elements for nuclear reactors. UOC is converted into uranium metal fuel for Magnox reactors, or alternatively into uranium hexafluoride, which is sent to Capenhurst for enrichment. Enriched uranium hexafluoride is returned to Springfields and used in the manufacture of uranium oxide fuel for advanced gas-cooled reactors (AGRs). The locations of these facilities are shown on Map 1.

7.1.2 At Springfields, discharges of alpha-emitting radionuclides (mainly uranium and thorium isotopes and their daughter products) to the River Ribble have declined significantly over the last two decades, due to the operation of uranium recovery plants and the selective processing of low thorium-containing grades of uranium ore concentrate. Although some high thorium ores are currently stored on site, BNFL has confirmed that these will not be processed and will be returned to their originator.

7.1.3 Beta discharges are principally the short-lived decay products of uranium isotopes U-238 and U-235 (see the box for an explanation of radioactive decay). These have remained relatively constant over the last twenty years, with some fluctuations. Beta discharges from Springfields are related to fuel production output, which varies with demand.

Radioactive decay

Radioactivity involves the spontaneous disintegration of atomic nuclei, a process which is termed decay and which results in the release of ionising radiation. Decay transforms one radionuclide into another and this process continues until a stable, non-radioactive nuclide is attained. This usually results in a decay series. The newly formed radionuclides are referred to as daughters or daughter products of the decaying radionuclide. As the amount of a radionuclide diminishes through decay, the radiation emitted by it decreases proportionately.

The rate of decay of a radionuclide is characterised by its half-life. This is the time taken for half of the atoms of a given quantity of the radionuclide to decay, so that its activity (measured in becquerels) is reduced by half. Each radionuclide has a unique and fixed half-life. Half-lives can vary from a fraction of a second to millions of years. For example, argon-41 has a half-life of 1.8 hours, tritium has a half-life of 12 years and uranium-238 has a half-life of 4,500 million years.

7.1.4 Doses to a number of critical groups as a result of discharges from Springfields are currently estimated to be below 0.03 mSv a year and are likely to decrease further. However, critical group members receive larger overall doses, due mainly to historic discharges from the Sellafield site. The most important marine pathway is external exposure, due to adsorption.
of radioactivity on the muddy areas of river banks and in salt marshes. The current total dose (including the Sellafield contribution) to houseboat dwellers in the Ribble estuary is estimated to be in the region of 0.15 mSv a year. Monitoring undertaken by the Environment Agency and BNFL shows an overall decrease in total dose to this group from around 0.35 mSv in 1981. This downward trend is expected to continue.

7.1.5 Monitoring for thorium in biota from the Ribble estuary indicates that concentrations in fish are not significantly different from those expected from natural sources. Similarly Th-232, the longest lived isotope of thorium, is close to background levels in sediment, even in the vicinity of the discharge pipeline.

**Capenhurst**

7.1.6 As noted at paragraph 7.1.1, enrichment of uranium hexafluoride (to increase its U-235 content up to 5% by weight) is carried out at Capenhurst in Cheshire, at a centrifuge enrichment facility run by URENCO Capenhurst Ltd. BNFL has responsibility for dismantling the redundant gaseous diffusion plant and tritium processing plant on its adjacent Capenhurst site. This work is well advanced. The very small amounts of liquid wastes (containing traces of uranium) from the URENCO facility are discharged via the BNFL site, so the discharges from both operators are considered together here.

7.1.7 BNFL’s decommissioning operations and the works incinerator were the principal source of small amounts of radioactive discharges, mainly tritium, uranium and its daughter products. A dry scrubber has now been fitted to the waste incinerator, which consequently produces no liquid effluents. The very small discharges from elsewhere on the site give rise to an estimated critical group dose of less than 0.001 mSv a year, even on the most pessimistic assumptions. Accelerating the decommissioning programme, which would increase discharges, would not raise the estimated dose above 0.003 mSv a year. There are no plans to build new facilities at Capenhurst.

**Sellafield MOX Plant**

7.1.8 The Sellafield MOX Plant (SMP) manufactures mixed (uranium and plutonium) oxide fuel, using plutonium separated in the Thermal Oxide Reprocessing Plant (THORP) and belonging to overseas customers. The MOX fuel produced will be returned to the overseas customers concerned. SMP utilises a dry process, which results in negligible liquid discharges. The main radionuclides involved are Pu-241 and Am-241. The estimated dose to the critical group as a result of liquid discharges from SMP is just 0.000000003 mSv a year.

**Possibilities for reducing discharges**

7.1.9 Future discharges from the uranium enrichment and fuel production sector will depend on the demand for nuclear fuels, particularly Magnox fuel (the manufacture of which accounts for the majority of the activity in discharges). They will be closely linked to the timetable for closure of Magnox nuclear power stations. In line with the planned closure of all remaining Magnox Nuclear Power Stations, the manufacture of Magnox fuel at Springfields will cease in 2006, with suitable provision for future fuel requirements of stations remaining operational beyond this date. Production of uranium hexafluoride will also cease by this date. BNFL will continue to fabricate oxide fuel at Springfields, primarily for UK AGR reactors.
7.1.10 BNFL has reviewed a study undertaken in the early 1990s, which identified 20 possible alternatives to the current operating regime, in order to check whether there have been fresh developments which may reduce discharges and impacts, and to update implementation costs. One of the options (selective processing of low thorium ores) has been implemented for some years now. Another (tidal discharge) has been subject to extensive trials and a somewhat modified version of this strategy is currently operated.

7.1.11 All of the remaining options regarded as technically feasible involve the treatment of the liquid “raffinate” arising from the uranium ore concentrate purification process. The least cost option, evaporation and beta decay storage, has been provisionally estimated to cost £20-25 million. Expenditure of this order is unlikely to be justified, given that all the identified abatement options would require between four and six years to implement, by which time the plant operations would be closed down or very close to closure. It is unlikely that any of the identified options would thus have a significant effect in practice on estimated critical group doses or environmental concentrations.

7.1.12 Projected operational liquid discharges for 2001 to 2020 from the nuclear fuel production and uranium enrichment sector are shown at Figure 3 (see note below regarding total beta). These decline sharply after 2006, reflecting the planned cessation of Magnox fuel manufacture and uranium hexafluoride production, linked to the programmed closure of the Magnox power stations. By 2020, complete cessation of beta/gamma discharges and a 96% reduction in alpha discharges are expected. Discharges from the decommissioning of facilities at Springfields and Capenhurst are not included in the profile at Figure 3 and will need to be assessed at a later date. All of the liquid discharges from the nuclear fuel production and uranium enrichment sector are made to OSPAR Region III, the Celtic Seas.

Note: The contributing beta-emitting nuclides are mainly Pa-234m, Th-234 and Th-231. However, for reporting purposes, “total beta” is calculated as a multiple of Pa-234m. This practice is followed here for projected discharge data. With respect to the alpha-emitting nuclides, “total alpha” is calculated as the sum of U-238, U-235, U-234, Th-232, Th-230, Th-228 (and daughter nuclides) and Pb-210, where the contribution of the Th-228 daughters is derived as a multiple of the parent nuclide. Again, this approach is reproduced as far as possible in the forward discharge projections presented here. See Annex 3 for a further explanation of the use of the terms “total alpha” and “total beta”.

<table>
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<tr>
<th>STRATEGY TARGETS</th>
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<tr>
<td><strong>By 2006</strong>, production of Magnox fuel and uranium hexafluoride at Springfields are expected to cease, with consequent major reductions in alpha and beta discharges.</td>
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<tr>
<td><strong>By 2020</strong>, total liquid discharges of beta-emitting radionuclides from the uranium enrichment and fuel production sector are expected to be reduced from around 120 TBq a year to virtually zero.</td>
</tr>
<tr>
<td><strong>By 2020</strong>, total liquid discharges of alpha-emitting radionuclides from the uranium enrichment and fuel production sector are expected to be reduced from about 0.25 TBq to less than 0.01 TBq a year.</td>
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7.2 Nuclear energy production

7.2.1 Nuclear energy currently accounts for about 27% of the UK’s electricity production. The Government wishes to maintain a diversity of power sources in the UK and is committed to meeting its targets on the reduction of carbon dioxide emissions. It is envisaged that there will continue to be a role for nuclear power production in the UK, but there are no current proposals for further development and this strategy assumes that no new nuclear power stations will become operational during the period to 2020.

7.2.2 Most of the nuclear power reactors in the UK are of the gas-cooled type (either the earlier Magnox reactor or the later AGR reactor) and were constructed between 1956 and 1988. A single pressurised water reactor (PWR) started operation at the Sizewell “B” site in 1995. The locations of nuclear power stations are shown on Map 1.

Magnox power stations

7.2.3 BNFL’s Magnox operations cover eleven power stations with Magnox gas-cooled reactors. At the time of publication of this strategy, five of these are currently closed down, three of which have been defuelled and are being decommissioned (Berkeley, Trawsfynydd and Hunterston “A”). Hinkley Point “A” is shut down and is being defuelled prior to decommissioning. Bradwell was shut down in Spring 2002 and is awaiting defuelling.

7.2.4 Magnox power stations are of two basic designs. Most of the operating stations are of the older, steel pressure vessel type, but two (Oldbury and Wylfa) are of the newer concrete pressure vessel type. All use uranium metal as fuel and have graphite moderators. The fuel elements consist of bars of uranium encased in a cladding made from a magnesium alloy known as Magnox. Pressurised carbon dioxide gas is used to transfer heat from the reactor to the boilers, where steam is produced to drive the turbines.

7.2.5 The most radiologically significant radionuclides in liquid discharges from Magnox power stations are caesium isotopes Cs-134 and Cs-137. These arise mainly by leakage from fuel elements in the cooling ponds, where spent fuel is stored prior to being sent for reprocessing. The exception is Wylfa power station, on the island of Anglesey (Ynys Môn) in Wales, which has a dry store for spent fuel instead of a cooling pond, and consequently lower radiocaesium discharges.

7.2.6 Caesium removal units, which incorporate beds of ion exchange resin, are used to reduce the amount of caesium and other radionuclides in cooling pond water. This is a key means of controlling liquid radioactive discharges. However, the resin cannot be recycled and use of the units generates solid intermediate level waste (ILW), which is stored in tanks on site prior to encapsulation. Greater use of ion exchange units would also lead to increases in these solid waste arisings and could result in higher operator doses. The performance and safe use of higher capacity ion exchange resins, which would reduce the volume of solid waste arisings, is currently being investigated. Work is also being done to re-examine the root causes of radiocaesium release from fuel stored in ponds. In addition to the caesium removal systems the pond water treatment plant systems also incorporate sand pressure filters for particulate control and cation and anion resins for chemical control. The cation and anion resins are regenerable and the regenerant is discharged after neutralisation.

7.2.7 The largest liquid discharge in terms of activity is tritium. This is of low radiotoxicity and contributes relatively little to doses to the public. To minimise oxidation of the graphite moderator, a small amount of methane is added to the carbon dioxide coolant and this leads to the production of water vapour. At most sites, this is removed by driers that contain a
desiccant. The desiccant is re-cycled by driving off the water it has absorbed, which contains tritium and other radionuclides.

7.2.8 Estimated doses to critical groups of fish and seafood eaters, from the operation of Magnox power stations, are less than 0.03 mSv a year. This includes the contributions from external exposure associated with discharges.

Advanced gas-cooled power stations

7.2.9 British Energy Generation Ltd operates seven power stations with twin AGRs. These were developed from Magnox stations as the next generation. AGR stations use uranium oxide fuel with stainless steel cladding, which allows higher operating temperatures and greater efficiency. As with the Magnox stations, graphite is used as a moderator and carbon dioxide as a heat transfer medium. Water vapour is removed from the carbon dioxide by passing it through dryers containing a desiccant. Regeneration of this desiccant is the main source of discharges of tritium and S-35 (which arises from impurities in the graphite moderator) from AGR stations.

7.2.10 As at the Magnox stations, spent fuel from AGRs is stored in ponds, where ion exchange resins are used to reduce radioactivity in the water. Oxide fuel cladding does not corrode significantly in water. Despite this, pond water is the main source of the radiologically significant radionuclide Co-60, produced principally by the irradiation of fuel components. A study is under way of possible improvements to pond management to achieve reductions in Co-60 discharges. Cs-134 and Cs-137 are also present in cooling pond water, but at much lower levels than at Magnox stations.

7.2.11 Estimated doses to critical groups of fish and seafood eaters, from the operation of AGR power stations, are typically less than 0.02 mSv a year.

Pressurised water power station

7.2.12 PWRs use uranium oxide fuel with zircalloy cladding. The mix of radionuclides discharged from the PWR at Sizewell “B” is similar to that from the AGRs, but the amounts are in general far smaller. The estimated dose to the critical group of fish and seafood eaters, from the operation of Sizewell “B”, is less than 0.005 mSv a year. Measured gamma dose rates are indistinguishable from natural background, except in the immediate vicinity of the power station.

Possibilities for reducing discharges

7.2.13 Greater use of ion-exchange technologies could be successful in reducing discharges of Cs-137 and Co-60 from spent fuel ponds. At each Magnox station, pond and fuel management options are under review. Part of this exercise involves re-examining the root causes of radionuclide release from the fuel storage ponds. Higher capacity resins for radiocaesium removal are also being introduced. Use of such resins reduces the volumes of solid waste arisings but dose implications for workers have to be considered carefully. Any solid wastes produced need to be in forms that are suitable for long term management (which could include potential future disposal in a repository).

7.2.14 For the AGR stations, the availability of more efficient ion-exchange resins is also kept under review. New resins have recently been installed at the Sizewell “B” PWR in order to improve the treatment of pond water. There is also some potential for improving the use that is made of existing treatment plant, and the management of pond water. Recent reviews of plant
operations have identified modifications that could be made to two AGRs in order to direct effluent streams that are currently not subject to ion exchange through the pond water treatment plant. These changes may lead to a slight reduction in discharges of Co-60 at one station and Cs-137 at the other. It is anticipated that similar opportunities may be identified at other sites.

7.2.15 The radionuclide that is most prominent in terms of activity (as Bq) in liquid effluents is tritium, although the resultant dose is very small. In the discharge, tritium is generally present in large volumes of water. It is not practicable to separate tritium from water, nor to store the liquid arising from regeneration of desiccant or convert it to solid ILW. Evaporation of tritiated water causes a greater off-site dose than discharge to sea. The possibility of storing specific tritium-containing liquors has been explored. However, the risks to workers and the public arising from the storage, transport and treatment of high specific activity tritiated liquids far outweigh any benefits from reducing discharges.

7.2.16 Disposing of used desiccant (see paragraph 7.2.9), instead of regenerating it, would be possible in theory if carried out on more or less a daily basis, but in practice major plant modification would be needed to avoid the need to shut the reactors down each time. This potential abatement option and the others described above would produce increased quantities of solid or liquid ILW, with no identified long term management option. Up to 20 tonnes per reactor per week could be produced in the case of desiccant non-regeneration. Such proposals would be unlikely to gain regulatory approval if the increase in stored wastes could lead to increased doses to workers. Airborne discharges might also increase as a consequence of reducing liquid discharges. Any environmental benefits obtained from such abatement options need to be measured against these considerations, as well as the financial costs, which are likely to be very high.

7.2.17 As a graphite-moderated nuclear reactor ages, greater quantities of C-14 are released from corrosion of the graphite core, leading to increased amounts of this radionuclide in liquid and atmospheric discharges. In the absence of either abatement technology or plant closures, C-14 emissions could in theory rise from the current level of around 10 TBq a year to 20-30 TBq a year by 2020. In practice, discharge levels are likely to level off and decline before 2020 as more nuclear power stations close down.

7.2.18 Another effect of ageing at AGRs is the deposition of carbon on boiler tubes, which leads to deterioration in heat transfer and reduced power generation. This problem has been halted, and even partially reversed, at Hartlepool AGR by injecting carbonyl sulphide (COS) into the carbon dioxide coolant. However, this has been observed to result in greater discharges of S-35. It is not necessary to inject COS at all AGRs because in some cases the level of COS due to impurities is already high enough. If COS injection were to be implemented at those AGRs that would benefit, it has been estimated that S-35 in liquid discharges could rise from the current level of about 4 TBq a year to around 7 TBq a year, in the absence of abatement measures or plant closures. This possibility is reflected in the projected discharge profiles at Figures 4.1 to 4.3, although the extent of the COS injection programme is not certain at present. Plant modifications to achieve abatement would be difficult and expensive, whereas the impact of S-35 (which has a 3-month half-life) is extremely small.

7.2.19 The pattern of radioactive discharges from the nuclear energy production sector until 2020 will be determined to a large extent by decisions taken on the operating lifetimes of the Magnox and AGR reactors. In Spring 2002, the Magnox power station at Bradwell closed down. In June 2002, BNFL announced their decision, on economic grounds, to bring forward the closure dates of Calder Hall and Chapelcross Magnox stations to 2003 and 2005.
respectively (previously planned for 2006-8 and 2008-10). All the remaining Magnox stations will close by 2010, at the latest. Individual lifetime planning assumptions for the Magnox stations are shown below. Actual closure dates may be earlier than those shown, for economic or technical reasons.

7.2.20 The consultation document indicated that a possible option for the two concrete pressure vessel stations (Oldbury and Wylfa) might be to convert them to run on a new type of ceramic oxide fuel called MagRox. MagRox fuel would not need to be reprocessed in the same way as Magnox fuel. This would enable Oldbury and Wylfa to continue to operate beyond the closure of the Magnox reprocessing facility at Sellafield. Although initial trials were technically successful, BNFL has taken the decision not to pursue this option, on economic grounds.

### Magnox Power station closure programme

<table>
<thead>
<tr>
<th>Station</th>
<th>Latest date for closure</th>
<th>Age at latest closure date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calder Hall</td>
<td>2003</td>
<td>47</td>
</tr>
<tr>
<td>Chapelcross</td>
<td>2005</td>
<td>46</td>
</tr>
<tr>
<td>Dungeness A</td>
<td>2006</td>
<td>41</td>
</tr>
<tr>
<td>Sizewell A</td>
<td>2006</td>
<td>40</td>
</tr>
<tr>
<td>Oldbury</td>
<td>2008</td>
<td>41</td>
</tr>
<tr>
<td>Wylfa</td>
<td>2010*</td>
<td>39</td>
</tr>
</tbody>
</table>

* Continuing to run Wylfa to this date will depend on the successful outcome of a further Periodic Safety Review.

7.2.21 AGR stations will continue to operate while it is safe and economic for them to do so. There are currently no planned dates for station closures. In order to arrive at projected discharges from the nuclear energy production sector, it has been assumed that AGR stations will close on the dates used in the 1998 UK Radioactive Waste Inventory, updated where necessary to reflect subsequent life-extensions. Actual closure dates may be earlier or later than these, for economic or technical reasons. The PWR station Sizewell “B”, the UK’s newest nuclear power station, is expected to operate until 2035. Although impending closure may be a factor in investment decisions taken by the operators, there will be no relaxation of the requirement for the use of BPM to minimise discharges, or of the reviews of discharge authorisations carried out by the environmental regulators. These will continue to apply throughout the decommissioning phase and as long as the site remains under regulatory control.

### Assumed AGR and PWR closure dates

<table>
<thead>
<tr>
<th>Station</th>
<th>Assumed closure date</th>
<th>Age at assumed closure date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hinkley Point B</td>
<td>2011</td>
<td>35</td>
</tr>
<tr>
<td>Hunterston B</td>
<td>2011</td>
<td>35</td>
</tr>
<tr>
<td>Dungeness B</td>
<td>2013</td>
<td>30</td>
</tr>
<tr>
<td>Hartlepool</td>
<td>2014</td>
<td>31</td>
</tr>
<tr>
<td>Heysham 1</td>
<td>2014</td>
<td>31</td>
</tr>
<tr>
<td>Heysham 2</td>
<td>2023</td>
<td>35</td>
</tr>
<tr>
<td>Torness</td>
<td>2023</td>
<td>35</td>
</tr>
<tr>
<td>Sizewell B</td>
<td>2035</td>
<td>40</td>
</tr>
</tbody>
</table>
7.2.22 Discharges of S-35 and tritium from AGRs will fall significantly when generation ceases and the gas dryers are no longer needed. Discharges of other radionuclides are expected to continue at normal rates until defuelling is complete. Thereafter discharges will depend on decontamination and other decommissioning work, with short term peaks likely (for instance draining of cooling ponds). Detailed predictions have not yet been made, so no credit for any reduction in other radionuclides by 2020 has been included in the current strategy.

7.2.23 The projected liquid discharge profiles for 2001 to 2020, from the nuclear energy production sector, are at Figures 4.1 to 4.3. Figure 4.1 shows total discharges, while 4.2 and 4.3 show discharges to OSPAR Regions II (Greater North Sea) and III (Celtic Seas), respectively. These discharge profiles indicate expected reductions of about 85% in total beta/gamma discharges and about 70% in tritium discharges, by 2020. It may be noted that the profiles for projected beta/gamma discharges do not reduce as sharply as might be expected from the station closure dates indicated above. This is because post-operational clean-out work, including the emptying of fuel ponds, will need to continue for some years after the closure of reactors, giving rise to further discharges. It is expected that this work will be largely completed, and discharges greatly reduced, by 2020. The rise in alpha discharges between 2005 and 2015 is due to post-operational clean out of the shut down Magnox stations. Alpha discharges will reduce to very low levels by 2020.

<table>
<thead>
<tr>
<th>STRATEGY TARGETS</th>
</tr>
</thead>
<tbody>
<tr>
<td>■ By 2010, all of the currently operating Magnox power stations are expected to have closed down, with consequent major reductions in discharges following defuelling and post-operational clean-out.</td>
</tr>
<tr>
<td>■ By 2020, total beta/gamma discharges (excluding tritium) from nuclear energy production are expected to be reduced from more than 10 TBq to less than 1.5 TBq a year.</td>
</tr>
<tr>
<td>■ By 2020, discharges of tritium from nuclear energy production are expected to be reduced from more than 2800 TBq to about 850 TBq a year.</td>
</tr>
</tbody>
</table>

7.3 Spent fuel reprocessing

Sellafield

7.3.1 BNFL operates Magnox and oxide fuel reprocessing plants at its Sellafield site in Cumbria. This is the largest nuclear complex in the UK and also includes the Calder Hall Magnox nuclear power station. The facility handles spent nuclear fuel from the UK nuclear power programme and from abroad (see box “What is Reprocessing?”). The location of Sellafield is shown on Map 1. As well as the reprocessing of spent fuel, activities giving rise to radioactive discharges include decommissioning and clean up of redundant facilities and management of historic stored wastes. Decommissioning and clean up activities are expected to continue for many years.

7.3.2 Discharged radionuclides of primary importance are C-14, Co-60, Sr-90, Tc-99, Ru-106, I-129 and Cs-137. Of these, Sr-90 and Tc-99 are present mainly in the Medium Active Concentrate (MAC) processed through EARP. The main source of C-14 discharge to sea is the dissolver off-gas scrubber liquor associated with reprocessing, with the remainder mostly from treatment of Salt Evaporator Concentrates in EARP. Both Ru-106 and Cs-137 arise primarily in Magnox fuel storage ponds. The storage of light water reactor fuel, in particular fuel from boiling
water reactors, gives rise to discharges of Co-60. Large amounts of tritium (in becquerel
terms) are also produced, but have little radiological significance. I-129 discharges arise from
Magnox fuel reprocessing and THORP. THORP is the major source of such discharges to sea.

**What is reprocessing?**

The average life of a nuclear fuel rod in a reactor is about four years, after which time its
efficiency declines due to the build up of waste products. Used or “spent” fuel rods are
removed from the reactor core and replaced by new ones. The spent fuel can be
reprocessed to separate out the uranium and plutonium, which can be re-used, from the
wastes. There are currently only two commercial reprocessing plants in the world:
Sellafield in the UK and La Hague in France. A third plant is under construction in
Japan. Russia also reprocesses its own civil and defence spent fuel, at its Mayak plant.

In the Magnox reprocessing plant, the metal cladding (magnesium/aluminium alloy –
Magnox) of uranium metal fuel rods is stripped away mechanically and the fuel rods
are dissolved in hot nitric acid. In contrast, at THORP both stainless steel and zircalloy
fuel pins, containing uranium oxide fuel pellets, are sheared into short lengths and the
fuel pellets are dissolved in hot nitric acid. There are three products from this process:
uranium (about 96%), plutonium (about 1%) and radioactive waste (about 3%). The
reusable uranium is converted back into nuclear fuel. The plutonium is currently stored
but that belonging to foreign customers may be used in the production of “mixed
oxide” fuel and returned to them in this form. The radioactive waste is vitrified and
safely stored, pending a decision on its long-term management.

7.3.3 Some 80% of the estimated critical group dose from Sellafield’s current liquid discharges is
attributable to Magnox reprocessing and associated historic waste treatment. The dose
arising from current discharges of the actinides (primarily Pu-alpha and Am-241) is very
small, although due to their persistence in the environment they continue to contribute a
significant fraction of the total estimated dose to the critical groups as a result of historic
discharges. Historic discharges in total contribute more than half the current estimated dose
to the critical group of seafood consumers of about 0.15 mSv a year8.

7.3.4 Estimated doses to fish and seafood consumers decline with distance from Sellafield. A
report by the Radiological Protection Institute of Ireland in September 200016 estimated the
dose to a typical heavy consumer of seafood on the eastern seaboard of Ireland in 1999, from
measured artificial radionuclides, to be 0.00133 mSv.

7.3.5 BNFL has undertaken a substantial safety and environmental investment programme over
the last 20 years. Older plants have been refurbished, new plants have been engineered to
high standards and discharge abatement measures have been introduced. As a result,
discharges have reduced and the subsequent estimated dose to the critical group of seafood
consumers has fallen from a peak of about 3 mSv a year in 1977 to the current level of about
0.15 mSv a year (see Figure 2). With the introduction of new facilities, which will provide
additional treatment measures for stored wastes, and a continuing programme of safe
maintenance and post-operational clean-up, discharges and estimated critical group doses
from operational plant are expected to decline further (Figure 6). However, some short-term
increases may be unavoidable as the legacy of stored wastes is worked through. A significant
amount of work associated with historical waste management and decommissioning
activities will continue after 2020.
7.3.6 Some of the waste treatment facilities being introduced or planned are outlined below.

- **Solvent Treatment Plant.** STP will destroy the solvents currently stored on site, producing an aqueous residue containing the bulk of the radioactivity. This will go to EARP for further treatment. STP commenced active commissioning in 2000.

- **Floc Retrieval.** Six sludge tanks have been used for the settling and storage of alumino-ferric flocs produced from effluent treatment operations up to 1987. Commencing in 2002 these sludges will be retrieved and treated in the EARP concentrates plant prior to encapsulation.

- **Sellafield Drypac Plant.** SDP will dry and compact Magnox sludge prior to encapsulation. It is scheduled to commence operation later in this decade, subject to the current review into the management of historic liabilities at Sellafield.

- **Box Encapsulation Plant.** BEP will encapsulate retrieved waste from the Dry Storage Silos, Magnox Storage and Decanner facility, Pile Storage Pond and Decanner facility and oversize material from the Magnox Storage Silos either direct or via SDP. BEP is scheduled to commence operation later in this decade, subject to the current review into the management of historic liabilities at Sellafield.

7.3.7 Environmental concentrations of Tc-99 have been the focus of criticism by some environmental pressure groups in recent years. Tc-99 is a radionuclide of low radiotoxicity but its half-life (the time taken for a given amount to reduce by half due to radioactive decay) is 213,000 years. Even the Sellafield critical group of seafood consumers is estimated to receive a dose of only 0.02 mSv a year from Tc-99 discharges (this allows for the bioaccumulation of Tc-99 in some shellfish, particularly lobsters) and doses to seafood consumers farther afield will be very much less.

7.3.8 Increased discharges of Tc-99 from 1994 resulted from the treatment of a historic backlog of liquid waste. The reprocessing of Magnox fuel produces MAC containing Tc-99 and other, more radiotoxic radionuclides, such as Pu and Am. Prior to 1981, this stream was discharged to sea after several years’ storage to allow for decay of short-lived radionuclides. In the early 1980s, discharges of MAC were suspended and the concentrate was retained in storage, pending the operation of EARP to remove the radionuclides of greatest radiological concern. It was recognised at the time, however, that EARP would not be capable of removing Tc-99.

7.3.9 EARP started operation in 1994 and began to clear the backlog of stored waste, as well as current arisings from Magnox reprocessing. As a consequence, Tc-99 was once more discharged to sea and concentrations of this radionuclide in the marine environment increased as a result. Discharges have been reduced since 1999 and environmental levels have also started to fall. Figure 5 shows Tc-99 discharges and activity levels in seaweed, winkles and lobsters, from 1994 to 2001.

### Possibilities for reducing discharges

7.3.10 The greatest contributor to discharges from Sellafield (including Tc-99) is the reprocessing of spent Magnox fuel, through a plant known as B205. Some responses to the consultation paper pointed out that the dry storage of Magnox fuel, as an alternative to reprocessing, would significantly reduce discharges from the reprocessing sector. Currently in the UK, the only dry store for spent fuel is situated at Wylfa power station, and is regarded as providing interim storage pending the reprocessing of Magnox fuel through B205 at Sellafield. The remainder of the Magnox stations have wet discharge routes.
7.3.11 Advice from the regulatory authorities and the Radioactive Waste Management Advisory Committee is that reprocessing is the only option acceptable on safety and economic grounds for Magnox fuel once it has been wetted. There are significant, unresolved technical issues associated with the drying and long term storage of previously wetted Magnox fuel. Also, dry storage does not achieve the level of passivity that would be required for indefinite storage and hence further treatment, inevitably involving some discharges, would be needed. The high costs associated with back-fitting dry discharge routes to Magnox stations are not considered to be justified, in view of their limited lifetimes.

7.3.12 The EA has carried out a review of all radioactive discharges from Sellafield and has consulted on its proposals. Discharge limits for Tc-99 were reviewed more urgently than those for other radionuclides. The EA consulted on proposals for reduced discharge limits for Tc-99 early in 2001 and issued its draft decision in September 2001. At the time this strategy went to press, Ministers were considering whether to accept the Agency’s proposals.

7.3.13 In its draft decision, the EA would require BNFL to re-route future arisings of MAC, from the reprocessing of Magnox fuel, to the Highly Active Liquor Evaporation and Storage Plant, for subsequent vitrification. This re-routing would be achieved by March 2003, subject to permission being granted by HSE. The vitrification process turns the liquid waste into a glass-like solid. The EA’s draft decision would also require BNFL to investigate urgently the feasibility of an abatement technology in EARP for precipitating and removing Tc-99.

7.3.14 The EA proposes to maintain the discharge limit for Tc-99 at 90 TBq a year for the time being and to reduce it to 10 TBq by around 2006. This proposal would be kept under review in the light of possible abatement measures and interim reductions in discharge limits may be possible before 2006. The UK is committed to reducing Tc-99 discharges. However, it should be noted that a study carried out by BNFL in the context of the review of Sellafield discharges, and verified by an independent review, concluded that the BPEO for Tc-99 is its continued discharge to sea. The EA did not agree with this conclusion in the case of new “salt free” MAC arisings, for which it considers the BPEO to be vitrification (subject to HSE permission).

7.3.15 One of the questions raised in response to the EA’s consultation on Tc-99 was why EARP operations could not be suspended, and MAC stored, pending the development of suitable abatement technology. MAC storage would cut Tc-99 discharges to almost zero. This option was implemented between 1982 and 1994, whilst EARP was being planned and built, to cut discharges of the more radiologically significant radionuclides. The difficulty with continuing to store MAC to prevent Tc-99 discharges relates to the strict regulation of on-site safety at Sellafield, under which HSE has set an objective that the hazards from storage of liquid radioactive wastes should be progressively reduced. This implies that the volume of MAC stored must be progressively reduced. A balance has to be achieved between the need to reduce discharges to the environment and the need to reduce hazards on site and the exposure of workers. In the case of Tc-99 discharges, which have a relatively small radiological impact when discharged to sea, that balance is reflected in the EA’s draft decision. In addition, the prolonged storage of MAC could be very costly if it were to involve the provision of new storage tanks.

7.3.16 A further possibility for reducing Tc-99 discharges might be to store the treated effluent from EARP instead of discharging it, pending the development of abatement technology. This would have less safety implications than the storage of MAC, since the majority of the activity is removed in EARP. This option would, however, require the construction of a large new storage facility and some modifications to EARP. The lead time required for the design
and approval of any such new plant means that it would not provide a viable interim solution. This option was not considered in detail in the Environment Agency’s decision document, as it was seen as being impractical because of the large volumes of treated effluent produced and the corresponding scale of the storage facilities required (capacity for about 4000 m³/yr).

7.3.17 A number of potential options are being considered for further treatment of effluent arisings from the reprocessing sector. Options under consideration for the priority radionuclides are:
- removal of Tc-99 from MAC by introduction of abatement technology consistent with the EARP process;
- routing MAC to vitrification, which would substantially reduce discharges of Tc-99, Sr-90 and Cs-137;
- installing C-14 removal plant for Magnox liquid effluents;
- installing a new head end plant on THORP to allow processing of Magnox fuel.

Some of these options may prove to be feasible. Many are at the stage of laboratory or pilot plant trials only, and some may produce waste forms that would be unsuitable for long-term storage or would disproportionately increase worker doses. The costs and potential timescales are subject to considerable uncertainty. In assessing possible abatement options, the BPEO will need to be identified, taking account of occupational and environmental risks, environmental impacts, costs and social implications.

7.3.18 The projected liquid discharge profiles to 2020 for the reprocessing sector are shown at Figure 7. All liquid discharges from this sector are made to OSPAR Region III (Celtic Seas). The profiles indicate expected reductions of around 35% for alpha discharges, around 70% for total beta and over 99% for technetium. These expected reductions are subject to a review of the impact of future decommissioning and clean-up activities at Sellafield. The Tc-99 discharge profile assumes that a 10 TBq discharge limit for Tc-99 will be introduced in 2006. This is based on the Environment Agency’s proposed decision. At the time this document went to press, Ministers were considering whether to accept the Agency’s proposals. Apart from the discharge reduction measures discussed above, a major driver for the profile will be the timetable for closure of Magnox power stations and for ending the reprocessing of Magnox fuel. The Magnox station closure programme is discussed at paragraphs 7.2.19 to 7.2.20 above. The discharge profiles shown at Figure 7 assume that all Magnox stations will close by 2010 and that Magnox reprocessing will shut down once all spent fuel has been reprocessed, which is expected to be around 2012. Ending Magnox reprocessing will cut C-14 discharges by 80% within a few years.

7.3.19 The proposed timetable for the closure of Magnox reprocessing operations was questioned by some respondents to the consultation document, on the grounds that the B205 reprocessing plant would have to improve considerably on past performance in order to deal with existing stocks of spent fuel and expected arisings by 2012. It is a key objective for BNFL to achieve closure of B205 by about 2012. The achievement of this objective requires balancing operations associated with reactor operation, reactor fuel pond management, fuel transportation, fuel receipt and storage at Sellafield, performance of the B205 reprocessing plant and operation of the downstream waste management plants. BNFL will closely monitor progress and will deploy contingency plans if it appears that B205 will fail to achieve the required level of throughput. In the event of a serious shortfall in performance, there would be no alternative but to review the closure programme, and bring forward the closure dates of some Magnox stations.
Continued operation of THORP beyond about 2016 will be dependent on new business being secured. The discharge profiles shown at Figure 7 assume that, if THORP continues to operate beyond 2016, it will do so on the basis of its current low discharges. In its White Paper, “Managing the Nuclear Legacy”, which was published on 4 July 2002, the Government stated that in relation to THORP:

“Any proposals for new contracts will similarly require approval by the Secretary of State. In the event that any such proposal was received, the Government would look in detail not just at the circumstances of the specific case but, in the light of the Bergen Declaration*, would also review the range of issues which would be involved in increasing the current volume of fuel to be reprocessed through THORP. Decisions would be taken in the best interests of the UK as a whole, in the light of advice from the LMA (Liabilities Management Authority) and on the basis that approval would only be given if the contract were:

- consistent with clean up plans for Sellafield and, in the LMA’s view, would not cut across implementation of those plans;
- was expected to make a positive return for the taxpayer after allowing for operational costs, business risks and any other costs which might be incurred as a result of the contract, including any additional clean up costs;
- consistent with the UK’s environmental objectives and international obligations”.

### STRATEGY TARGETS

- Tc-99 discharges from reprocessing are expected (if the Environment Agency adopts its proposed Decision) to be reduced from close to 90 TBq a year to below 10 TBq a year as soon as possible and by no later than the end of 2006, and to less than 1 TBq a year by 2020.
- By around 2012, reprocessing of spent Magnox fuel is expected to cease.
- By 2020, total beta liquid discharges from reprocessing (excluding tritium) are expected to be reduced from 165 TBq a year to around 50 TBq a year.
- By 2020, total alpha liquid discharges from reprocessing are expected to be reduced from 0.31 TBq a year to about 0.2 TBq a year.

### 7.4 Research facilities

7.4.1 The United Kingdom Atomic Energy Authority (UKAEA) has four licensed nuclear sites, at Dounreay in Scotland, Windscale in Cumbria, Harwell in Oxfordshire and Winfrith in Dorset. Their locations are shown on Map 1.

7.4.2 These sites were nuclear research establishments and the reactors located on them are now closed down and are at various stages of decommissioning. The small amount of liquid radioactive effluent produced at Windscale is transferred under authorisation to BNFL, where it is processed in treatment plants before being discharged as a tiny addition to the total liquid discharges from the BNFL Sellafield site. Discharges from Windscale are included in the discharge profiles for the reprocessing sector. UKAEA also operates a site at Culham in Oxfordshire where the main task is fusion research and development. This is not a licensed nuclear site. Over the next 20 years, UKAEA’s main activities leading to discharges of...

* Ministerial Declaration of the Fifth International Conference on the Protection of the North Sea, 20-21 March 2002 which, inter alia, encourages relevant North Sea states to evaluate the options for spent fuel management after current reprocessing contracts come to an end.
radioactivity into the environment will be associated primarily with the decommissioning of redundant nuclear facilities at its sites. Future discharges will, therefore, depend on the decommissioning programmes for each site, which are currently under review.

7.4.3 Radioactive discharges from the research sector have reduced substantially over the last twenty to thirty years and are now relatively small. The resulting estimated critical group doses are below (and in most cases well below) 0.01 mSv. Over the next two decades, predicted discharges from UKAEA sites will reduce even further and from Winfrith are likely to cease. Within this overall trend, there may in some years be small short term increases to facilitate decommissioning and so secure longer term environmental benefit.

Dounreay

7.4.4 Until 1994, Dounreay’s prime role was research and development of fast reactor technology, including the reprocessing of fast reactor fuel. Following closure of the fast reactor research project, the last of the three reactors at Dounreay closed in 1994 and a number of support facilities are no longer operational. Dounreay also has a spent fuel reprocessing plant for research reactor fuel. This is currently shut down and in July 2001 the Minister for Energy announced that it will not be re-started to complete the reprocessing of spent fuel from the fast reactor and other research programmes. Resources are currently focussed on decommissioning and the environmental restoration of the site.

7.4.5 The small percentage of alpha activity in effluent discharges has been mainly Pu-239/240 and Am-241. These nuclides are typically associated with reprocessing but will also arise during decommissioning of the Fuel Cycle Area. Beta discharges are mainly Cs-137 with contributions from Sr-90 and Co-60. The exact composition of nuclides discharged at any future time will depend on the precise state of operations and decommissioning at that time. However, it is likely that alpha discharges will continue to be dominated by Pu-239/240, with smaller contributions from Pu-238 and Am-241. Beta discharges will continue to be mainly Cs-137, with smaller amounts of Sr-90, Pu-241 and Co-60. The total activity discharged, while currently very low, will continue to decline as plant is decommissioned.

7.4.6 Estimated doses to the critical groups as a result of discharges from Dounreay have been below 0.02 mSv for the last decade. The current calculated dose rate to all critical groups is less than 0.01 mSv/y. By 2020, annual discharges of both alpha and beta/gamma radionuclides are projected to have been reduced by approximately an order of magnitude below the levels typical of operations during 1991-1995. Environmental concentrations will be correspondingly lower and estimated critical group doses less than 0.001 mSv/y.

Harwell

7.4.7 In the past, UKAEA operated a variety of research reactors and other plant at this site, which carried out research and development in support of the UK nuclear power programme. Discharges from Harwell are already very low and are predicted to drop steadily. The main alpha-emitters in discharges are various isotopes of U and Pu, and Am-241. Beta discharges are largely Sr-90, yttrium (Y)-90 and Cs-137, with a smaller contribution from Co-60.

7.4.8 As well as managing its own radioactive effluents, UKAEA will continue to provide a waste disposal service to groups based on the Harwell campus who generate small quantities of radioactive effluents. Whilst these arisings have historically been small, the progressive reduction in UKAEA discharges has meant that contributions from other organisations making use of the Harwell waste management facilities have become relatively more significant for some radionuclides.
7.4.9 Doses to members of critical groups arising from discharges from Harwell are estimated to be less than 0.0001 mSv per year from current discharges. They are expected to reduce to less than 0.00001 mSv per year by 2020.

Winfrith

7.4.10 The operations giving rise to radioactive discharges from Winfrith have changed significantly over recent years following the closure of the Steam Generating Heavy Water Reactor and other facilities. As at the other research sector sites, the focus is now on the decommissioning of redundant plant and discharges are currently very low. In addition, UKAEA provides infrastructure and support services to tenants on the site. Liquid and solid radioactive wastes from the commercial operations of tenants are transferred to UKAEA for disposal. The activity discharged from Winfrith into the sea is mainly tritium from a tenant’s operation to recover tritium from obsolete trimphone dials – an operation which removes much of the tritium for recycling and thus substantially reduces the potential environmental problem posed by trimphone dials.

7.4.11 Other radionuclides present in liquid discharges are mainly Cs-137, Nickel (Ni)-63, Sr-90 and Iron (Fe)-55, as well as small amounts of alpha activity, mostly from Pu isotopes and Am-241. The estimated dose to the critical group of fish and seafood eaters is currently below 0.005 mSv and will remain below this level.

Windscale

7.4.12 Windscale is located on the Sellafield site. The main activity is decommissioning plant from past nuclear operations. The small amount of liquid effluent that arises from waste remediation work is transferred by pipeline or tanker to the adjoining BNFL site for treatment and is discharged with Sellafield effluents.

Culham

7.4.13 Culham is the site of the Joint European Torus (JET) experimental fusion facility, which carries out experiments using tritium. It has a purpose built plant for handling and treating tritium and other hydrogen isotopes in gaseous form. Due to the nature of the facility, the quantities of discharged radioactivity are not readily predictable in the long term, but liquid discharges have averaged less than 0.1 TBq per year in recent years. The estimated critical group dose is well below 0.0001 mSv a year. Neither discharge nor resulting dose is expected to increase significantly.

Possibilities for reducing discharges

7.4.14 The projected liquid discharge profiles to 2020 for the research sector are at Figure 8. This indicates expected reductions of around 78% for alpha discharges and around 80% for beta discharges. Discharges of tritium will be reduced by around 98% to very low levels by 2020. Levels of both alpha and beta discharges are expected to show a steady downward trend. Within this trend, discharges of some radionuclides may need to increase for short periods, to allow decommissioning and remediation activities to continue.

7.4.15 No account has been taken in this discharge profile, in advance of operational experience, for new plant, including a Low Level Liquid Effluent Treatment Plant and ion exchange facilities, being installed at Dounreay. SEPA has asked for the development of a liquid effluent treatment strategy for Dounreay, which should have the effect of further reducing levels of radioactivity in liquid discharges. Future discharges are therefore likely to be lower
than assumed for the purposes of the discharge projections shown here. Beyond the introduction of new facilities, the only further scope for discharge reduction at Dounreay lies in proceeding more slowly with decommissioning and remediation activities at the various sites. This may have implications for on-site safety and is unlikely to have any measurable effect on concentrations in the marine environment.

7.4.16 At Winfrith, for the very dilute liquid waste streams relevant to the site in general, the annualised cost of further abatement would be of the order of £100M. Such an annual cost would not be reasonable given the small radioactive content of the expected discharges and their impact on the environment. Dealing with waste, for example, by evaporation would have other environmental disadvantages, such as increased solid waste production and storage (with consequent increased worker risk) and very high energy use and its resulting production of greenhouse gases.

7.5 Defence facilities

7.5.1 The UK Government is committed to maintaining a nuclear deterrent and consequently has a requirement to develop, manufacture and deploy nuclear weapons. As part of this commitment, the Ministry of Defence is taking delivery of the last of its four nuclear powered Vanguard Class Trident Ballistic Nuclear Missile Submarines (SSBNs). It also continues to operate nuclear powered Hunter Killer Submarines (SSNs) and has recently commissioned the build of the Astute class to replace the Swiftsure class.

Weapons production

7.5.2 The development, manufacture, maintenance and eventual decommissioning of nuclear warheads is carried out on behalf of the Ministry of Defence by the Atomic Weapons Establishments (AWE) at Aldermaston and Burghfield. These and other defence facilities are shown on Map 1. The majority of discharges arise from safety and legacy waste related activities, for example, the decommissioning of redundant facilities. The main radionuclides in discharges from AWE are tritium, Pu and U. Liquid discharges from Aldermaston are authorised via a pipeline to the Thames at Pangbourne. Trade waste containing very small amounts of radioactivity is discharged to a sewage works at Silchester. Liquid discharges from Burghfield were previously made to the Burghfield Brook, which is a tributary of the Thames. These discharges stopped completely as from 1 April 2000, when new discharge authorisations came into force.

7.5.3 Liquid discharges from AWE are expected to reduce to extremely low levels by 2010, due to the completion of decommissioning programmes and the proposed introduction of a new effluent collection and treatment system. The Pangbourne pipeline to the Thames is programmed to close in 2005, the point at which the new effluent treatment plant becomes operational. The estimated dose to the local critical group, as a result of discharges from AWE, is currently less than 0.005 mSv a year.
Nuclear propulsion programme

7.5.4 The Royal Navy operates a fleet of nuclear powered submarines, based at the Clyde Naval Base at Faslane, Scotland, and at the Devonport Naval Base at Plymouth, Devon. These are powered by small, pressurised water reactors that use enriched uranium fuel clad with zircalloy, manufactured by Rolls Royce Marine Power Operations Ltd., in Derby. The operation of the reactor produces activation products within the primary coolant circuit. Many of these are short-lived and pose no disposal problems; however, of the longer-lived activation products Co-60, tritium and C-14 are of importance.

7.5.5 The current classes of SSN use a pressurised water reactor known as PWR1 that occasionally discharges coolant into the ocean during submarine operations (due to expansion of the coolant). The discharges of beta/gamma activity are monitored and recorded. However it is not practicable to monitor directly the discharges of tritium and these are estimated by scaling from other beta/gamma discharges.

7.5.6 The current class of SSBN brought into service in the 1990s uses a newer design of pressurised water reactor, PWR2, that does not discharge to sea. Each of the current class of SSBN is also to be fitted with a new reactor core providing “fuel for life” over the next decade. This will reduce, but not eliminate, the discharges from the dockyards when the submarines undergo maintenance. The new Astute class of SSN now in development will also use the PWR2 reactor (so will not discharge at sea) and will have “fuel for life”. Within the time scale covered by the OSPAR Strategy it is intended that nearly all PWR1 powered submarines will be taken out of service in favour of the new class.

7.5.7 Submarines undergo refit, repair or decommissioning at the Royal Dockyards at Devonport and Rosyth. Refitting work at Rosyth has ended and all future refits will be carried out at Devonport, although some decommissioning work is likely to continue at Rosyth for several years. As a consequence, Devonport Royal Dockyard will manage increased amounts of primary coolant. In addition to the discharge of contaminated coolant, some other liquid discharges arise when submarines are decommissioned. The main radionuclides in discharges from the Royal Dockyards are tritium and C-14. Co-60 and small amounts of other activation products are also present in contaminated coolant, but most of this activity is removed by treatment before discharge.

7.5.8 The estimated doses to critical groups resulting from discharges from the Royal Dockyards and Naval Bases are in all cases less than 0.01 mSv a year. When refitting of PWR2 submarines commences at Devonport, the discharges and hence estimated critical group doses may rise. Discharge levels will only be determined with confidence when MOD has experience of refitting these submarines.

Possibilities for reducing discharges

7.5.9 Projected liquid discharge profiles for the defence sector, for the period 2001 to 2020, are shown at Figure 9. The projected beta/gamma discharges result almost entirely from the submarine programme, while the alpha discharges relate solely to weapons production. The maintenance programme for nuclear submarines does not result in regular annual discharges and so the annualised average figures given may not relate directly to required annual discharge authorisations. Because complete data for operational discharges from submarines at sea are not available for the period 1996-2000, no column for this period appears in the bar chart. Also, because the locations at which operational discharges are made from submarines at sea cannot be predicted, the projected discharge profile can only be given on a total basis and can not be allocated to the OSPAR regions.
7.5.10 By comparison with other nuclear sectors, the discharges from the defence sector are already very low. Nonetheless, significant reductions in discharges are expected in the period to 2020. Tritium discharges are expected to be reduced by about 43% and other beta/gamma discharges by about 40%. Scope for accelerating the programme for reducing discharges from Aldermaston and Burghfield is likely to be small. Waste minimisation techniques have been applied for some time and are subject to periodic review.

7.5.11 The great majority of tritium discharges originate from neutron reaction with lithium-6 in ion-exchange resins contained in the primary cooling circuits of submarine reactors. Lithium is used to control acidity levels and prevent the build up of activated corrosion products, especially Co-60. The Government has in place a programme to use higher grade lithium with reduced lithium-6 content. The higher grade lithium can only be introduced at specific maintenance periods, which means that it will take about 10 years to install in all the submarines. This is an effective method of reducing tritium production and the implementation of the lithium replacement programme is reflected in the discharge projections at Figure 9.

<table>
<thead>
<tr>
<th>STRATEGY TARGETS</th>
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<tbody>
<tr>
<td>■ By 2005, radioactive discharges to the Thames from AWE Aldermaston are expected to cease.</td>
</tr>
<tr>
<td>■ By 2020, discharges of tritium from the defence sector are expected to be reduced from 0.7 TBq a year to 0.4 TBq a year.</td>
</tr>
<tr>
<td>■ By 2020, total beta/gamma liquid discharges from the defence sector (excluding tritium) are expected to be reduced from 0.005 TBq to 0.003 TBq a year.</td>
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</table>

7.6 Other sources of discharges

7.6.1 Discharges from individual non-nuclear sites tend to be lower than those from nuclear licensed sites; however, there are many more of them. At present, there is no nationally compiled information on collective radioactive discharges from non-nuclear activities. In future, the EA intends to extend its pollution inventory to include both nuclear and non-nuclear activities regulated under RSA93. This will extend to the whole of the UK. With this information, it should be possible to track changes in the pattern of radionuclide discharges and focus on those discharges which are, individually or collectively, the most significant.

Radioisotope manufacture and supply

Amersham plc

7.6.2 Amersham plc is a global health science company, part of whose business is the supply of radioactive products to the medical, pharmaceutical and academic sectors. The company has facilities on nuclear licensed sites at Amersham, Cardiff and Harwell. These locations, and those of the other operations mentioned below, are shown on Map 1. Manufacturing operations at Harwell have now ceased and the site is being decommissioned. No appreciable liquid discharges are made from Amersham plc operations at the Harwell site.

7.6.3 A wide range of radionuclides is used in manufacturing processes and in research and development, for products used in medical diagnostic tests, therapeutic treatments and life science research. The most prominent radionuclides in liquid discharges from the Maynard Centre at Cardiff are H-3, C-14 and from the Grove Centre at Amersham are short-lived medical isotopes. Discharges from the Amersham and Cardiff sites are made to sewer. Those from
Amersham pass through a sewage treatment works before entering the Grand Union Canal and subsequently the River Thames. Since spring 2002, those from Cardiff pass through a sewage treatment works before entering the Severn Estuary. Liquid discharges from the Grove Centre have an indiscernible effect on the marine environment and are not considered here further.

7.6.4 Environmental monitoring of the Severn Estuary near Cardiff has indicated higher concentrations of tritium in marine organisms than conventional environmental modelling predicted. Since 1998, this has been the focus of regulatory interest. Recent research work shows that some of the organic labelled compounds discharged from Amersham plc’s Maynard Centre are likely to be the most significant cause of the unusually high levels of tritium found in the Severn Estuary and the River Taff. A study carried out on behalf of the Environment Agency suggests that the content of organically bound tritium (OBT) in discharges from the Maynard Centre has been variable and may have ranged over 0-55% over the last ten years. Amersham’s own data indicate that the total organic tritium content in discharges from the Maynard Centre was typically around 45% prior to May 1998. The company is currently restricting its discharges by storing waste on-site and this has resulted in an 85% reduction in discharge since 1995.

7.6.5 Amersham plc proposes to introduce new technologies at the Maynard Centre that will lead to the recovery and recycling of much of its current waste effluent, resulting in substantial reductions in both liquid and gaseous discharges of H-3 and C-14 within the next few years. It is anticipated that the plant will become fully operational in early 2004. This programme represents a major undertaking to reduce the existing liquid and gaseous waste streams by capturing as much of them as possible and then recycling the materials for re-use in the manufacturing processes. Some of the products Amersham plc manufactures at Cardiff are radioactively labelled organic chemicals, composed mainly of hydrogen, carbon and oxygen. The radioactive raw materials used are H-3 and C-14. The new technology will capture the liquid and gaseous wastes and convert the many individual components back to the basic raw materials, using a variety of chemical processes.

Phosphoric acid purification

Rhodia Consumer Specialties Ltd

7.6.6 Rhodia Consumer Specialties, at Whitehaven in Cumbria, currently manufacture products for use within the foodstuffs industry. Prior to 1992, as Albright and Wilson, the plant discharged to sea phosphogypsum arising from the processing of phosphate ore for phosphoric acid production. This was an important discharge source of natural radionuclides during the 1980s and gave rise to enhanced concentrations of naturally occurring thorium, uranium and their daughter products in the marine environment. In 1992, phosphate rock processing stopped, resulting in an 85% drop in uranium and thorium discharges. On-stream treatment plants introduced in 1993 and 1998 have further reduced the activity in discharges, which is currently very low. Phosphate manufacture and the associated importation of phosphoric acid ceased in December 2001.

7.6.7 Monitoring of marine biota has shown that concentrations of polonium (Po)-210 have fallen to less than a fifth of those in the early 1990s. However, Po-210 and Pb-210 from historic discharges continue to contribute to the estimated dose to the critical group of fish and shellfish eaters, as do discharges from the nearby Sellafield reprocessing facility. It should be noted that the estimated dose to the critical group shown in Table 1 as 0.42 mSv in 2000 is due mainly to enhanced concentrations of natural radioactivity. The estimated dose from artificial radionuclides in 2000 was an additional 0.049 mSv. Similarly, high rate fish and...
shellfish consumers in the Sellafield area were estimated to receive 0.38 mSv in 2000 as a result of enhanced natural radioactivity from this source.

Offshore oil and gas production

Offshore platforms

7.6.8 In offshore oil and gas production platforms, NORM accumulates as scale inside pipework and valves, and as sludge in separator tanks and other vessels. The oil and gas production stream passes through a separator, where the oil, gas and water are divided into separate streams on the basis of their different fluid densities. Most of the solids removed in the separator accumulate there. Scales form in all piping, valves, etc., with the highest concentrations of NORM being found closest to the well-head. Radionuclide concentrations in scale are in general higher than those in sludge. Natural radionuclides that become concentrated in this scale are mainly radium (Ra)-226 and Ra-228 and their daughters. Small amounts of Po-210 and Pb-210 may also be present.

7.6.9 Scales and sludges must be removed so that they do not adversely affect production. They are released to sea under discharge authorisations granted by the appropriate environmental regulatory body. Authorisations usually include restrictions on particle size, requiring scale to be ground up before discharge.

7.6.10 The total annual activity authorised for release as liquid radioactive waste from UK platforms is 596 GBq, all of which is made to OSPAR Region II (the Greater North Sea). However, the total amount of activity actually discharged in 2000 was only 15.8 GBq. There are also discharges of natural radionuclides in water produced during the extraction process. Initial findings of the European Commission’s Marina II study, which is examining the exposure of the European population from radionuclides in the marine environment, indicate that discharges of alpha activity to sea in produced water from the oil and gas sector could be an important contributor to overall discharges of alpha activity.

Scotoil

7.6.11 Scotoil has a decontamination facility at Aberdeen for the removal of scale from oil and gas industry equipment. This replaced a phosphoric acid plant on the same site and Scotoil has an authorisation to discharge macerated solid material to sea via a pre-existing pipeline. Decontamination is carried out mainly by high pressure water jetting. As with scale discharged from sea platforms, the activity is mostly Ra-226 and Ra-228. In 2001, Scotoil discharged 35 tonnes of low specific activity scale, with a total activity of 9.9 GBq.

AEA Technology

7.6.12 AEA Technology also has a decontamination facility on the UKAEA site at Dounreay. The recovered scale is encapsulated in cement and the drums of conditioned waste are transferred on-site to UKAEA, to await disposal as low level radioactive waste, so this facility makes a negligible contribution to marine discharges. The plant is scheduled to close in 2003.

7.6.13 Offshore operators routinely use scale inhibitors and possibilities for reducing discharges from oil and gas production mainly focus on the greater use of encapsulation and disposal of the material as solid waste. However, the only authorised disposal site for low level waste, at Drigg in Cumbria, has a limited capacity to accept radium wastes. In theory at least, there is also the possibility of re-injecting macerated scale into sub-seabed oil reservoirs.
Medical sector

7.6.14 A number of general and teaching hospitals have departments that use radioactive materials for diagnostic and therapeutic purposes. These facilities are numerous and are not shown individually on Map 1. They are authorised to discharge short half-life isotopes, mostly contained in patient excreta. The radionuclides involved are mostly short-lived (e.g. Tc-99m, I-131) and, where discharged to sewer, are likely to decay to very low levels before entering the marine environment. Tritium and C-14 are the only long-lived radionuclides of any significance in discharges from medical uses of radioactivity. It has been estimated that 53 GBq of tritium and 3 GBq of C-14 entered the marine environment from UK hospital discharges in 199923.

7.6.15 The use of radioisotopes in medicine in the UK is increasing by around 3% a year, but is currently less than in other European countries. Most of the activity administered is by way of radiotherapy to cancer patients. One in three people are expected to develop cancer, so the potential number of radiotherapy treatments administered is high. As cancer treatments become more effective, patients have a longer life expectancy with a resulting increase in radiotherapy sessions during the follow up period, extending over several years. Most treatments (around 90%) are given to outpatients, who return home afterwards. In order to reduce radiation doses to patients following treatment, the accepted procedure is to encourage frequent elimination of body wastes, so increasing discharges to the environment.

7.6.16 A study by the EA18 has indicated, using pessimistic assumptions, that some workers in sewage treatment plants could be exposed to doses of up to 0.238 mSv a year, from excreta from cancer patients receiving radiotherapy, if discharges are made at the authorised limits. The same study estimated that doses to members of the public eating large quantities of river fish caught downstream of sewage outfalls could be as high as 0.18 mSv a year, if all discharges were made at the authorised limits. While these figures are higher than the estimated dose to the Sellafield critical group for 2000 (0.15 mSv a year), based on actual discharges, the quality of the assessments is very different. The estimated critical group dose for Sellafield is conservative, but probably realistic, while the estimated dose to sewer plant workers is an upper bound in unlikely circumstances.

7.6.17 Reducing discharges from hospitals might be possible, perhaps by using holding tanks to allow the decay of short-lived radionuclides. This could be effective at hospitals where large numbers of patients are treated, but may only have a minimal effect at other hospitals, since most discharges to sewers are from outpatients who return home after treatment. Holding tanks have already been installed at some large new cancer therapy facilities, such as at University College Hospital in London. However, the use of holding tanks is known to be falling out of favour in Germany, due to their high cost and the potential for transferring risk to staff on site.

7.6.18 Within the requirement to apply BPM, discharge limits for hospitals will need to be set in a way that is flexible enough to be consistent with the Government’s targets for effective cancer treatment. As noted above, many of the radionuclides discharged by the medical sector are short-lived and are unlikely to have a measurable effect on concentrations in the marine environment.

<table>
<thead>
<tr>
<th>STRATEGY TARGET</th>
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<tbody>
<tr>
<td>Due to the diverse nature of other minor sources of radioactive discharges, no discharge profile or target is set for this sector. The presumption is that these discharges will continue to be tightly controlled and reduced wherever practicable.</td>
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Chapter 8: Taking forward the UK STRATEGY

8.1 Implementation of the strategy by statutory guidance

8.1.1 The Environment Act 1995 enables the Government to give the environmental regulators guidance on statutory objectives to which they must have regard when discharging their functions. The Government will be issuing statutory guidance to the Environment Agency, which sets out a clear framework within which it will operate in England when authorising the discharge of radioactivity into the environment from nuclear licensed sites. Similar arrangements will apply in Scotland and Wales. The statutory guidance will make clear that, when granting discharge authorisations, the Environment Agency should seek to ensure that they are consistent with this UK strategy for radioactive discharges.

8.2 Reviewing the UK strategy

8.2.1 It is not the Government’s intention that this UK strategy should be an immutable blueprint for radioactive discharges for the whole of the period to 2020. However, the Government intends to continue to apply its policy of progressive reduction of such discharges. Other policy decisions by Government, commercial decisions within the nuclear industry and other sectors, technological developments in waste management and abatement, and improvement of our knowledge about the impact of radionuclides in the marine environment, could all influence the direction of the UK strategy in the future. Further international obligations that are relevant to the strategy will also need to be addressed.

8.2.2 Future editions of the UK strategy should be able to present more information about concentrations of radionuclides in the environment, as indicated by the monitoring criteria discussed at paragraph 5.3.2. They should also be able to give a clearer indication of how the OSPAR Commission will assess progress against its objectives. Aerial emissions will also be considered fully in the next edition and their impact on the marine environment will be assessed.

8.2.3 The Government intends to revise and re-issue the UK strategy at periods of about four years. This ties in with the requirement in the statutory guidance to the Environment Agency that discharge authorisations be reviewed on a four yearly cycle. The next UK strategy will draw on the experience gained in the implementation of this one. It is expected to be issued for consultation in 2004 and to cover the period 2005 to 2024.

8.2.4 This UK strategy aims to contribute to the achievement of the OSPAR objective to the extent envisaged in the time frame set out in the OSPAR Strategy with Regard to Radioactive Substances. This requires that, by the year 2020, the OSPAR Commission will ensure that discharges, emissions and losses of radioactive substances are reduced to levels where the additional concentrations in the marine environment above historic levels, resulting from such discharges, emissions and losses, are close to zero.

8.2.5 By 2020, it is assumed that the major sources of radioactive discharges in the UK at present will either have closed down or will have employed abatement technology, so that overall discharges will have reduced very substantially from current levels. There will be a continuing programme of decommissioning of redundant facilities and the remediation of contaminated sites, which is likely to extend into the second half of this century. The discharges associated with these activities will be closely regulated and kept as low as
reasonably practicable, although short-term increases in the discharges of some radionuclides may be an unavoidable consequence of dismantling and remediation activities. Any new or increased business activities would be expected to result in only very small discharges.

8.2.6 The UK has a continuing commitment to a nuclear weapons programme and nuclear propulsion programme and medical uses of radioactivity are likely to continue and increase. Discharges from these sectors will be closely controlled and they will be reduced whenever it is practicable and reasonable to do so.

8.2.7 Decommissioning and remediation will also lead to substantially increased amounts of LLW being sent to shallow disposal facilities. The discharges from such facilities will be strictly controlled and carefully monitored. More information on plans for managing discharges from LLW disposal sites will be included in the next UK strategy consultation document, in 2004.
Chapter 9: Conclusion

9.1 Because of its legacy of nuclear fuel cycle activities over the last fifty years, the UK faces a more demanding task than most other OSPAR contracting parties in meeting its targets for reducing radioactive discharges. It is a task that the UK is committed to completing within the agreed time frame and taking account of the guiding principles set out in the OSPAR Strategy. The historic legacy of radioactive wastes and of contaminated plant and equipment must now be dealt with, in the interests of sustainable development, to reduce onsite risks and to avoid leaving a burden to future generations. In addition, older facilities are coming to the end of their lives and will need to be decommissioned and dismantled.

9.2 This strategy sets real and challenging targets for the next twenty years. These make clear the Government’s determination to respond to public concern over radioactive discharges and to fully implement the OSPAR Strategy. In summary, the objective and targets set out in this strategy are as follows.

- The objective of the UK Strategy for Radioactive Discharges 2001-2020 is to implement the UK’s obligations in respect of the OSPAR Strategy rigorously and transparently.
- The discharge reductions set out in this strategy are expected to result in a representative member of a local critical group of the general public being exposed to an estimated mean dose of no more than 0.02 mSv a year as a result of authorised radioactive discharges to the marine environment made from 2020 onwards.
- **Nuclear fuel production and uranium enrichment**: By 2006, production of Magnox fuel and uranium hexafluoride at Springfields are expected to cease, with consequent major reductions in alpha and beta discharges. By 2020, liquid discharges are expected to be reduced from around 120 terabecquerels (TBq) a year to virtually zero for beta-emitting nuclides and from about 0.25 TBq to less than 0.01 TBq a year for alpha-emitting nuclides.
- **Nuclear energy production**: By 2010, all of the currently operating Magnox power stations are expected to have closed down, with consequent major reductions in discharges following defuelling and post-operational clean-out. By 2020, total beta/gamma discharges (excluding tritium) are expected to be reduced from more than 10 TBq to less than 1.5 TBq a year. Discharges of tritium are expected to be reduced from more than 2800 TBq to about 850 TBq a year.
- **Spent fuel reprocessing**: Tc-99 discharges from reprocessing are expected (if the Environment Agency adopts its proposed Decision) to be reduced from close to 90 TBq a year to below 10 TBq a year as soon as possible and by no later than the end of 2006, and to less than 1 TBq a year by 2020. By around 2012, reprocessing of spent Magnox fuel is expected to cease, with consequent significant reductions in discharges. By 2020, total alpha/beta liquid discharges (excluding tritium) are expected to be reduced from 165 TBq a year to around 50 TBq a year.
- **Research facilities**: by 2020, total alpha/beta discharges (excluding tritium) are expected to be reduced from more than 4 TBq a year to less than 1 TBq a year; tritium discharges are expected to be reduced from more than 1000 TBq a year to about 20 TBq a year.
9.3 The strategy also provides a new clarity and sense of direction, for central Government and devolved administrations, for the regulatory bodies and for the nuclear operators and others responsible for the management of radioactive wastes. The UK’s ongoing nuclear operations in the 21st Century will result in very low discharges to the environment. Discharges arising from decommissioning and clean-up operations will need to continue for some time but will also be kept very low through the application of BPM.

9.4 Current uncertainties in the UK nuclear industry mean that the discharge profiles to 2020 presented in this document are indicative at present. These uncertainties relate, in particular, to the operating lifetimes of nuclear power stations, the reprocessing of spent nuclear fuel and the timetables for decommissioning redundant facilities and cleaning up historic waste liabilities. In particular, a review of the impact of future decommissioning and clean-up activities at Sellafield is to be carried out. Although at present the UK has no plans for new nuclear build, any future expansion in capacity would need to be carried out in a way that does not add significantly to the totality of discharges to the environment or otherwise detract from the aims of this strategy. Four yearly reviews of the UK strategy will provide an opportunity to focus forward discharge profiles with greater accuracy, as assumptions about future operations become more robust.

9.5 The need to protect both human health and the environment remains paramount. Estimated doses to members of the public from radioactive discharges are already well within international dose limits and will fall further as a result of the discharge reductions set out in this strategy. The UK will follow closely the development by the OSPAR Commission of environmental quality indicators for radioactive substances and work being carried out in other international fora to develop standards and criteria for protecting the environment from the effects of man-made radiation. In parallel, the UK will review and develop its own core data set of environmental concentrations in order to provide a reliable tool for demonstrating compliance with the OSPAR Strategy target for 2020.

9.6 Over 40 years ago, a Government White Paper was published, responding to a Radioactive Substances Advisory Committee report on the control of radioactive wastes. It concluded, “it is the essence of a prudent system of control that discharges should be kept not only within the upper limits of safety, but as far below them as can reasonably be achieved”. The UK has consistently applied that principle and will continue to do so, in ways that reflect both the current state of scientific knowledge and the prevailing policies and attitudes regarding environmental radioactivity.
References


15. NRPB website, http://www.nrp.org.uk


Chapter 9: Conclusion


Annex 1: OSPAR Strategy with regard to radioactive substances

Preamble

RECALLING the Convention for the Protection of the Marine Environment of the North-East Atlantic ("OSPAR Convention") and in particular Article 2.1(a) in which Contracting Parties agree to take all possible steps to prevent and eliminate pollution and to take the necessary measures to protect the maritime area against adverse effects of human activities so as to safeguard human health and to conserve marine ecosystems and, when practicable, restore marine areas which have been adversely affected;

The Contracting Parties to the Convention for the Protection of the Marine Environment of the North-East Atlantic ADOPT the following objective and strategy for the purposes of directing the future work of the Commission with regard to radioactive substances:

1. Objective

1.1 In accordance with the general objective, the objective of the Commission with regard to radioactive substances, including waste, is to prevent pollution of the maritime area from ionising radiation through progressive and substantial reductions of discharges, emissions and losses of radioactive substances, with the ultimate aim of concentrations in the environment near background values for naturally occurring radioactive substances and close to zero for artificial radioactive substances. In achieving this objective, the following issues should, inter alia, be taken into account:
   a. legitimate uses of the sea;
   b. technical feasibility;
   c. radiological impacts on man and biota.

2. Guiding principles

2.1 Assessments made, and the programmes and measures adopted, to achieve this objective will be in accordance with the general obligations as set out in Article 2 of the OSPAR Convention and consequently will involve the application of:
   a. the precautionary principle;
   b. the polluter pays principle;
   c. best available techniques and best environmental practice, including, where appropriate, clean technology.

2.2 When adopting programmes and measures in relation to radioactive substances, including waste, the Contracting Parties shall also take account of:
   a. the recommendations of the other appropriate international organisations and agencies;
   b. the monitoring procedures recommended by these international organisations and agencies;
c. existing scientific assessments of dose and risk as part of the tools for setting priorities and developing action programmes;

d. the relevant international conventions and Contracting Parties’ obligations under international law relevant to this OSPAR objective.

3. **Strategy of OSPAR with regard to radioactive substances**

3.1 The Commission will develop programmes and measures to identify, prioritise, monitor and control (i.e. to prevent and/or reduce and/or eliminate) the emissions, discharges and losses of radioactive substances caused by human activities which reach, or could reach, the marine environment and which could cause pollution through ionising radiation. To these ends, the Commission will:

a. identify radioactive substances and/or human activities which give rise to concern about the impact of discharges, emissions or losses of radioactive substances.

This identification should be based upon an evaluation of:

i. the sources and pathways of radioactive substances and their concentrations in the maritime area;

ii. the radiation exposure of humans and marine ecosystems;

iii. biological and ecological effects in the marine environment, including the vulnerability of marine ecosystems, arising from existing and future foreseen discharges, emissions and losses of radioactive substances;

iv. other adverse effects which may affect other legitimate uses of the sea;

and take account of:

v. results of scientific investigations relevant to radioactive substances in the marine environment such as the MARINA-Project of the European Commission and UNSCEAR 1996 ‘Effects of Radiation on the Environment’;

vi. existing methodologies for the scientific assessments of dose and risk;

b. assess and prioritise such substances or activities to judge whether there is a need for action;

c. develop programmes and measures which ensure the application of BAT/BEP including, where appropriate, clean technology and taking into account and not unnecessarily duplicating:

i. work practices including waste management, that meet the objectives with regard to radioactive substances;

ii. international conventions and standards;

iii. the outcome of the study by the Nuclear Energy Agency of the OECD concerning a thorough technical review and an assessment of the reprocessing and non-reprocessing options for spent fuel management;

iv. Contracting Parties’ obligations under international law.

3.2 The Commission and Contracting Parties, jointly or individually, should encourage international organisations and agencies to develop further the scientific tools for assessing radiation exposure and risk especially to marine organisms.
4. **Time frame**

4.1 This strategy will be implemented in accordance with the following time frame:

**by the year 2000**

a. the Commission will, for the whole maritime area, work towards achieving further substantial reductions or elimination of discharges, emissions and losses of radioactive substances;

**by the year 2020**

b. the Commission will ensure that discharges, emissions and losses of radioactive substances are reduced to levels where the additional concentrations in the marine environment above historic levels, resulting from such discharges, emissions and losses, are close to zero.

5. **Implementation**

5.1 This strategy will be implemented and further developed on the basis of the Commission’s Action Plan which will establish priorities, assign tasks and set appropriate deadlines and targets. The Action Plan shall concentrate on substances and/or human activities of the highest concern to the marine environment and make best use of resources.

5.2 The Commission will review and prioritise radioactive substances and/or human activities which may give rise to concern in order to identify topics for action.

5.3 Effective action is to be taken by Contracting Parties concerned, when there are reasonable grounds for concern that radioactive substances introduced into the marine environment, or which reach or could reach the marine environment, may bring about hazards to human health, harm living resources and marine ecosystems, damage amenities or interfere with other legitimate uses of the sea, even when there is no conclusive evidence of a causal relationship between inputs and effects.

5.4 Action identified by the Commission should include:

a. assessment of those situations, including an identification of the sources of radioactive substances, their pathways to the marine environment, the relative contribution of remobilised historic discharges and current discharges and the radiation exposure which they cause to humans and marine ecosystems;

b. establishment, with the help of an appropriate combination of monitoring, modelling and dose and risk assessments, as to whether these sources represent a widespread problem or are restricted to regional or local environments within the maritime area;

and draw upon the work relevant to the concerns identified, which is carried out by other international organisations and agencies. The Commission should cooperate with such organisations and agencies in developing means of action which may contribute to the solutions of problems in the maritime area.

5.5 As a result, the Commission will identify and adopt relevant measures to deal with the problems.

5.6 The Commission will undertake the development of environmental quality criteria for the protection of the marine environment from adverse effects of radioactive substances and report on progress by the year 2003.
5.7 Furthermore, the Commission will continue to develop programmes and measures to reduce radioactive discharges from nuclear installations to the marine environment by applying BAT.

5.8 The Commission and Contracting Parties, individually or jointly, will endeavour to maintain and develop further a constructive dialogue with regard to radioactive substances, including waste, with all parties concerned. This should ensure that all relevant information is available for the work of the Commission in connection with this strategy.

5.9 The implementation of this strategy should take due account of Article 24 on regionalisation and Annex IV on assessment of the quality of the marine environment of the OSPAR Convention 1992.

6. Overall evaluation and review of progress

6.1 The Commission will develop appropriate machinery to enable the preparation of a quinquennial review of progress achieved through this strategy. Based upon this review the Commission will, if necessary, revise the strategy. Such a review should, for the first time, take place by the next ministerial meeting of the Commission, and take account of inter alia:

a. assessment of the implementation and effectiveness of measures;

b. the experience gained with this strategy;

c. the findings of the quality assessment reports of the maritime area (e.g. the QSR 2000);

d. progress achieved in reviewing areas of potential concern and assessment of these areas;

e. any further new information.

Annex 1 - Definitions

For the purpose of this strategy:

a. “Radioactive substances” mean natural occurring and artificial radionuclides;

b. “Radiation exposure assessment” means the estimation of doses to which humans and marine organisms are or may be exposed and is based on the determination of the emissions, discharges and losses, the environmental transfers and exposure pathways (incl. food-chains) of radioactive substances;

c. “Risk assessment” means the estimation of the likelihood of a radiation effect in humans or marine organisms.

Annex 1 - Footnotes

(1) A number of terms used in this strategy are defined in Annex 1.

(2) The Commission will take account of all recommendations and methodologies, as well as legally binding documents, that have been developed in other international fora, and which are relevant to the OSPAR Strategy with regard to Radioactive Substances. Examples of relevant documents are the recommendations of the International Commission on Radiological Protection, the Safety Series 111 of the International Atomic Energy Agency, the Joint Convention on the Safety of Spent Fuel Management and the Safety of Radioactive Waste Management and the EU Basic Safety Standards.
Annex 2: Regulatory Impact Assessment

Title: The UK Strategy for Radioactive Discharges 2001-2020 ("the strategy").

Purpose and intended effect

(i) Identify the issue and objective

1. The purpose of the strategy is to set out how the UK will meet targets for reducing radioactive discharges by 2020 that were agreed by Ministers at the 1998 meeting of the OSPAR Commission.

2. The UK is a Contracting Party to the 1992 Convention on the Protection of the Marine Environment of the North-East Atlantic (the OSPAR Convention). In 1998, Ministers signed an agreement in support of a number of strategies for the protection of the marine environment, one of which relates to radioactive substances.

3. The objective of the OSPAR Strategy with regard to Radioactive Substances is to prevent pollution of the maritime area from ionising radiation, through progressive and substantial reductions of discharges, emissions and losses of radioactive substances. The ultimate aim is to achieve concentrations in the environment near background levels for naturally occurring radioactive substances and close to zero for artificial radioactive substances.

4. The OSPAR Strategy is to be implemented in accordance with the following time frame:

   ● by the year 2000, the OSPAR Commission will, for the whole maritime area, work towards achieving further substantial reductions or elimination of discharges, emissions and losses of radioactive substances;

   ● by the year 2020, the OSPAR Commission will ensure that discharges, emissions and losses of radioactive substances are reduced to levels where the additional concentrations in the marine environment above historic levels, resulting from such discharges, emissions and losses, are close to zero.

5. The OSPAR target for 2020 is imprecise in that the terms "historic levels" and "close to zero" are open to interpretation. The OSPAR Commission is continuing to work on establishing agreed definitions. However, it is clear that the intent is for radioactive discharges to be progressively and substantially reduced over the next two decades. At the OSPAR Commission meeting in June 2000, all Contracting Parties agreed to a Programme for the More Detailed Implementation of the OSPAR Strategy with regard to Radioactive Substances. This requires Contracting Parties to produce national plans for achieving the objectives of the OSPAR Strategy. The UK strategy for radioactive discharges comprises the UK's national plan for the purposes of the OSPAR Programme.

6. Proposals for a UK strategy were issued for consultation in June 2000. The strategy will be implemented in part by Statutory Guidance to the Environment Agency on the regulation of radioactive discharges from nuclear licensed sites in England (in preparation). Dischargers of radioactive waste must take measures to ensure that such discharges are within authorised limits set by the regulatory bodies. However, the strategy does not identify specific requirements for further regulatory action. The Government considers that, by using Best Practicable Means (BPM) to reduce discharges so that public exposure to ionising radiation arising from such discharges is As Low As Reasonably Achievable (ALARA), it will achieve the
objective of the OSPAR Strategy, to the extent set out in the timeframe for 2020. In the unlikely event that it appeared that the application of ALARA/BPM would not deliver the objective of the OSPAR Strategy, the Government would urgently review its discharges strategy.

(ii) Risk assessment

7. Risks to the general public from radioactive discharges are currently very low. Members of those groups that receive the highest radiation doses as a result of their diet or habits (critical groups) are exposed to less than 0.15 millisieverts (mSv) a year as a result of authorised discharges to the marine environment. This is just 15% of the internationally recognised dose limit of 1 mSv. For an average member of the public, discharges from nuclear installations contribute less than 0.1% to the annual dose of 2.6 mSv, the great majority of which results from natural background. The annual risk of death as a result of nuclear discharges is estimated to be less than one in ten million. The reductions in radioactive discharges set out in the strategy are unlikely to reduce this risk significantly.

8. Risks to the marine environment are more uncertain. The current system of radiological protection for man has in the past been assumed to be sufficient in itself to protect the environment. However, there is now a growing recognition that protection of the environment merits attention in its own right. Concern was expressed in some consultation responses that exposure to levels significantly higher than natural background may occur and that risks to wildlife are not explicitly considered in human dose assessment methodology. However, at present, there is no evidence that exposure to anthropogenic radiation is causing damage to wildlife in the UK. The OSPAR Quality Status Report 2000 for the Celtic Seas considers that estimated dose rates to organisms in the part of the Irish Sea closest to Sellafield are unlikely to produce adverse effects at the population level.

9. Reducing radioactive discharges reduces risks to the public and the environment but it could increase risks to workers at nuclear installations and other facilities. Reducing discharges may require greater quantities of waste to be retained on site or for engineering work to be carried out in controlled areas to fit new equipment. HM Nuclear Installations Inspectorate (NII) has a responsibility to ensure that any changes to operations on nuclear licensed sites do not result in unacceptable increases in worker exposure. Measures to reduce discharges could also, in theory, increase the risk of an accident (due to greater quantities of waste on site). In practice, the systems of control in place would ensure that such measures were not permitted. The discharges strategy recognises that, within the Government’s policy of progressive reduction of discharges, some flexibility will need to be maintained to safeguard other key Government objectives, in particular the safe and timely decommissioning of redundant facilities, the clean-up of the historic legacy of radioactive wastes, security of energy supply, the expected growth in the use of radionuclides in medicine and the operational capabilities of the armed forces.

Options

(i) Identify options

10. All significant, man-made radioactive discharges are regulated, under the provisions of the Radioactive Substances Act 1993, by the Environment Agency, the Scottish Environment Protection Agency and the Environment and Heritage Service of the Department of the Environment, Northern Ireland. The size, type and distribution of radioactive discharges in the UK shows that, in order to meet the OSPAR target for 2020, discharge reductions will need to be focussed on the nuclear fuel cycle of fuel fabrication, energy production and, particularly, the reprocessing of spent fuel at Sellafield.
11. These discharges are currently controlled through limits imposed on operators in authorisations granted by the regulators. As a general policy, the authorised limits should be progressively reduced and kept close to the levels of actual discharges. Operators are required to use BPM to minimise discharges. Considerable reductions in discharges have already been achieved in the last 25 years.

12. Ministers have made a commitment to implement the OSPAR Strategy and to achieve its objective, to the extent set out in the time frame, by 2020. Non-compliance with the OSPAR Strategy is not considered to be an option. Three options have been considered for achieving the reductions in discharges required by the OSPAR Strategy:

- Option 1 - Continue to rely on the current system of reviewing discharge limits and application of BPM, together with expected plant closures before 2020, to deliver the necessary discharge reductions.
- Option 2a – Issue a UK Strategy for Radioactive Discharges 2001-2020 that meets the OSPAR requirements for national plans and sets targets for reducing discharges from each industry sector. These targets would have the overall result that the dose to a typical member of a critical group would not exceed 0.02 mSv per year due to discharges made to the marine environment from 2020 onwards.
- Option 2b – Set targets for reducing discharges that would result in very much lower critical group doses, of 0.01, 0.005 or 0.001 mSv, from discharges made to the marine environment from 2020 onwards.

(ii) Issues of equity or fairness

13. The strategy will impose rigorous and stringent requirements on nuclear operators and other dischargers of radioactive waste. The burden is likely to fall most heavily on the larger nuclear operators, particularly British Nuclear Fuels plc (BNFL) in respect of its operations at Sellafield, in West Cumbria. Small users of radioactive substances, such as hospitals and universities, would not normally be expected to install expensive abatement equipment, unless this is justified on radiological grounds. They will, however, be expected to manage their wastes in ways that minimise discharges to the environment.

14. There will be a significant regional impact on the West Cumbria economy from the ending of Magnox fuel reprocessing at Sellafield around 2012, and smaller regional impacts associated with the closure, by 2010, of the six remaining Magnox power stations at locations around the country.

Benefits

(i) Identify the benefits

15. The overall picture to be drawn from the responses is a lack of information on tangible benefits to be derived from the strategy. Some notional gains may be seen in pollution-related health, and in activities in areas benefiting from a cleaner environment, such as tourism and fishing, especially around the Irish Sea coasts of Britain.

16. In addition, there is the softer, political benefit of seeking to improve international relations with neighbouring countries. As far as radioactive discharges are concerned, the UK is seen in some quarters as a polluter of the marine environment, insensitive to the concerns and protestations of its European neighbours. It is undeniable that the UK, due to Sellafield, is the largest discharger of radioactive substances into the OSPAR maritime area. By putting
forward, and adhering to, a clear programme for reducing radioactive discharges within the OSPAR time frame, the UK is likely to gain greater respect and credibility among the OSPAR contracting parties and a reduced risk of legal challenges. Indeed, at the present time (mid 2002), the UK is facing international legal challenges related to discharges from Sellafield. Publication of the discharges strategy may help to reduce the risk of further such challenges. The avoidance or reduction of the associated legal costs alone could potentially be a very substantial benefit, running to millions of pounds in value.

(ii) **Quantify the benefits**

17. The values ascribed to the benefits of the strategy are likely to be subject to a large degree of uncertainty. For human health, an annual benefit of £0-10 million has been estimated, based on assessment of the savings in human exposure that would be achieved at Sellafield. A further £0-5 million a year has been estimated as the benefit to the fishing industry and £0-7 million a year to tourism. However, it has not been possible to distinguish between the various options in estimating these benefits, as the summary at Table 1 indicates.

<table>
<thead>
<tr>
<th>Table 1. Summary of identified benefits</th>
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<tbody>
<tr>
<td>General Impact</td>
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<tr>
<td></td>
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<tr>
<td>Human Health</td>
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<tr>
<td>Environmental</td>
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<td>Socio-economic</td>
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<td></td>
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<tr>
<td>Other</td>
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<tr>
<td>Total</td>
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**Compliance and other costs**

(i) **Business sectors affected**

18. The strategy will have a direct impact on the following business sectors. The estimated direct costs to these sectors are shown in the summary at Table 2:

- Nuclear fuel production and uranium enrichment – carried out by BNFL at its Springfields and Capenhurst sites.
- Nuclear energy production – carried out by BNFL at 6 Magnox power stations and by British Electric plc at 7 advanced gas-cooled reactor stations and 1 pressurised water reactor station. An additional 5 Magnox stations are shut down and in various stages of decommissioning.
- Spent fuel reprocessing – carried out by BNFL at Sellafield in two plants, B205 for Magnox fuel and THORP for other fuels.
- Research facilities – former nuclear research establishments operated by UKAEA at Dounreay, Winfrith, Windscale, Harwell and Culham. Reactors are now shut down and the focus is on decommissioning and site restoration.
- Defence facilities – Atomic Weapons Establishments at Aldermaston and Burghfield and nuclear powered submarines based at Faslane and Devonport.
- Other sources of discharges - including radioisotope manufacture and supply, phosphoric acid purification, offshore oil and gas production and medical facilities.

19. Possible indirect effects of the strategy were investigated regarding health and safety aspects, socio-economic issues and other disbenefits, including the likely societal costs associated with the closure programme for Magnox power stations and the associated ending of Magnox reprocessing at Sellafield. Estimated indirect costs are shown at Table 3. A considerable number of these potential costs could not be readily quantified and, for those that could, assumptions have had to be made to resolve conflicting information and create a balanced and probable picture.

(ii) Compliance costs for a typical business

20. Because of the widely varied nature of businesses that discharge radioactive wastes, no attempt has been made to describe a typical business. However, the most significant costs will be borne by BNFL in respect of their Sellafield site. BNFL has estimated that implementing the strategy (option 2a) will cost them £0.75 billion in direct costs. This reflects the full cost of closure of the Magnox power stations and with them the closure of Magnox fuel reprocessing, at dates that are earlier than those in BNFL’s “ideal scenario”. The extent to which these costs are actually attributable to the strategy, or would arise in any case, is debatable and the allocation of annual direct costs shown in the summary table above is therefore subject to considerable uncertainty.
21. Option (2b) involves discharge reduction to give dose rates substantially below the strategy aim of 20 Sv/yr, down as low as 1 Sv/yr. The major impact would again be felt at Sellafield, as major additional abatement and waste treatment facilities would be required to meet the reduced 2020 ‘targets’. BNFL’s estimated costs are speculative, at £5 - 10 billion and the same societal issues would also apply to this scenario.

(iii) Total compliance costs

22. Current Government policy is the progressive reduction of discharge authorisations and actual discharges. Some discharge abatement measures would undoubtedly be required by the regulators, to employ BPM, in the absence of the strategy (option 2a). Safety cases for the operation of nuclear installations would also need to be reviewed by the NII and such reviews may lead to plant closures on economic grounds. The real added cost of implementing the strategy may therefore be lower than the nuclear industry believes.

<table>
<thead>
<tr>
<th>Table 3. Summary of indirect costs to achieve scenarios</th>
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<tbody>
<tr>
<td>General Impact</td>
</tr>
<tr>
<td>Costs million £. Blank means no data.</td>
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<tr>
<td>Scenario 1</td>
</tr>
<tr>
<td>Health and Safety</td>
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<tr>
<td>Site workers exposed to extra radiation through concentrate and contain measures</td>
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<tr>
<td>Decommissioning activity - assumed costs:</td>
</tr>
<tr>
<td>:statistical life @ £1 m,</td>
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<tr>
<td>:major injury @ 50k.</td>
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<tr>
<td>Dose to sewerage workers above perceived safe level</td>
</tr>
<tr>
<td>Hospitals - risk of reduced treatment availability from limits on discharges.</td>
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<tr>
<td>Food safety - perception of old ‘unsafe’ limits/failing to meet new, lower ‘safe’ limits.</td>
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<tr>
<td>Socio-Economic</td>
</tr>
<tr>
<td>533 - 558</td>
</tr>
<tr>
<td>Health</td>
</tr>
<tr>
<td>Housing</td>
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<tr>
<td>Small Business</td>
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<tr>
<td>Other disbenefits</td>
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<tr>
<td>Regulatory</td>
</tr>
<tr>
<td>Confidence</td>
</tr>
<tr>
<td>0-67</td>
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<tr>
<td>Total</td>
</tr>
<tr>
<td>Confidence on these figures suggests a range of -50% to +100%</td>
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</table>
23. The total estimated costs of implementing the strategy, from addition of the totals in Tables 2 and 3, are as follows:

- Option 1 £808-900 million
- Option 2a £808-1,050 million
- Option 2b £5,993 – 11,126 million

Consultation with small businesses

24. The primary costs of the strategy will be borne by major businesses in the power generating and reprocessing sector, and to some extent by the MoD. However, there are significant on-costs in the areas surrounding the major nuclear facilities and some of these will undoubtedly be borne by small businesses supplying these major operators. Insufficient data is available to quantify this, but it appears that the remote location of the major nuclear facilities creates a local employment and business pattern disproportionately reliant on the major employer. The result of any negative change in spending patterns by the major employer is therefore felt more by small businesses than would be the case in other areas of the country with a more diversified economy.

Results of consultations

25. A draft of the strategy was issued for consultation in June 2000 and responses received from a wide range of users of radioactive substances, regulators and non-governmental organisations. To explore further the possible impact of the strategy, a questionnaire was sent to representatives of those organisations and groups potentially most affected by the strategy. The questionnaire described the scenarios set out in paragraph 12. The questionnaire required respondents to examine existing business plans (option 1), measures to meet the targets of the discharges strategy (option 2a) and the measures required to go significantly beyond that (option 2b).

26. Potential respondents to the questionnaire were identified from various sectors that discharge radioactive wastes, from regulatory and local government bodies, from those groups historically opposed to the use of radioactive materials, and from others who may be affected by discharges. The responses to the questionnaire have been used along with the responses to the strategy consultation to inform the Regulatory Impact Assessment. The questionnaire attempted to draw from dischargers not only their thoughts on techniques to cope with reduced discharge levels, but also their estimates of associated costs. Similarly, groups negatively impacted by radioactive discharges were encouraged to offer the value of benefits that would accrue. Comparatively few respondents were able to associate any meaningful costs to their comments and this has inevitably increased the margin of error in the conclusions.

27. Most consultees were supportive of the need to carry out an RIA, although some were uncertain of the distinction between scenarios 1 and 2a. Some consultees (mostly “small users”) saw the references to dose consequences in Scenarios 2a and 2b as an intention by the Government to impose new and more stringent dose limits, and commented that this would be unwarranted on radiation protection grounds. Non-dischargers on the whole welcomed the discharge reductions set out in the strategy, but some felt that only total closure of facilities and zero discharges would be acceptable. Consultees who were also dischargers were able to provide reasonable estimates of costs, but no consultees attempted to quantify benefits. The cost estimates provided were dominated by those from BNFL.
Summary and recommendations

28. A summary of annual costs and benefits is at Table 4. From the information received and the assumptions made in developing cost models, the base case (scenario 1) will cost the UK as a whole some £23-50 million/year, to 2020.

29. The discharges strategy implemented to meet scenario 2a will cost a similar amount, up to perhaps £59 million/year. The maximum incremental costs over the base case are therefore between 0 and £9 million/year, to 2020. As identified, the key costs are felt within BNFL, both through loss of generating revenue and some costs brought forward for Magnox decommissioning. There are also external societal costs associated with job losses in local economies. As stated, considerable uncertainty surrounds the base data, so the margin of error is high.

30. For scenario 2b, largely speculative costs have been proposed by BNFL which drive the whole equation. These costs, £5 - 10 billion to 2020, cannot be checked in a meaningful way. Using them, and costs/benefits derived from other calculations, puts the net cost of scenario 2b at £333-623 million/year, to 2020. The incremental costs over the base case and scenario 2a are therefore around £274 - 578 million/year, to 2020. Due to considerable uncertainties in the data it is felt that a range of values should be considered here of £100 - 600 million/year.

31. In conclusion, the data available suggests costs up to £50 million/annum will be borne by the UK over the next two decades to meet the aims of OSPAR, with the additional targets in the discharges strategy (scenario 2a) adding between 0 and £9 million/annum to these costs. Going beyond the primary targets of the strategy to scenario 2b will add hundreds of millions of pounds/annum to this cost.

32. Issuing the strategy (option 2a) has a relatively small incremental cost and has considerable (but difficult to quantify) benefits in terms of meeting the OSPAR reporting criteria and demonstrating the UK’s commitment to achieving the OSPAR Strategy objective in terms of the 2020 time frame. Going further than the scale and pace of discharge reductions set out in the strategy would involve large additional costs of hundreds of millions of pounds a year, with little discernible additional benefit.
Enforcement, sanctions, monitoring and review

33. Compliance with the discharge reductions set out in the strategy will be via discharge authorisations granted by environmental regulatory bodies and reviewed every four years. For nuclear licensed sites, statutory guidance will be issued to the environmental regulatory bodies on the setting of such authorisations and this will reflect the aims of the strategy. Authorisations specify annual and shorter term limits for amounts of radioactivity discharged, with separate limits for at least some individual radionuclides. Monitoring systems are in place to ensure that any breach of the authorised limits would be detected. The regulatory bodies have powers to bring prosecutions under the Radioactive Substances Act 1993 in relation to any breach of the conditions of a discharge authorisation.

Footnote

This RIA is based on a study carried out by Entec UK Limited, under a consultancy contract let by the Department for Environment, Food and Rural Affairs. Copies of Entec’s final report under this contract are available on request from DEFRA Radioactive Substances Division, Zone 4/F6, Ashdown House, 123 Victoria Street, London SW1E 6DE.

### Table 4. Summary of annual costs and benefits

<table>
<thead>
<tr>
<th>General area of impact</th>
<th>Costs (-)/Benefit (+), £ million/yr.</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Scenario 1</td>
<td>Scenario 2a</td>
</tr>
<tr>
<td>Direct sector costs</td>
<td>-15</td>
<td>-15 to -21</td>
</tr>
<tr>
<td>Indirect costs</td>
<td>-30 to -35</td>
<td>-30 to -38</td>
</tr>
<tr>
<td>Benefits</td>
<td>+22 to 0</td>
<td>+22 to 0</td>
</tr>
<tr>
<td>Total</td>
<td>-23 to -50</td>
<td>-23 to -59</td>
</tr>
</tbody>
</table>
| Increment over base case | 0 -9     | 288 - 573    | Incremental costs for 2a are modest, for 2b potentially large.
Annex 3: Accounting for total alpha and beta activity in radioactive discharges

Some of the target figures and discharge profiles shown in the draft UK discharge strategy are expressed in terms of “total alpha” and “total beta” activity. For some nuclear sites and sectors, these projected target figures were derived by summing the activity of selected individual alpha and beta emitting radionuclides. In practice, several nuclear sites account for discharges of alpha and beta emitting radionuclides by an actual measurement of “total alpha” and “total beta” rather than by summing the individual radionuclide measurements. One advantage of a total alpha or total beta measurement is that it will potentially include the contribution to the overall activity from radionuclides which, individually, would be difficult to measure or would be below detection limits.

For alpha emitters, a total (or gross) alpha measurement is fairly straightforward as alpha particles from individual radionuclides usually have non-overlapping and narrow peak energies and are detected with similar efficiency. By contrast, beta particles have a wide range of energies, often overlapping and individual beta emitting radionuclides have different detection efficiencies. The value for “total beta” as determined by measurement thus depends on the mix of radionuclides discharged from sites. Some radionuclides, such as Sr-90, have a short lived daughter which also contributes to the total beta activity figure, ie there are two beta particles (one from Sr-90 and one from its radioactive daughter Y-90) which will potentially be detected for each single strontium 90 decay. The total beta measurement will also depend upon the radionuclide which is taken as the reference standard, and upon the method of measurement and the detection efficiency of these measurement techniques (eg liquid scintillation counting, gas proportional counting or other techniques).

When analysing samples of liquid and gaseous effluents, tritium is normally excluded from total beta measurements. This radionuclide emits very weak beta particles and its radiometric detection efficiency by a gross measurement technique will generally be low. Tritium is sometimes removed from effluent samples by distillation and is normally analysed separately.

Limits on the aggregate of “alpha emitting radionuclides”, “beta emitting radionuclides” or “other radionuclides” are included in discharge authorisations under the Radioactive Substances Act 1993. Usually, compliance with this type of authorised limit is determined by means of total alpha and total beta measurements. The methods of measurement used for determining compliance with these limits are set out in authorisations or in documents that are part of each site’s regulatory control systems. For the above reasons, care must be taken when making comparisons of “total beta” discharges from different nuclear sites and particularly those from different sectors. Thus the methods of measurement and accounting that are used to comply with discharge authorisations are site specific and produce total beta measurements which, strictly speaking, are not directly comparable. However, they give a broad enough indication of the level of beta discharges to be useful when examining trends and longer term changes. For the purposes of the strategy total alpha activity and total beta activity in discharges from nuclear industry sectors have been combined and summed in showing past and predicted future discharges to the OSPAR regions.