INFORMATION IN SUPPORT OF APPLICATIONS BY MAGNOX ELECTRIC LIMITED UNDER THE RADIOACTIVE SUBSTANCES ACT 1993 TO DISPOSE AND DISCHARGE RADIOACTIVE WASTES FROM CHAPELCROSS SITE

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Contents Page

1. SUMMARY 7

2. INTRODUCTION 8

3. THE CHAPELCROSS SITE 9

3.1 Location 9

3.2 Description 11

3.3 Justification for Activities Post Generation 11

3.4 Sources of radioactive waste 11

3.5 Management Arrangements for Company and Site 14

3.6 Waste Strategy 27

4. DISCHARGE OF LIQUID RADIOACTIVE WASTE 30

4.1 Sources and Management of Liquid Effluent Discharges 30

4.2 Principal Nuclide Contributors to aqueous discharges 34

4.3 Current Discharge Authorisations 36

4.4 Historic Discharges 36

4.5 Anticipated liquid effluent arisings 2009- 2014 41

4.6 Future Needs and Proposed Limits for liquid radioactive discharges to 2014 46

4.7 Alternative Options for Managing Radioactive Liquid Waste (BPEO/BPM) 48

4.8 UK Strategy for Radioactive Discharges to the Marine Environment 49

4.9 Radiological Impacts 49

5. DISCHARGE OF GASEOUS RADIOACTIVE WASTE 51

5.1 Sources of Radioactive Releases to Atmosphere 51

5.2 Principal Nuclide Contributors to Aerial discharges 53

5.3 Current Authorisations for Gaseous Discharges 56

5.4 Historic Discharges 56

5.5 Future Needs and Proposed Limits to 2014 64

5.6 Alternative Options for Managing Radioactive Gaseous Waste (BPEO/BPM) 67

5.7 Radiological Impacts 68

6. TRANSFER OF WASTE FOR INCINERATION 70

6.1 Description of Waste 70

6.2 Sources and Production 70

6.3 Management of Waste 71

6.4 Historic Arisings 72

6.5 Consideration of BPEO and BPM 74

6.6 Future Management Strategy 75

6.7 Future Needs and Proposed Limits to 2014 75

6.8 Radiological Impacts 76

7. DISPOSAL OF LOW LEVEL WASTE TO THE NATIONAL LOW LEVEL WASTE REPOSITORY. 77

7.1 Description of Waste 77

7.2 Sources and Production 78

7.3 Management of Waste 79

7.4 Historic Arisings 80

7.5 Consideration of BPEO and BPM 82

7.6 Future Needs and Proposed Limits to 2014 83

7.7 Radiological Impacts 87

8. TRANSFER OF LOW LEVEL WASTE TO WASTE MANAGEMENT TECHNOLOGY WINFRITH 88

8.1 Description of Waste 88

8.2 Sources and Production 88

8.3 Management of Waste 88

8.4 Limits 88

9. TRANSFER OF INTERMEDIATE LEVEL WASTE TO BNG, SELLAFIELD 89

9.1 Description of Waste 89

9.2 Sources and Production 89

9.3 Management of Waste 90

9.4 Historic Arisings 90

9.5 Consideration of BPEO and BPM 91

9.6 Future Management Strategy 91

9.7 Future Needs and Proposed Limits to 2014 91

9.8 Radiological Impacts 95

10. ENVIRONMENTAL IMPACT 96

10.1 Landscape and Ecology 96

10.2 Impact of Activities on Environmentally Sensitive Areas 96

10.3 Concentrations and Accumulation of Radionuclides in the Local Environment from Past and Future Discharges 97

11. CONCLUSIONS 105

12. REFERENCES 107

13. GLOSSARY OF TECHNICAL TERMS 108

14. LIST OF ABBREVIATIONS AND ACRONYMS 112

APPENDIX 1 SUMMARY OF QUARTERLY BULK EFFLUENT SAMPLES FOR 2003TABLE A56 – SUMMARY OF QUARTERLY DISCHARGE RESULTS FOR 2003 **115**

APPENDIX 2 SUMMARY OF QUARTERLY BULK EFFLUENT SAMPLES FOR 2006 **116**

APPENDIX 3 ESTIMATE OF AERIAL DISCHARGES DUE TO NATURAL LEAKAGE RESULTING FROM EVAPORATION THE CHAPELCROSS COOLING PONDS **117**

APPENDIX 4 RADIOLOGICAL RISK ASSESSMENT SUMMARY **120**

APPENDIX 5 AERIAL ASSESSMENT METHODOLOGY **125**

APPENDIX 6 MARINE ASSESSMENT METHODOLOGY **128**

APPENDIX 7 ACTIVITY FINGERPRINTS FOR LLW STREAMS **131**

APPENDIX 8 AGREEMENT IN PRINCIPLE FOR DISPOSAL OF ORGANIC WASTE FOR INCINERATION **133**

APPENDIX 9 INTERSITE AGREEMENT FOR TRANSFER OF BETA / GAMMA WASTES TO SELLAFIELD **136**

Tables

Table 1 - Breakdown of Fission Product contributors (% contribution to total beta) 35

Table 2 – Current Liquid Discharge Authorisation (issued 1986) 36

Table 3 Total radioactive liquid discharges, 1996-2006 36

Table 4 – Nuclides Analysed Routinely In Liquid Quarterly Bulk Effluent Samples. 37

Table 5 – Representative annual volumetric liquid arisings by source since cessation of generation. 37

Table 6 - Principal beta radionuclides in liquid discharges, 1996-2006 40

Table 7 – Percentage Contributors to Alpha Sludge Activities 41

Table 8 – Estimated annual volumetric and activity arisings by principal nuclides for the Ponds Facility 42

Table 9 – Estimated annual liquid effluent arisings from CXPP 2009-2014 42

Table 10 – Estimated Annual groundwater arisings 2009 - 2014 43

Table 11 – Estimates of Annual arisings from Reactor Active Drain Tanks 2009-2104 43

Table 12 – Estimated annual arisings for flask handing during reactor defuelling 44

Table 13 – Summary of estimated total annual effluent discharges for the period 2009-2014 45

Table 14 - Proposed liquid discharge limits 47

Table 15 - Proposed discharge limits and radionuclide composition assumed for doses arising from discharge of liquid effluents 49
Table 16 - Individual Doses to Candidate Critical Groups arising from liquid discharges at the proposed limits 50
Table 17 - Collective dose from one year's liquid discharges at the proposed limits 50
Table 18 - Gaseous outlets 51
Table 19 - Beta Particulate contributors 55
Table 20 - Current Gaseous discharge limits (Authorisation issued 1986) 56
Table 21 - Radioactive gaseous discharges, 1996 to 2006 56
Table 22 – Revised estimate of C14 discharges from Reactors R1-R4 for 2006..58
Table 23 - Minor discharge outlets and estimated discharges 62
Table 24 – Calder Hall Annual Aerial Discharges - 5 Year Summary 63
Table 25 – Calder Hall Aerial Discharge by Year 1997 - 2001 63
Table 26 - Proposed gaseous discharge limits 67
Table 27 - Annual Critical Group dose for gaseous discharges at the proposed limits 69
Table 28 - Collective dose from one year's aerial discharges at the proposed limits 69
Table 29 - Maximum radionuclide composition of waste oil at Chapelcross 72
Table 30 - Total estimated radionuclide inventory in waste oil at Chapelcross 73
Table 31 - Current transfer limits for liquid scintillant 73
Table 32 - Proposed annual transfers of combustible liquid waste from Chapelcross 76
Table 33 - Proposed annual transfers of activated charcoal granules from Chapelcross 76
Table 34 - Annual solid LLW disposals, 1996-2006 (Proposed Definitions) 82
Table 35 – Anticipated LLW Arisings to 2018 84
Table 36 - Proposed solid LLW disposal volume limits 86
Table 37 - Proposed solid LLW radioactivity limits 86
Table 38- Solid Intermediate Level Waste stream descriptions 89
Table 39 - Intermediate Level Waste transfer volumes to MBGW, 1996-2006 90
Table 40 – Anticipated LLW Arisings to 2018 95
Table 41 - Proposed solid ILW volume disposal limits 95
Table 42 - Activities (Bq/kg wet weight) Reported in Flounder and Salmon/Sea Trout 98
Table 43 - Activities (Bq/kg wet weight) reported in seaweed and silt 99
Table 44 - Stake Net area Gamma Dose Rates 100
Table 45 - Annual mean Pipeline Gamma Dose Rates at 2m 101

Table 46 - Activities ($Bq.l^{-1}$) Reported in Inner Farm Milk (0-3 km from Chapelcross) ... 102

Table 47 - Activities ($Bq.l^{-1}$) Reported in Outer Farm Milk (3-6 km from Chapelcross) ... 103

Table 48 - Activities ($Bq.kg^{-1}$ fresh weight) Reported in Local Green Vegetables (0-2km from Chapelcross Site) ... 104

Table 49Activities ($Bq.kg^{-1}$ fresh weight) Reported in Control Green Vegetables(1) ... 104

Table 50 - Proposed gaseous discharge limits ... 105

Table 51 - Proposed liquid discharge limits ... 105

Table 52 - Proposed annual transfers of combustible liquid waste from Chapelcross ... 105

Table 53 - Proposed annual transfers of activated charcoal granules from Chapelcross for incineration ... 105

Table 54 - Proposed solid LLW radioactivity and volume limits ... 106

Table 55 - Proposed solid ILW volume disposal limits ... 106

Table A56 Annual Proposed Limit for Discharges to Atmosphere from the Chapelcross ... 120

Table A57 Annual Proposed Limit for Liquid Discharges to the Solway Firth from Chapelcross ... 120

FIGURES

Figure 1 Chapelcross Site location ... 9

Figure 2 Chapelcross Site plan ... 10

Figure 3 Organisational structure of Magnox North Ltd. Board and Executive ... 19

Figure 4 Simplified diagram of active liquid effluent treatment routes ... 32

Figure 5 Historic discharges of tritium, 1996 to 2006 ... 38

Figure 6 Historic discharges of ‘Other Beta Activity’, 1996 to 2006 ... 39

Figure 7 Historic discharges of alpha activity, 1996 to 2006 ... 40

Figure 8 Historic discharges of argon-41 ... 57

Figure 9 Historic discharges of carbon-14 ... 57

Figure 10 Historic discharges of sulphur-35 ... 58

Figure 11 Historical discharges of tritium ... 60

Figure 12 Disposal volumes of LLW from Chapelcross sent to the LLWR near Drigg ... 81

1. SUMMARY

Chapelcross Power Station began operation in 1955, with four Magnox Reactors producing a combined power of 200 MW to the national grid. In 1980 the Chapelcross Processing Plant (CXPP) became operational, producing tritium from neutron absorber cartridges irradiated within the reactors.

Power generation and operations within the CXPP ceased in 2004 and the site has entered the decommissioning phase. Initial decommissioning operations will include the defuelling of all four reactors, with fuel being transported to Sellafield for reprocessing. Following defuelling the station will enter the Care and Maintenance preparation phase, during which, dismantling, demolition and waste management activities will be undertaken to remove most radioactive and non-radioactive plant and buildings.

This document supports an application by Magnox Electric Ltd. under Section 13 of the Radioactive Substances Act 1993 (RSA93) for authorisations to discharge aerial and liquid wastes and dispose of solid wastes in support of the planned decommissioning activities, with the aim of reducing the overall liabilities on the site and to place any residual activities in a suitable condition for safe long-term storage.

The revised application recognises that the radioactive discharges during the decommissioning phase will be significantly less than those generated during station operation and the summary report seeks to substantiate the appropriateness of the requested limits.

Details have been provided of historical discharges of gaseous, liquid and solid waste arisings and recommendations of likely future discharge requirements made.

Options for processing aerial, liquid and solid wastes have been examined to determine the Best Practicable Environmental Option (BPEO) for managing the identified arisings

Magnox Electric Ltd. recognise that, at this early stage in the decommissioning process, there is a significant uncertainty within the estimates provided, however, as detailed decommissioning plans are developed and programmed, more definitive estimates of the waste arisings will be developed and the chosen management option optimised through the application of a robust Best Practicable Means (BPM) process.

Magnox Electric Ltd. are committed to maintaining an open dialogue with SEPA throughout the decommissioning process and it is believed that as detailed decommissioning plans are developed, this will allow more appropriate authorisation limits to be applied which reflect the specific planned operations.

2. INTRODUCTION

The control of radioactive substances is subject to the provisions of the Radioactive Substances Act 1993 (RSA93). RSA93 provides for the control of radioactive substances in such a way as to minimise the creation of radioactive waste and to ensure that any radioactive waste generated is disposed of in a controlled fashion. Magnox Electric Ltd. currently holds a number of Certificates of Authorisation to dispose of gaseous, liquid and solid wastes resulting from its operations on the Chapelcross site. These were granted by Her Majesty's Industrial Pollution Inspectorate (HMIPI) under RSA60 and RSA93. These Certificates set out the conditions and limitations under which the site is permitted to make aerial and aqueous discharges to the environment and dispose of low level solid wastes off-site. During operation, discharges of radioactive waste from the Chapelcross Site have been made in accordance with these authorisations.

Reactor operations at Chapelcross ceased in June 2004. The Company has declared that the reactors will be defuelled as soon as practicable and the site has progressively moved forward into decommissioning.

Government strategy on decommissioning a nuclear power station, set out in Cm 2919 (Reference 1), is that following final defuelling, buildings external to the reactor should be removed and, after a period of 100 years Care and Maintenance, the reactor demolished. This strategy has been adopted in the Site Lifetime Plan (LTP) (Reference 2).

The purpose of this document is to substantiate the continued need for radioactive waste discharges and disposals throughout the period following reactor operation when the reactors will be defuelled, the fuel despatched away from site and the site prepared for care and maintenance. Although the limits for radioactive gaseous, liquid and solid waste disposals are considered separately in this report, the basis for the substantiation of the discharge requirements is the same. From a consideration of future activities, the requirements are laid out in a way which is consistent with the approach adopted by the Scottish Environment Protection Agency (SEPA). SEPA require that the limits applied for should exceed actual routine discharge levels only by a margin sufficient to allow for the normal variations that might be expected during routine operations on the site. The source and nature of each of the arisings is considered and it is argued that the processes and procedures at Chapelcross Site ensure that Best Practicable Means (BPM) are used to minimise discharges and disposals from the site. It is shown that even discharges at the proposed limits would give rise to radiological impacts that are significantly less than the relevant dose constraints and limits..

3. THE CHAPELCROSS SITE

3.1 Location

Chapelcross is situated in the Chapelcross Ward within the Annandale and Eskdale District of the Dumfries and Galloway Region of Scotland (National Grid Reference NY 215 696)[1]. It lies approximately 3 km north-east of Annan in Dumfriesshire, with a population of 10,000 and is some 6 km from the coast of the Solway Firth (Figure 1) and 13 km from the land border with England.

The power station was built on the site of a former RAF station. There are no other nuclear installations adjacent to Chapelcross.

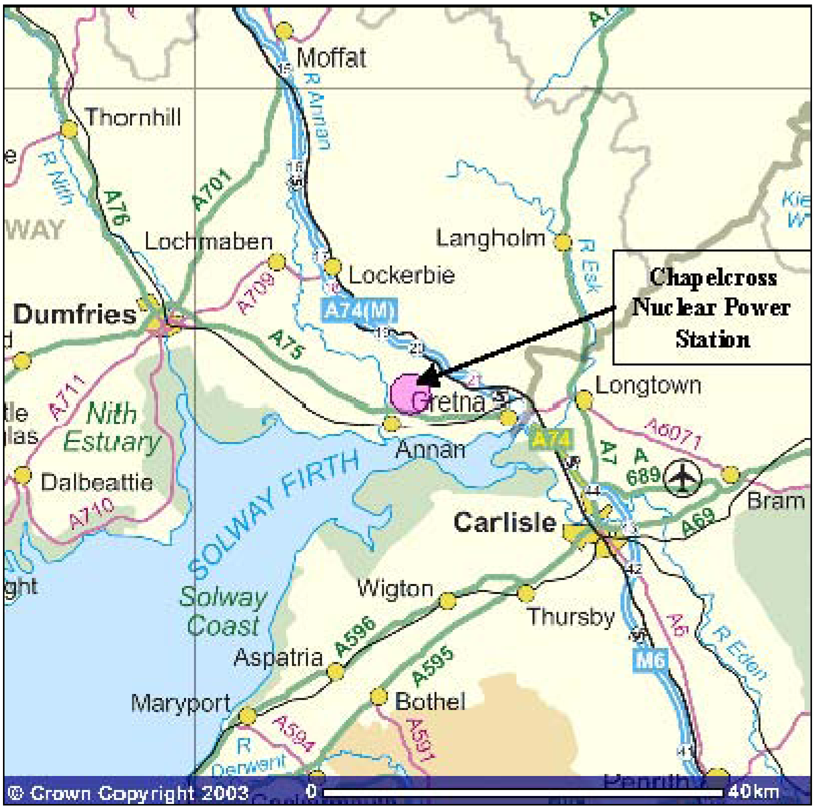

Figure 1 Chapelcross Site location

Access to Chapelcross is via minor roads, which connect to the A74(M) motorway approximately 7 km to the east, the B6357 to the north of the site, and B721 to the south. There is a railway-line, which passes through Annan, however there is no railhead near Chapelcross.

The Nuclear Decommissioning Authority (NDA) owns land comprising some 188 hectares, of which the Nuclear Licensed Site comprises some 96 hectares, which is substantially larger than the immediate area of the main power station structures. The Site comprises the power station operational site and an area to the north of the cooling towers, described as ‘North Site’. A site plan is given in Figure 2. The majority of the area surrounding Chapelcross is farmed land that is privately owned. The site is currently operated by Magnox Electric Ltd. on behalf of the Nuclear Decommissioning Authority.

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[1] From: Ordnance Survey Landranger Series (Landranger 85: Carlisle and Solway Firth, 1:50,000 scale).

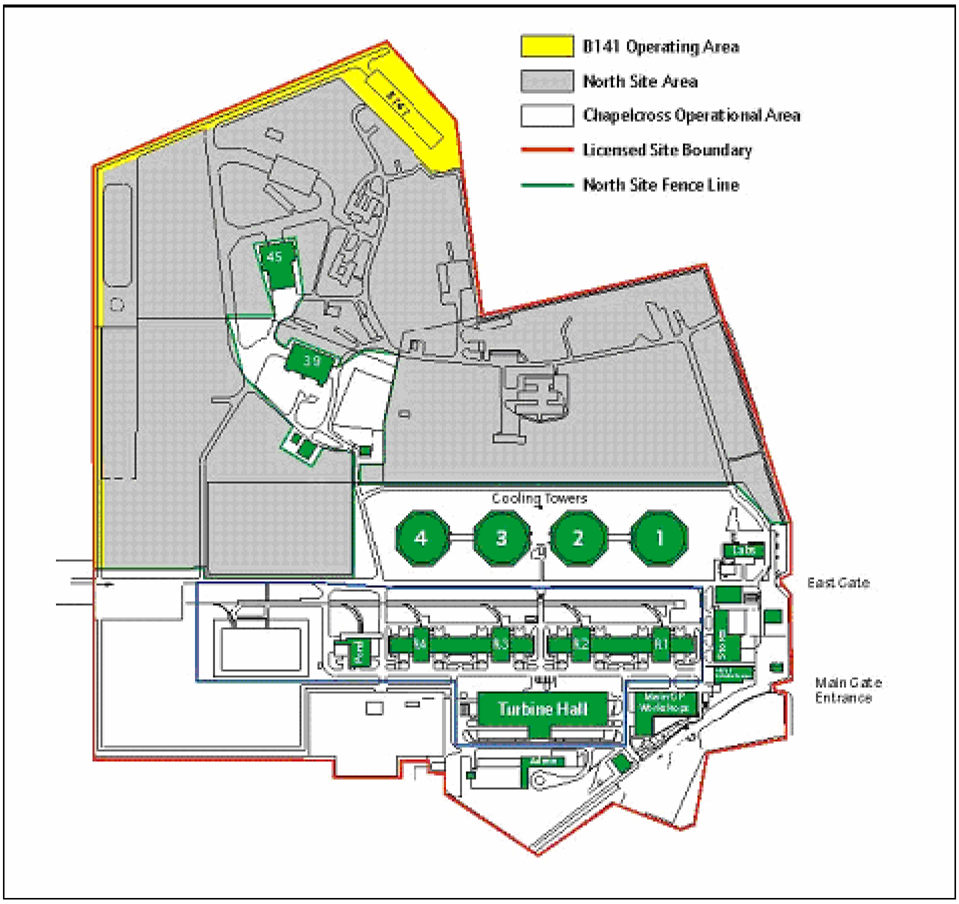

Figure 2 Chapelcross Site plan

The Site does not lie in any designated area, but the effluent pipeline discharges into a Site of Special Scientific Interest (SSSI). The Upper Solway Flats and Marshes SSSI was notified in 1988 for wintering wildfowl and wading birds and is also noted for its breeding birds, populations of Natterjack toad and invertebrates. This area is also designated at the European level as a Special Protection Area (SPA) and a Special Area of Conservation (SAC). In addition the Solway estuary wetland is of international importance under the Ramsar Convention.

Chapelcross is surrounded by a Nuclear Safeguarding Zone in which graded planning controls apply to new developments and within which applications for such new developments must be referred to the Nuclear Installations Inspectorate (NII) by the Planning Authority. Consultation with the NII is required in the following cases:

- within approximately 1.5 km (0.9 miles) of the site, development leading to an increase in residential accommodation or likely to cause an influx of non-residential population;
- between 1.5 to 3 km (0.9 to 1.8 miles) of the site, development providing residential accommodation, permanent or temporary, for more than 50 people or likely to cause an influx of non-residential population exceeding 50 people; and
- within an area enclosed by a circle of 8 km (5 miles) radius, development likely to lead to an increase of 500 people in the population at any place.

Magnox Electric Ltd. understands that the move to the post operational period of the power station at Chapelcross will have no immediate effect on the definition of these zones.

3.2 Description

Chapelcross was the first nuclear power station in Scotland, designed to generate 200 MW of electrical power to the grid system. The site is comprised of the Chapelcross power station and Chapelcross Processing Plant (CXPP).

3.2.1 Chapelcross Power Station.

Work to build Chapelcross Power Station began in October 1955. Reactor 1 was completed and started generating electricity in February 1959. Reactors 2, 3 and 4 entered service in 1960. Chapelcross Power Station therefore generated electricity from four Magnox reactors where the heat generated by the controlled chain fission reaction in uranium fuel was transferred by carbon dioxide gas at high pressure to boilers where it was used to raise steam. The steam then powered the turbine used to drive the electrical generators. Each reactor was capable of a nominal electrical output of 60 MW.

Each reactor contains approximately 10,000 fuel elements manufactured from uranium metal encased in magnesium alloy cans. These are located within a graphite moderator. Following closure the carbon dioxide coolant gas has been depressurized and replaced by dry air. The fuel elements are to be removed from each reactor and despatched to Sellafield Limited for reprocessing.

For most of its operational life Chapelcross exported 1.4-1.5 TW per year. The Plant formally ceased its operational life on 29 June 2004.

3.2.2 The Chapelcross Processing Plant

The Chapelcross processing plant is a separate operational unit for the production of tritium. This plant operated from 1980 until 31st March 2005.

3.3 Justification for Activities Post Generation

Following the cessation of operational activities at Chapelcross, a Post Operational Safety Case (POSC) has been introduced. This formally enabled much of the equipment and procedures utilised during the operational phase to be discontinued, releasing resources for other hazard reduction and clean-up activities.

Magnox Electric Ltd. is keen to ensure that progress is made with the hazard reduction and cleanup of various ancillary buildings at Chapelcross to enable the site to move forward into care and maintenance. The removal of the redundant Graphite Handling Facility, as part of the North Site clearance programme, is in progress. Other redundant buildings will also be removed. This will lead to the creation of Low Level Waste (LLW). Magnox Electric Ltd. is undertaking a review of all operations that will need to be undertaken on the site during the period of preparation for site care and maintenance. This will identify the impact of the various works being undertaken at a given time on the likely generation of all waste forms.

3.4 Sources of radioactive waste

3.4.1 Operational Conditions

A range of radionuclides were produced during the operational phase of the reactors life. The origins of individual radionuclides and those identified as being pertinent following the cessation of power generation are discussed below.

Uranium Contamination

Magnox reactors are thermal nuclear reactors that use uranium as the nuclear fuel and have graphite moderators (see Section 3.2). Each fuel element consists of a bar of uranium metal encased in cladding manufactured from a magnesium alloy known as Magnox. When the reactors were operating, the uranium in the fuel elements underwent a nuclear fission process which produced heat and fission products. In addition, some neutrons produced in the fission process were absorbed in the uranium in the fuel elements and produced atoms of actinides such as plutonium and americium. During operation of the reactors, the fission products and actinides were retained within the fuel element by the Magnox cladding. Tritium was also produced by neutron absorption cartridges, subsequently processed in the Chapelcross Processing Plant (CXPP), which is discussed below. Some of this tritium could diffuse through the cladding into the reactor coolant. Damage to any fuel element which resulted in a release of actinides or fission products from a fuel element was routinely monitored using the Burst Can Detection (BCD) system which allowed prompt action to be taken in the event of a fuel element failure.

It is known that a very small quantity of uranium contamination was inevitably present on the surface of fuel elements, arising from the manufacturing process. During operation, the neutron bombardment of this surface uranium contamination produced fission products and actinides which were not contained by the cladding and could be released into the reactor primary circuit.

In order to minimise the amount of fission products and actinides that could be released into the primary circuit stringent limits were placed during fuel manufacture on the quantity of uranium contamination permitted on fuel elements. In addition, Chapelcross operated strict controls and procedures to prevent the adventitious introduction of inappropriate materials into the reactor.

The limitation of surface uranium contamination on fuel elements, the use of the installed BCD System and the Site operating rules ensured that there was no significant release of fission products or actinides into the Magnox reactor gas circuits during normal operation.

Neutron Bombardment

When the reactors were operating, neutrons produced by the nuclear fission process bombarded the structural materials in the core, particularly the graphite moderator, producing radioactive “neutron activation products”, including tritium. Graphite oxidation allowed neutron activation products to be released into the coolant gas and be discharged either in normal operations or during operations to remove fuel elements from the core.

Processing Plant

Two of the Chapelcross reactors contained neutron absorption cartridges in place of some standard fuel elements. Their purpose was to produce tritium which was extracted from the cartridges in the Chapelcross Processing Plant (CXPP) following the removal of the cartridges from the reactor during the routine annual refuelling programme. This plant operated from 1980 until 31st March 2005 and has had a significant impact on the quantity of tritium in waste arising from the site.

3.4.2 Decommissioning

The main planned activities during the period covered by the authorisation being applied for are anticipated to be:

- Defuelling of Reactors 1-4 and transfer of spent fuel to Sellafield
- Post-Operative Clean-Out, decommissioning and demolition of Cartridge Cooling ponds 1 and 2
- CXPP Post-Operative Clean out
- Packaging and transfer of Uranium Oxide containers to BNG Capenhurst for storage.
- Removal and disposal of asbestos containing material (e.g lagging from site buildings including the Heat Exchangers, Turbine Hall, and Reactor associated plant.

All these activities will be scrutinised to identify the Best Practicable Environmental Option (BPEO) and ensuring that Best Practicable Means (BPM) are applied to optimise the option selected.

The fuel currently in the shutdown reactors will remain there until the necessary safety case has been made to defuel the reactors. The fuel will then be removed from each reactor in accordance with the Magnox operating Plan (MOP). It is anticipated that this will be completed by September 2011.

The removal and processing of neutron absorption cartridges from the reactors has been completed. It is therefore intended that the CXPP will be used to repackage some Intermediate Level Waste (ILW), for example the 200 or so Temporary Storage Vessels containing used lithium pellets, part of the tritium generation process, which are currently stored in the Uranium Store. This will take place as part of the plant operational clean out (POCO) in preparation for CXPP decommissioning. Such processes are expected to result in some gaseous wastes (mainly tritium), with small quantities of liquid effluent arisings. In addition, some solid LLW will be produced for disposal along with the repackaged ILW.

The site is making arrangements for the future use of M2 fuel transport flasks for the transport of fuel from the Chapelcross site. To date, some 93 tonnes of fuel have already been shipped from the fuel storage ponds to Sellafield. However, for the removal of fuel currently in the four reactors, a dry route will be implemented which will not make use of the existing fuel storage ponds but will require several modifications to defuelling equipment are being implemented. These are due for completion in early 2008 and include:

- the installation of new control equipment to fuel discharge machines;
- the alterations to fuel discharge wells to accommodate modern flask geometry; and,
- the construction of a new flask handling building to provide flask reassurance checks prior to despatch.

These modifications will allow spent fuel rods to be placed directly into transport flasks for shipment to Sellafield, eliminating the previous operational necessity to allow the activity in the fuel to reduce by radioactive decay during storage in ponds prior to transport to Sellafield. This is no longer necessary because sufficient radioactive decay will have occurred by the time the fuel is removed from the reactors.

These operations, and the subsequent pond clean up as part of the preparation for the site care and maintenance period, will give rise to continuing aqueous discharges.

3.5 Management Arrangements for Company and Site

3.5.1 Company Environment, Health and Safety Policy

Under the name of Magnox North Ltd., Magnox Electric Ltd. currently operates the nuclear sites at Chapelcross, Hunterston A, Oldbury, Trawsfynydd and Wylfa. As corporate body it holds for these sites:

- Nuclear site licenses issued under the Nuclear Installations Act 1965 (as amended); and,
- Authorisations issued under the Radioactive Substances Acts 1960 and1993 (RSA60, RSA93) and other authorisations, consents and permits issued under environmental legislation.

Responsibility for the compliance with the Nuclear Site Licence and other legal requirements rests unambiguously with the Magnox North Ltd. board. As such, the arrangements for managing the Environment, Health and Safety (EH&S) form part of Magnox North Ltd.'s overall arrangements to manage all aspects of the business.

Magnox North Ltd. believes that the protection of the environment and the health and safety of our workforce, contractors and the public are fundamental to the business. Excellence in environment, health (including welfare) and safety is an integral part of the business and is essential to commercial success.

An important aspect of the management of EH&S is having a well established safety culture within the organisation. Leadership is key to establishing and maintaining a positive safety culture within an organisation and this is promoted by the Company carrying out the following activities:

- Applying a Behavioural Safety improvement programme for training people to be more aware of how their and others' behaviours, actions, or omissions affect safety;
- Developing a conservative decision-making ethos to give overriding priority to safety, particularly nuclear safety and environmental protection, in all plant and process based decisions;
- Providing training aimed at the inclusion of sound attitudes towards safety, safety awareness safety culture and environmental protection from consideration of past events, root causes and good national and international practices;
- All managers and supervisors, including the Managing Director and Board, leading by example in demonstrating good safety culture.

General and Worker H & S

The Health and Safety at Work etc Act 1974 lays responsibilities on Magnox North Ltd. to protect the public and workers from all hazards arising from its operations.

Magnox North Ltd.'s Environment, Health and Safety (EH&S) Policy (Reference 3) has been prepared to satisfy the requirements of Section 2(3) of the Health and safety at Work etc. Act 1974 and aims, by seeking continuous improvement, to achieve and maintain excellence in EH&S and operational performance.

The policy's primary goal is that no harm should result from its activities and that it will be respected and trusted by its workforce, the public and its stakeholders. In pursuing this it is the policy of Magnox North Ltd. to work in partnership with employees and contractors at all levels to strive to:

- Maintain high standards of nuclear safety;
- Eliminate injuries and ill-health at work and minimise radiation doses;
- Prevent accidents, but nevertheless maintain effective emergency arrangements;
- Prevent pollution and minimise waste and the use of natural resources as part of Magnox North Ltd.'s contribution to sustainability and environmental improvement;
- Ensure the appropriate and safe disposal or storage of radioactive and other waste;
- Achieve and sustain an excellent safety and environmental culture;
- Learn the lessons from events, implement corrective actions and seek out and use good practices wherever identified; and,
- Ensure activities, products and services are in compliance with applicable legislation and meet the requirements of good practice and applicable standards of EH&S performance.

In doing this Magnox North Ltd. will:

- consult with employees on EH&S matters of mutual interest;
- listen to and respond to customers, shareholder, suppliers and neighbours;
- openly report on EH&S performance every year;
- work with regulators, the rest of the industry and customers and contractors to raise EH&S standards;
- inform, instruct, train and develop the people who work for Magnox North Ltd. and ensure that competent EH&S advice is available;
- audit the management system which flows from the EH&S policy, and set and review EH&S objectives and targets, working within a quality framework; and,
- maintain high standards in the conduct of operations, in particular by ensuring that they are adequately resourced and carried out by suitably qualified and experienced people and with regard to nuclear safety at all times.

The Managing Director of Magnox North Ltd. is responsible for ensuring that the Policy statement on EH&S and the mandatory requirements which flow from it are implemented and kept under review. The Company EH&S Policy is further developed at sites and a site policy statement is issued detailing how the Company policy is implemented at a site specific level.

The Magnox North Ltd.'s Director of Environment, Health, Safety, Security and Quality (EHSS&Q) is accountable for advising on the development and promotion of the Company's overall environment, health and safety arrangements and systems including its policies, objectives and targets.

Radiological Protection

Chapelcross Site will continue to have access to sufficient expertise of the appropriate quality and experience commensurate with its obligations to comply with the Nuclear Site Licence Conditions, the terms of discharge authorisations and other statutory obligations. Where possible one set of arrangements have been made to comply with all legislative requirements.

The Health and Safety at Work etc Act 1974 (HSWA) lays responsibilities on the Company to protect the public and workers from all hazards arising from its operations. Detailed arrangements for compliance with site specific Authorisation Conditions under RSA93 are given in site specific documents. The EHSS&Q Director is responsible for the provision of high level advice and guidance on compliance with the Conditions.

The Chief Nuclear Operating Officer (CNOO) is responsible, through line accountability, for the operation and maintenance of the plant, including waste management activities. He is also responsible for the provision of support, as necessary, to meet the requirements of the Authorisations.

The Radiological Safety Rules (Reference 4) not only ensure that radiation doses to individuals are kept As Low as Reasonably Practicable (ALARP) they also form part of the company arrangements to ensure compliance with the Ionising Radiations Regulations 1999 (IRR99). The company obtains advice, as necessary, from a suitable Radiation Protection Adviser (RPA) Body in accordance with the requirements of the IRR99. The RPA Body and the associated arrangements, are stand alone arrangements, based on those previously used by the predecessor company (Magnox Electric Limited).

The Nuclear Safety Committee consider and advise on all matters required by or under the Conditions of the Nuclear Site Licence or arrangements or documents specified by the Nuclear Installations Inspectorate (NII) to be referred to the Nuclear Safety Committee. This includes changes to its terms of reference, the arrangements for the consideration of, or advice on, urgent safety proposals and the arrangements for compliance with the Nuclear Site Licence Conditions.

Site Directors are responsible for ensuring that there is an adequate nuclear safety case for any operation that may affect safety which includes: plant operation; accumulation, storage and transport of nuclear matter; and the decommissioning of part or parts of the plant. Site Directors are also responsible for ensuring that a comprehensive periodic review of the validity of their nuclear safety case is undertaken, in accordance with Licence Condition 15. They are also responsible for reviewing the implications of operational experience on the continuing adequacy of their nuclear safety case.

The EHSS&Q Director is responsible ensuring that occupational radiation exposures are measured and recorded in line with the requirements of the Ionising Radiations Regulations 1999 and Condition 12 of Chapelcross' Nuclear Site Licence. If exposure levels exceed those specified by the NII for any class of person, he is responsible for notifying the NII.

Emergency Arrangements

Although the aim is to prevent accidents that might have radiological consequences for workers and the public, emergency arrangements are provided at nuclear power stations for responding to such accidents. It is the nature of any accident that its course cannot be foreseen in every respect, and therefore in drawing up the emergency arrangements, the plan defines a firm framework that can support a flexible response to a wide range of possible events.

Site Directors, supported by other resources from within the Company, produce local plans for each site and arrangements for dealing with contingencies and emergencies. These arrangements include:

- The setting up of an emergency control centre (ECC) on each site;
- The setting up of a local emergency centre (LEC) to co-ordinate the various off-site organisations under the control of the police. In the event of a nuclear emergency, Company staff will attend the LEC;
- The setting up of a Company Central Emergency Support Centre (CESC) to provide additional technical and logistic support.

On-site emergency arrangements are demonstrated at each site annually by Level 1 exercises in accordance with an agreed programme. The function of each off-site facility is demonstrated at Level 2 exercises every three years. Other formal plans describe the arrangements for dealing with emergencies or incidents arising from the transport of radioactive material.

The appointment to the posts of CESC Controller and Assistant CESC Controller within the CESC is made by the Managing Director on the advice of the Emergency Planning Section. The appointment to senior posts within the sites emergency arrangements is made by the Site Director with advice from an EHSS&Q Site Inspector, who works for the E,H,S&Q Director, but is independent of the Site..

In addition to the arrangements outlined above, a Crisis Management Centre (CMC) may be established to manage other issues as they impact on the company.

3.5.2 Company Nuclear Safety Policy

The Company recognises the existence of statutory limits for the radiation exposure of individuals as a result of normal operation, and requires that the exposure from normal operation and the risks arising from potential accidents shall be As Low As Reasonably Practicable (ALARP). This approach, outlined in the Site Lifetime Plan (Reference 5) is in accordance with NII “Safety Assessment Principles” (Reference 5, in turn derived from recommendations of the International Commission on Radiological Protection and subsequently implemented by IRR99.

3.5.3 Company Training Policy

The Magnox North Ltd. Training and Development policy describes the organisation’s vision of training to all employees to ensure roles are performed safely and effectively and that employees fulfil their potential within the business. The Company is committed to creating an environment in which continuous training and development of people in line with business needs is encouraged as essential to the success of the business.

The Company’s Training and Development Policy aims to:

- improve the capability of the Company to meet its short and longer-term business objectives and to ensure that all statutory and regulatory requirements are satisfied;
- ensure that all direct employees are developed to help them gain the necessary knowledge, skills and behaviours to meet the requirements of their jobs and the expectations of the Company’s key stakeholders;
- ensure that, where applicable, contractors and agency supplied workers receive the necessary training to meet the requirements of their jobs;
- provide the opportunity to develop a competent, motivated and flexible workforce that is able to respond positively to the needs of the business against a background of continuing change; and,
- encourage all direct employees to maximise their contribution and achieve their potential consistent with the needs of the business.

It is the responsibility of the heads of sites to demonstrate commitment to the training and development of employees by ensuring sufficient resources are available to enable agreed activities to take place. Training is managed within the framework of the Quality Management System to ensure a systematic approach to the identification, design, delivery and evaluation of training activity.

Key elements of the Training and Development Policy include:

- All training and development activities within the Company will support Company and site objectives as described in the business plans as appropriate.
- Training and development requirements and the resources required to support them will be clearly identified at individual, team, site and Company level to ensure consistency, value for money, and for prioritisation to take place.
- Training and development activities will be regularly evaluated to ensure that they are effective in meeting their purpose, that they maximise learning and that they remain aligned with business objectives.
- Prioritisation, to comply with appropriate statutory and regulatory requirements and both national and international codes of best practice.
- The overall focus for training and development activity will be based on objectives agreed through the performance management process and will include all regulatory and statutory requirements. Longer term development will need to satisfy both the needs of the individual and the business.
- Line managers are responsible for ensuring that:
- personnel have the necessary skills, qualifications and behaviours to carry out the jobs assigned to them safely and effectively;
- all training and development meets its predetermined objectives and achieves business benefit through effective evaluation.
- Where appropriate, recognised external standards of training and development activities will be identified and applied.
- Information on the range of appropriate training and development opportunities will be made available to all direct employees across the company. This will include formal courses, on-the-job training, open and distance learning, project work etc.
- All personnel within the organisation are required to have a personal responsibility for their own training through personal development planning.

3.5.4 Company staff structure, management roles and responsibilities for compliance

The Magnox North Ltd. Company is comprised of the Magnox North Ltd. Board and the Magnox North Ltd. Executive. The overall Magnox North Ltd. Company structure is shown in Figure 3.

The Board is responsible for ensuring that Magnox North Ltd. meets the conditions of its nuclear site licenses and authorisations, monitoring governance of the business, including its role as an employer and ensuring that the company maintains the safety of its employees. The Board is made up of a Non-Executive Chairman, the Managing Director, three other Executive Directors and three Non-Executive Directors.

The Magnox North Ltd. Executive was formed by the Board to help carry out the work of managing Magnox. The purpose of the Executive is to provide stewardship of the company's business by giving leadership and direction. Its objectives are to achieve the strategy, policies and standards required by the board, and to improve all aspects of Magnox North Ltd. Site activities, including operation al aspects involving safety, environment, quality, programmes and people. This is achieved through performance monitoring and review, and sharing and learning from experience between the Magnox North Ltd. Sites. The Executive is the primary advisory body linking the Magnox North Ltd. Sites on licence and authorisations compliance issues.

The key roles and responsibilities of the Company's senior officers, in relation to the environment, health and safety, are provided below.

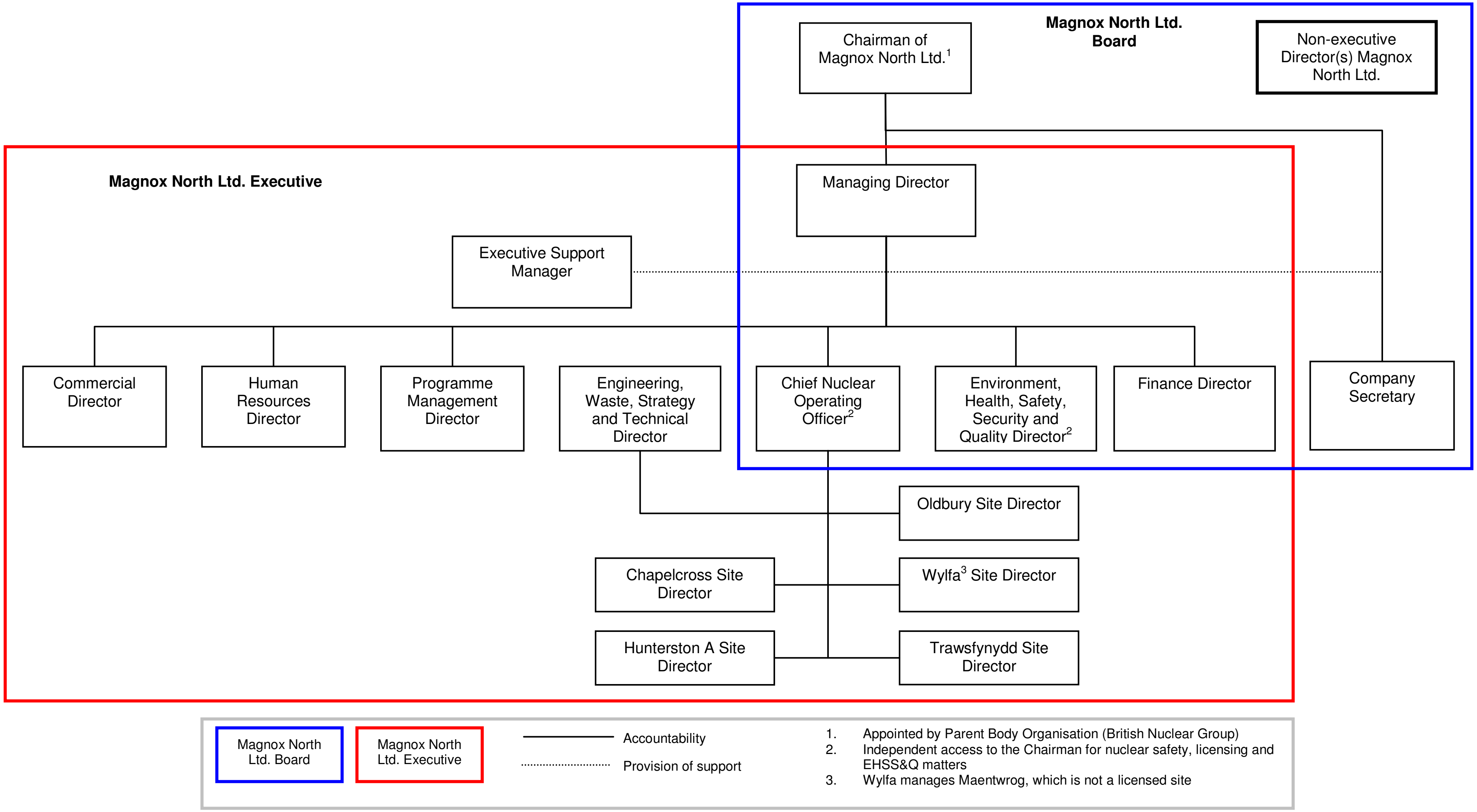

Figure 3 Organisational structure of Magnox North Ltd. Board and Executive

Non-Executive Chairman

The Chairman of Magnox North Ltd. is responsible for providing coherent leadership of the Company. In particular the Chairman is responsible for:

- Overall management of the Board, ensuring its effectiveness on all aspects of its role and setting its agenda;
- Ensuring the provision of accurate, timely and clear information to Directors;
- Ensuring effective communication with the Shareholder and other key stakeholders;
- Arranging regular evaluation of the performance of the Board, the Executive and individual Directors;

Facilitating the effective contribution of Non-Executive Directors and ensuring constructive relations between Executive and Non-Executive Directors.

Non-Executive Directors

There are three Non-Executive Directors, each with a prime area of responsibility related to Health and Safety, Environmental Performance and Operational Performance, with a remit to review company matters and report regularly on their topic areas at Board meetings. As appropriate, the Non-Executive Directors may also act as Independent members of the relevant Nuclear Safety and Environment Committees.

The Non-Executive Directors are responsible for:

- Providing constructive challenge and contributing to the development of strategy and policy;
- Scrutinising the performance of management in meeting agreed goals and objectives, and monitoring the performance reporting process;
- Satisfying themselves that all aspects of environmental and safety performance reporting are accurate and that the systems for environment and safety reporting are accurate and that systems for environment and safety management are robust and defensible;
- Satisfying themselves that financial information is accurate and that financial controls and systems of risk management are robust and defensible.

Managing Director

The Managing Director of Magnox North Ltd. reports directly to the Chairman and has specific responsibility to lead, direct, control and develop Magnox North Ltd. in the safe and compliant delivery of contracts to the NDA. Specifically the Managing Director is responsible for:

- Ensuring that sound safety, environment, health and business processes and business controls are embedded into Magnox North Ltd.;
- Ensuring the organisational structure, culture and values are those appropriate for a company that holds Nuclear Site Licences and Environmental Authorisations;
- Ensuring that the way business is managed allows the Board to carry out its legal duties arising from the sites nuclear licences and authorisations and from Magnox North Ltd.'s role as an employer, and to maintain the safety of Magnox North Ltd.'s employees;
- Ensuring that Magnox North Ltd. delivers value for the NDA by:

- Delivering the lifetime plan;
- Identifying improvement opportunities in the lifetime plan;
- Complying with contractual and security requirements;
- Continual improvement in performance.

- Providing effective leadership for the Executive in defining goals, standards and expectations;
- Delivering excellent financial, operational and safety performance through aggressive and innovative delivery programmes and effective use of the supply chain;
- Agreeing the environmental, safety and performance objectives of Magnox North Ltd. with the NDA and delivering against these objectives; and,
- Receiving, and taking due cognisance of, the advice of the Nuclear and Environment Safety Committee.

Chief Nuclear Operating Officer

The Chief Nuclear Operating Officer (CNOO) reports directly to the Managing Director, and has independent access to the Chairman of Magnox North Ltd. for nuclear safety, licensing and EHSS&Q matters.

The CNOO is responsible for:

- acting as Chief Nuclear Officer on behalf of the Managing Director to ensure, monitor and advise that adequate arrangements for nuclear safety are established, maintained and monitored on sites;
- providing effective leadership for operations across the Magnox North Ltd. Sites by leading, directing, controlling and developing the Magnox North Ltd. Sites.
- providing a technical support function, including the company's design authority capability, in the safe and compliant operation of the Sites and delivery of contracts to the NDA;
- providing an overview of the adequacy of arrangements for nuclear safety on Sites to the Managing Director;
- ensuring personal and professional development of Operations staff across Magnox North Ltd. and delivering and effective delivery organisation;
- ensuring that appropriate arrangements for the transfer of low level wastes for Magnox North Ltd. Sites to an appropriate authorised facility are in place;
- ensuring that procedures are established to define the responsibilities and standards for the implementation of a quality management system in accordance with licence condition 17;
- ensuring sufficient suitably qualified and experiences people are available for the operations function to operate effectively; and,
- acting as the formal interface with the Regulators.

Environment, Health, Safety, Security and Quality Director (Director EHSS&Q)

The Director for Environment, Health, Safety, Security and Quality (Director EHSS&Q) reports directly to the Managing Director and has independent access to the Chairman of Magnox North Ltd. for nuclear safety, licensing and EHSS&Q matters.

The Director EHSS&Q is responsible for ensuring that sound safety, environment, health, quality and security processes are embedded into Magnox North Ltd. for the safe and compliant delivery of contracts to the NDA. This is achieved through establishing policies, standards and processes and for setting the functional strategy and direction of Magnox North Ltd.. In addition, responsibilities include:

- acting as Agent for the Licensee in respect of Licence Conditions 1 (interpretation), 3 (restriction on dealing with the site), and 36 (management of change), ensuring that adequate arrangements are made for compliance;
- ensuring obligations under the Health and Safety at Work (HASAW) Act are discharged through the Magnox North Ltd. management system;
- ensuring sufficient suitably qualified and experienced people are available and ensuring personal and professional development of EHSS&Q staff for the EHSS&Q function to deliver an effective EHSS&Q function;
- providing high-level advice to Sites in the areas of environmental safety, radiological safety, safeguards, industrial safety, human factors/safety culture, quality, security, licensing and management of change; and,
- providing assurance across all operations including the supply chain to ensure that, for EHSS&Q, standards are being effectively implemented and regulatory and contractual requirements are being met.

Human Resources Director

The Human Resources Director has specific EH&S responsibilities for:

- managing the provision of training necessary to remain compliant with the Nuclear Site Licence, RSA93 and other legislation, particularly the HASAW Act, and to improve management and functional skills; and,
- managing an occupational health service.

Engineering Waste Strategy and Technical Director

The Engineering Waste Strategy and Technical Director is accountable to the Chief Nuclear Operations Officer for:

- ensuring Magnox North Ltd. maintains a licensable intelligent customer capability supporting delivery of planned work;
- ensuring that the applicability of engineering, technical and safety case standards is defined, appropriate to plant lifecycle;
- establishing and managing arrangements for Magnox North Ltd. Site Nuclear Safety Committees and acting as the principal interface with the NII on generic nuclear safety issues relating to engineering and safety cases; and,
- developing and delivering effective policies and strategies for decommissioning and waste management.

Site Director

The Site Directors are full members of the Executive and report to the Chief Nuclear Operating Officer. They have the responsibility for ensuring that a Site delivers value for the NDA through the safe and compliant delivery of the scope of work defined in its lifetime plan. Specifically, a Site Director:

- provides effective leadership for a Magnox North Ltd. Site and ensures compliance with statutory requirements, including the Nuclear Site Licence and RSA Certificates of Authorisation;
- ensures suitably qualified and experienced people are available for the Site to operate effectively and ensures there are clearly defined roles, responsibilities and levels of delegated authority and accountabilities in place;
- acts, under the Chief Nuclear Operating Officer's delegated authority, as the formal point of contact for the Site with the Regulators; and,
- secures the regulatory consents, approvals and authorisations needed to operate the site and implement the contracted scope of work.

3.5.5 Arrangements to ensure sufficient availability of expertise and resources

Magnox North Ltd. has made arrangements to ensure the continued availability of suitably qualified and experienced personnel to ensure safe, compliant and efficient delivery key management and functional activities. The Support Services Lifetime Plan for Chapelcross (Reference 6) covers work provided by Magnox North Ltd. and the Site Licence Company Management in providing governance and system frameworks, as well as the activities of the Site Lead Team. The functions of EHSS&Q, Finance, Nuclear Decommissioning Authority (NDA) Contract Management and Personnel are also covered.

These functions provide the Site contractor with the ability to comply with legislation in the appropriate areas.

The Support Services for Chapelcross site goes through significant changes associated with the changing status and requirements of the Site. Key to maintaining the appropriate expertise is the completion of training to allow an effective management of the workforce skills between each phase of the site's life.

3.5.6 Arrangements for control of organisational change

Magnox North Ltd. Sites each have arrangements made under Licence Condition 36 to control organisational change. The EHSS&Q Director sets the standards for implementing these arrangements. Changes are categorised depending on their potential impact on environment, health or safety. To ensure an appropriate level of independent challenge the arrangements include, where appropriate, independent assessment and approval of the change prior to implementation.

To ensure the accumulative effect of changes are considered each Magnox North Ltd. licensed site carries out an annual review of changes the finding of which are copied to the EHSS&Q Director.

3.5.7 Arrangements for control of operations

The Magnox North Ltd. Company and site management processes include operational controls to minimise environmental impacts and ensure that BPM are applied throughout site, including both strategic and day-to-day decisions and all procedures that might impact on waste arisings.

Appropriate ownership is acknowledged for all environmentally sensitive plant and sampling equipment to ensure that the responsibility for maintenance lies with the plant or equipment operators, who are best placed to recognise equipment failure. Maintenance priorities are reflected in operating procedures. In addition, the site's independent nuclear safety assessment process includes scrutiny to ensure that BPM is applied to plant modifications.

In addition to the definition of "normal state of plant" conditions, abnormalities in environmentally sensitive plant are addressed in procedures. Where equipment failure requires maintenance, appropriate tagging of the failed equipment is used.

Emergency arrangements are in place to cover both nuclear and environmental emergencies. All operations of plant are carried out under written quality graded procedures.

3.5.8 Arrangements for supervision of discharges and disposals

A management and document hierarchy is in place to ensure the safe disposal and discharge of generated wastes. The document hierarchy defines responsibilities and principal requirements through detailed work instructions that are used by staff. The management hierarchy ensures that operations staff work to these instructions and that suitable supervision is in place.

Prior to disposal, discharges and other disposals are monitored for radionuclide activity. Prior authorisation by nominated persons is required for planned liquid discharges and, prior to the transfer of solid waste for disposal, all documents associated with the generated waste are checked by a suitably qualified and experienced person.

3.5.9 Arrangements for maintenance, particularly with regard to having sufficient availability of operational and stand-by plant

Maintenance activities may comprise a combination of time-based preventative maintenance, predictive maintenance, condition monitoring and corrective maintenance appropriate to the type and duty of the equipment. The arrangements are set out in the schedule which includes an element of routine functional and performance testing of systems and general surveillance capable of identifying unforeseen degradation where practicable.

The management system facilitates the collection of data, which may be used to show that the reliability of these plant and systems is not outside assumptions.

Where the particular systems provide a significant function required by the discharge authorisation, the Plant Maintenance Schedule (PMS) incorporates any ancillary plant necessary to achieve this; for example if the provision of seal oil is essential to the operation of a pump, that plant which delivers lubricating oil should also be included in the PMS. Equipment included in the Plant Maintenance Schedule is inspected, tested and maintained within a predetermined time period, to specified procedures.

3.5.10 Arrangements for supervision of maintenance

Maintenance Team leaders are appointed as Suitably Qualified and Experienced Persons (SQEP) to control and supervise maintenance activities. The controls on the activities are the documented arrangements. On maintenance work these controls include instructions specifying how to carry out the task, record sheets to record the results, risk assessments and safe system of work documents including permits, radiological control certificates and confined space certificates. Maintenance activities are supervised by the maintenance team leaders to ensure:

- that personnel are SQEP to do the work;
- that the work is being done in accordance with written instructions;
- that correct tools and PPE are being used;
- that the working environment is safe; and,
- that corrective actions are being taken to rectify any deficiencies.

The supervision can vary from a simple pre and post job brief, through safety walkdowns and task observations to direct supervision of the entire task. The level of supervision employed varies for each activity and depends on how much risk was involved and how experienced and competent the people are who are doing the job.

3.5.11 Arrangements for control of modifications

Under the Nuclear Installations Act the 'licensee' of the Chapelcross Site has the ultimate responsibility for the safety of plant. It is necessary therefore for the Magnox North Ltd. to have an effective management system to ensure that a high standard of safety will be maintained throughout the various phases of its life. An important aspect of an effective management system is the development of a safety culture which at all levels within the organisation emphasises safety, and which by the use of managerial, supervisory and individual practices and constraints sustains attention to safety through an awareness of the risks posed by the plant and of the potential consequences of incorrect actions.

It is therefore necessary to control the modifications and experiments that take place to existing plant and buildings and the construction and commissioning of new buildings and new plant and processes. Additionally, any decommissioning projects must similarly be controlled.

The Engineering, Waste, Strategy and Technical Director is responsible for the development and maintenance of nuclear safety and engineering standards which include:

- details relating to the arrangements for the preparation and review of nuclear safety cases for new and existing plant;
- details relating to the arrangements which define the categorisation criteria and safety clearance routes for proposals for experiments and modifications to the safety case, maintenance schedule, Operating Rules and Referenced Station Operating Instructions (as appropriate), including where such matters must be referred to the Nuclear Safety and Environment Committee or NII.

These arrangements ensure that safety cases and safety submissions are prepared and verified by SQEPs and are subject where appropriate to Independent Nuclear Safety Assessment (INSA) by SQEPs who are independent of those preparing and verifying the case or submission.

Prior to the implementation of any proposal to: establish a new nuclear safety case; or change an existing nuclear safety case, Operating Rule, Referenced Station Operating Instructions, or Maintenance Schedule; or modify or decommission a plant or process; or carry out an experiment:

- The safety of the proposal must be justified in sufficient detail to enable an assessment to be made of the implications for nuclear safety;
- The proposal must be categorised according to the safety significance of the proposal by the Site Director;
- The proposal must be approved by the Site Director; and,
- The safety clearances appropriate to its categorisation must be granted.

New plant and modifications to plant under construction are also subject to the assessment arrangements outlined above. In addition, the arrangements for the modification to plant also consider and assess the potential impacts on the environment and security arrangements.

3.5.12 Arrangements for auditing

Site Directors and Function Directors have arrangements for quality assurance audits to gauge the adequacy and effectiveness of their EH&S management system. These may be supplemented by other proprietary audits such as ISO 9001 and 14001 certification audits. Arrangements are also established for the periodic review of the installation's safety case as required by Licence Condition 15.

Independent scrutiny of EH&S arrangements is carried out by the Director EHSS&Q. He is supported in this role by Site Inspectors who scrutinise environment, health, safety and security arrangements at sites and in relevant support office activities.

In line with international nuclear industry practice, the Company have a Peer Evaluation process that provides for a comprehensive review of site activities against the performance objectives and criteria established by the World Association of Nuclear Operators (WANO). This process identifies areas for improvement, along with strengths and good practices where appropriate. If required a Technical Support Mission (TSM) could be requested to examine known plant problems and identify potential solutions. The Company also participates in WANO reviews and TSMs at the sites of other nuclear operators around the world, learning from their experience and sharing good practices.

3.5.13 Arrangements for liaising with and reporting to stakeholders and regulators

Magnox North Ltd. is committed to keeping the population near its nuclear installations informed. In addition to the statutory accountability required under the Radiation Emergency Preparedness and Public Information Regulations 2001 (REPPIR), the Company seeks to ensure that local stakeholders are provided with information about the operational and safety aspects of its nuclear installations. At Chapelcross, this information is disseminated via the Chapelcross Site's Stakeholders Group (SSG), either at the meetings held quarterly or through correspondence.

The SSG is chaired by an elected councillor, who is currently Chair of the Lower Annandale Area Committee. Members include community and regional councillors, an MP and MSP, representatives of local emergency services (e.g. police, health and fire services), representatives of local organisations, NII, SEPA, the Scottish Executive Rural Affairs Department and Department for Transport, should they so wish. The media is invited to attend and report on the proceedings. General members of the public are invited to attend as observers. Magnox North Ltd. provides a team of support staff from the site.

3.5.14 Arrangements for managing records

Chapelcross site has put in place arrangements to identify records that need to be kept to demonstrate compliance with all relevant statues, all licenses and permits all Magnox North Ltd. policies, and the Nuclear Decommissioning Authority (NDA) Contract.

Records are retained to meet the requirements with Site Licence Condition 6, Radioactive Substances Act 1993, BS EN 9001 – 2000 & BS EN 14001 – 2004 and stored to meet the requirements of IAEA Series No 50- CS/G – Q. All identified records relevant to the disposal of radioactive material are archived and stored for the appropriate period set out in the site management system instructions.

3.5.15 Arrangements to exchange information and learn from the experience of other sites and operators

Experience from other sites is considered in the application of BPM at Chapelcross site. There are several fora, both Company wide and industry wide, for sharing experience in operations, including the management of radioactive wastes.

3.6 Waste Strategy

3.6.1 The Magnox North Ltd. Integrated Waste Strategy

Magnox North Ltd. has an integrated approach to waste management that has been developed in line with Company objectives and UK Government policy.

Government Policy has been set out in White paper Cm 2919 (Reference 1), which has been revised to reflect the role provided by the Nuclear Decommissioning Authority (NDA) (Reference 7). The revised Government Policy states that:

Each operator is expected to produce and maintain a decommissioning strategy and plans for its sites… Strategies should include a comprehensive site decommissioning plan for safely carrying out the decommissioning process with due regard to security and protection of the environment… Operators of sites which are the responsibility of the Nuclear Decommissioning Authority (NDA) are expected to produce and maintain plans for their sites. Each plan will need to be consistent with the overall strategy of the NDA and be subject to its approval. A strategy may apply to more than one facility on a site or to a number of similar facilities on different sites… [para. 4].

Magnox North Ltd., as the Site Licensee of the northern bundle of Magnox reactor nuclear licensed sites, is responsible for developing and implementing decommissioning and waste management strategies consistent with the requirements and overall national strategy of the NDA.

The company's decommissioning and waste management strategies are to be in accordance with relevant Government policies including:

- The Review of Radioactive Waste Management Policy: Final Conclusions; Cm 2919
- UK Strategy for Radioactive Discharges 2001-2020;
- Managing Radioactive Waste Safely - Proposals for developing a policy for managing Solid Radioactive Waste in the UK; and,
- Managing the Nuclear Legacy: A Strategy for action (Cm 5552).

Strategies will also be compliant with legislation including:

- The Nuclear Installations Act 1965 (NIA65) as amended;
- The Health and Safety at Work Etc. Act 1974 (HSWA74 as amended);
- The Environmental Protection Act 1990 (EPA90);
- The Town and Country Planning Act 1990 (TCPA90);
- The Radioactive Substances Act 1993 (RSA93) as amended;
- Nuclear Reactors (Environmental Impact Assessment for Decommissioning) Regulations 1999 (EIADR99);
- The Ionising Radiations Regulations 1999 (IRR99);
- Nuclear Industries Security Regulations 2003;
- Article 37 of the Euratom Treaty; and,
- Energy Act 2004.

The key objectives of Magnox North Ltd.'s waste management policy are:

- To ensure the continued safety of the public, the workforce and the protection of the environment;
- To deliver a systematic and progressive reduction of hazard on each site;
- To achieve an appropriate balance in the use of environmental, social and economic resources both now and in the future; and,
- To clear and de-licence the sites.

These objectives, and associated principles, have been formally endorsed by the Magnox North Ltd. Board and provide a clear framework to guide and constrain the development of decommissioning and waste management strategy. Magnox North Ltd.'s generic decommissioning and waste management strategy can be summarised as:

- Reactors are defuelled as soon as practicable after shutdown in accordance with the Magnox Operating Plan.
- All buildings, except the reactor buildings, are dismantled as soon as practicable after they are no longer needed.
- Reactor buildings and their remaining contents are placed in a passive safe storage condition for Care and Maintenance.
- All ILW wastes are placed into a passively safe state for on-site storage, and will be handled in the long term in accordance with Government policy.
- Retrieved ILW is stored on-site within the reactor buildings or, where appropriate, in an alternative facility.
- Wet ILW is encapsulated to Nirex specifications using mobile plant.
- Miscellaneous Activated Components (MAC), where justified as passively safe, are retained within its existing storage facilities in the reactor buildings.
- Other Solid ILW is retrieved for containerised storage during Care and Maintenance Preparations. However, some Fuel Element Debris is treated using dissolution or encapsulation as a result of site-specific factors.
- Suitable LLW, asbestos wastes and non-hazardous wastes will be disposed of on-site wherever it is practicable and economic to do so and where regulatory approval has been gained.
- Radioactive contaminated ground is managed to maintain public safety and minimise unnecessary arisings of low activity spoil for off-site disposal.
- The reactors will be finally dismantled in a sequenced programme with a start date and duration to be decided in the light of circumstances prevalent at that time. Currently, Magnox North Ltd. considers that a sequenced programme across all sites, leading to a range of deferral periods notionally around 100 years from station shutdown, is appropriate. However, this decision will be dominated by the overall national civil nuclear decommissioning context under the direction of the NDA. In the meantime, the Company proposes to maintain a degree of flexibility over the deferral timescale.
- Boilers will remain in position until the reactors are dismantled during Final Site Clearance.
- The end point for reactor decommissioning strategy is site clearance and de-licensing, based on the assumption of a reasonably practicable interpretation of the "no danger" clause in the Nuclear Installations Act 1965 (as amended).

This strategy is subject to ongoing review and development, and may be modified in the light of future circumstances. The strategy will be reviewed using defined processes, in line with government policy and taking account of all relevant factors. In particular, strategy development will continue to ensure consistency with NDA's evolving national strategy.

3.6.2 Chapelcross Integrated Waste Strategy

The Chapelcross Integrated Waste Strategy (IWS) is to process arisings in the most efficient manner, taking into account current and future disposal options, whilst adhering to the principles of the corporate and government policies and regulatory requirements (Reference 8). The IWS addresses the management of all forms of waste, both radioactive and non-radioactive and of material which may become waste in the future. The IWS is subject to periodic review and revised to reflect any changes in national decommissioning strategy and as the process of site decommissioning progresses. It is key to understand that the IWS and decommissioning strategy for Chapelcross cannot be considered in isolation, rather it must be considered in the context of the national decommissioning strategy, where programming, and funding, priorities may be varied to best suit the overall management of nuclear liabilities.

The IWS is underpinned by an examination of the Best Practicable Environmental Options Study [Ref. 9] which was carried out to support the identification of appropriate management options for waste arisings during the Care and Maintenance phase of decommissioning activities at Chapelcross.

Two main waste categories were considered during the study:

- Intermediate Level Waste (ILW) and
- Low Level Waste (LLW)

Individual waste streams and arisings will be subject to further BPEO assessments as appropriate.

Various operational wastes arise during defuelling, including Intermediate Level Waste (ILW). In addition, LLW and non-radioactive waste arises from plant operations and maintenance activities. Key elements in the waste strategy are the current waste inventory and predicted arisings. These are provided by waste volumes and arising profiles in existing databases. A key database is the Baseline Decommissioning Plan (BDP), developed by the Chapelcross waste team in preparation for decommissioning activities. During the process, each nominated project manager was required to provide estimates of waste likely to be generated over the project life.

The resulting BDP provides an estimate of the likely volumes in each identified waste category along with estimated programme dates for all projects identified in the Near Term Work Plans for decommissioning activities. The supporting databases are live documents that will be revised as initial estimates of project arisings are refined and also reflects changes in the NDA programming priorities. Chapelcross has also adopted a Waste Accountancy Template to better identify and monitor all waste.

The principles of the Chapelcross Integrated Waste Management Strategy include the minimisation, as far as reasonably practicable, of radioactive waste generation and any accumulation of radioactive waste on site. Full use is, and will be, made of existing routes for the disposal of radioactive waste from the site. Any radioactive waste produced on site is characterised and segregated into ILW, LLW and non-active wastes in order to facilitate safe and effective management, transport and disposal. Such waste is processed into a passively safe state as soon as reasonably practicable and is stored in accordance with good engineering practice, which takes account of the overall management strategy. ILW is segregated into various streams which are stored and processed. Non-active wastes are segregated into non-hazardous and various hazardous/special wastes and recyclable materials.

Best Practical Means (BPM) is an important feature of the Chapelcross Integrated Waste Management strategy. BPM is applied through consideration of work procedures and the resultant radioactive waste that could be generated before work starts to ensure the minimisation of waste at all stages. This is applied to all site procedures that might impact on waste arisings, for example: procedures for waste disposal, control of fuel cooling ponds radioactivity levels and exclusion of unnecessary “waste” from radiation controlled areas. BPM is also applied to both strategic and day-to-day decisions; the latter is achieved by addressing the impact of operations on waste arisings routinely at operational meetings. In addition, BPM is considered for the control of waste arisings from projects during the design phase.

As identified projects within the Life-Time Plan are developed through to detailed planning stages, the BPEO will be revisited to ensure that the original assumptions and outputs remain valid. Detailed BPM studies will be integral to ensuring that the identified options are optimised.

4. DISCHARGE OF LIQUID RADIOACTIVE WASTE

This section provides information in support of the application by Magnox North Ltd. for an authorisation to dispose of liquid radioactive waste from the Chapelcross site. Discharges of liquid effluents from Chapelcross are made via a dedicated pipeline to the Solway Firth at Seafield, approximately 6 km from the site.

4.1 Sources and Management of Liquid Effluent Discharges

The current authorisation (IPB/4/1/2/3) for radioactive liquid discharges places limits on the discharge of tritium, alpha emitting radionuclides and all radionuclides other than alpha emitters and tritium. Sources of liquid effluent arisings are summarised below, historic discharges via these routes are given in Section 4.4with anticipated future arisings shown in Section 4.5

The majority of the liquid radioactive waste historically arose from cooling ponds and gas circuit dryers. The site active liquid effluent treatment routes are shown in Figure 4. Prior to discharge, liquid effluents pass through two detention tanks, allowing further settling of suspended particulate material. When the liquid waste in Detention Tank 2 has reached the tank discharge level, the effluent is pumped to Detention Tank 1, from which it is discharged following sampling.

Representative samples from the final Detention Tank are taken and the levels of radioactivity in the samples are determined before sanction to discharge the effluent from the tank is given. Suitable methods have been agreed with SEPA for determining the quantities of the specified individual radionuclides, or groups of radionuclides, in the effluent that is to be discharged.

After sampling and analysis to confirm that the effluent is suitable to be discharged, it is pumped through coarse and fine particulate filters to the discharge pipeline. Clean, uncontaminated water is also discharged in order to provide the necessary hydraulic “push” to ensure that effluent is discharged within the 2 hr high tide window.

The final diluted liquors are discharged to the Solway Firth through a further strainer/filter in the vicinity of the pipeline outfall. This strainer was installed in the early 1990s to reduce the potential for the migration of contaminated pieces of lime scale from inside the pipe on to the foreshore. This strainer is changed at an appropriate frequency, defined in the Plant Maintenance Schedule (PMS),to prevent the build up of materials, which may lead to the reduced flow through the strainer.

The site is committed to the use of the BPM process to reduce the level of the liquid discharges from site. A BPEO study including active liquid effluents at Chapelcross has been conducted (Reference 9).

4.1.1 Cooling ponds

The major source of radioactivity in liquid discharges is from the operation of the two fuel cooling ponds and the site expends considerable effort to minimise such arisings.

When the Chapelcross Site was operating, fuel discharged from the reactors was held in cooling ponds at the Site for a minimum of 90 days to allow thermal cooling and the decay of short half life fission products before the fuel was dispatched to Sellafield. During the residence of the fuel in the ponds, radioactivity (principally fission products) on the outside of the fuel elements could be transferred to the pond water. In the event of a leak developing in the cladding of a fuel element, additional radioactivity could be released to the pond water from inside the fuel element. In addition, radioactivity could be introduced into the pond from contaminated fuel transport skips.

No more fuel elements will be discharged from the reactors directly to the ponds due to the installation of a new dry fuel element discharge route. The fuel elements will be discharged directly into the M2 transport flask which will be topped up with water in accordance with transport requirements. However there will be a requirement to discharge a small quantity from each M2 flask before transport, in order to undertake the caesium leak-rate test and provide an ullage space for subsequent filling with a nitrogen blanket prior to transport. All fuel previously held within the ponds has been transferred to Sellafield and, therefore, there should be no future increase in Pond water activity concentrations.

Periodically the ponds have been drained for cleaning and painting to minimise activity build-up. The liquors arising from pond maintenance are pumped to Detention Tanks and, after treatment to remove particulate material, are discharged to the Solway Firth. During routine reactor operations ponds were emptied in alternate years, with one pond being discharged approximately annually. However, following reactor shut-down, the ponds themselves have not been discharged and arisings from the pond facility have been related to arisings from the decontamination area.

During the period of operation of the proposed revised authorisation, it is planned to decommission the ponds facility, requiring the discharge of the full volume of supernate held in each of the two ponds. It is anticipated that this will be achieved over a two year period.

Slightly contaminated water arises from the washing of plant items used in the Ponds Area. Within each of this area, there is a drainage system which collects the potentially radioactive liquors and transfers it to the Detention Tank which serves that facility (see Figure 4). Arisings from each of the four reactor buildings, the Flask Handling Building, the Uranium Store, the laboratories and groundwater ingress to the reactor basements are transported by bowser to the Detention Tank in the Ponds Area.

The quality of the pond water is maintained by periodic replenishment of the water, as there is no installed water treatment plant. To limit the levels of soluble fission products, such as caesium, in the water, a submersible ion exchange unit containing zeolite can be used. The zeolite removes caesium from pond water, which is pumped through the unit. Removing radioactive caesium from the pond water results in a corresponding reduction in the quantity present in liquid effluent discharged from the site. However, the use of the ion exchange units results in the production of ILW as high levels of radioactivity are retained in the zeolite material. Although the generation of additional ILW on site could lead to increased doses to operators, the operator dose implications from increased use of the ion exchange units are not considered to be significant and hence would not inhibit their use.

Discharges of pond water occur intermittently, typically once per year, and therefore result in a discrete short term elevated level of activity being discharged. Use of the ion exchange resin significantly reduces any impact of such discharges. Ion exchange resin will therefore continue to be used to reduce the concentrations of caesium products in pond water before it is due to be discharged as liquid effluent in line with BPM principles.

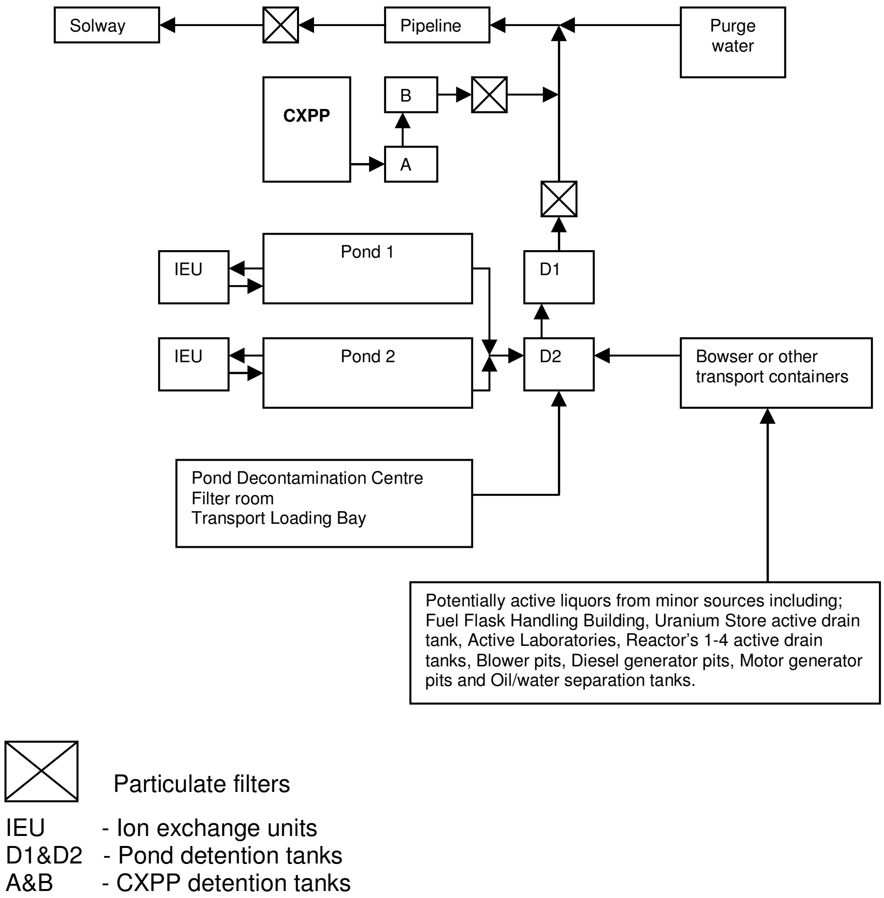

Figure 4 Simplified diagram of active liquid effluent treatment routes

4.1.2 Gas Circuit Dryers

When the reactors were operating, a small amount of radioactive liquid effluent was produced from the operation of the gas circuit dryers. This was a significant source of the tritium discharged in liquid effluent from the site and, in addition, the liquors contained some S-35.

4.1.3 Groundwater Arisings

The level of the groundwater below the reactor buildings results in an ingress of groundwater which may subsequently become contaminated with very low levels of radioactivity. The level of groundwater ingress is monitored and arisings are processed from the reactor blower pits and cable basements to ensure that no oil is present, then transferred by bowser to the pond detention tanks for discharge via the existing authorised route.

Groundwater entering the site has shown elevated levels of tritium due to historic discharges from the site, therefore, a proportion of the radioactivity associated with this waste-stream may be attributed to authorised discharges from previous years.

4.1.4 Minor systems contributing to liquid discharges

Small volumes of low active liquid wastes also arise from operations in the site's analytical laboratories. These are transferred either in small volume containers from the analytical laboratories to the Detention Tank in the Ponds Area. Any arisings from operations within the Uranium Store will be similarly transferred to the Ponds Area Detention Tank.

Additional minor sources include:

- Fuel Flask Building tank;
- Reactor active drain tanks; and,
- Showers and washdown water.

These are also transferred by bowser to the ponds area detention tank.

4.1.5 Reactor Active Drain Tanks

The Reactor Active Drain Tanks are situated to the rear of each reactor building. The main source of effluent arisings are from wash down of fuel flasks in the discharge well following loading of spent fuel. Washings are collected via a floor drain and transferred to the active drain tanks. Tanks contents are subsequently transferred via a bowser to the detention tanks within the Ponds facility prior to off-site discharge via the authorised route.

4.1.6 Uranium Store Active Drain Tank

The Uranium Store contains approximately 10,000 drums of uranium oxide which are being processed for transfer to British Nuclear Group Capenhurst for long-term storage. Currently, liquid effluent arisings are restricted to hand and shower washings along with some minor arisings from wet decontamination processes.

Effluent collected is transferred by bowser to the detention tanks within the Ponds Facility.

The near term work plan for this facility shows that transfer of stored uranic material to Capenhurst is scheduled to be completed during 2009. However, if delays to this project occur, it will be a minor contributor to overall site liquid discharges during the effective period of the new authorisation.

4.1.7 Flask Handling Building Active Drain Tank

The Flask Handling Building Active Drain Tank receives the liquid effluent arisings from the M2 flask caesium leak rate tests and the liquor run-off to allow nitrogen padding of the M2 flask prior to transfer to Sellafield. The estimated arisings will be 8-10 m^3 per annum.

4.1.8 Active Laboratories Active Drain Tanks

The Active Laboratories active drain tanks receive the liquid effluent arisings from the site active laboratories. The current arisings from this route are minor and are transferred to the Ponds Facility Detention tanks in 20 litre Carboys.

4.1.9 Chapelcross Processing Plant

The Chapelcross Processing Plant is currently involved in the recovery of tritium contaminated stainless steel, originally from the neutron absorption cartridges, and these activities are currently anticipated to continue into 2009. Subsequently, the main activities will comprise the recovery of the lithium pellet waste, utilised in tritium production whilst the plant was operational and currently stored within the uranium store, for repackaging as ILW. The ILW packages will subsequently either be transferred off-site under a suitable Inter-Site Agreement for long-term storage on a suitably authorised Nuclear Licensed Site or for conditioning for long-term storage on-site, awaiting the identification of an authorised final disposal option. Subsequent activities will include decontamination of the CXPP primary lines.

Liquid effluent arisings are collected in two dedicated detention tanks within the CXPP facility, with effluent being discharged, following suitable settling times, via the effluent discharge pipeline.

4.2 Principal Nuclide Contributors to aqueous discharges

4.2.1 Tritium

Tritium is a radioactive isotope of hydrogen that emits very low energy beta radiation. Waste tritiated water arose from the operation of gas dryers (humidriers) within the reactor primary coolant circuit. All the reactor humidrier liquors, from when the reactors were operating, have been discharged to sea under the current authorisation (IPB/4/1/2/3).

Since the cessation of power generation and CXPP operations, the release of tritium in liquid effluents associated with the Site will be significantly lower than during the operational phase. There may be some residue humidrier liquors produced during reactor post operation clean out work, but the volumes will be significantly less than during electricity generation and there is no longer any risk of liquid discharges resulting from boiler tube leakage. However, there will still be tritium discharges from operations in the ponds and CXPP. Groundwater seepage into the reactor basements contains trace levels of tritium and therefore is required to be treated as an active liquid effluent.

4.2.2 Beta emitting radionuclides (other than tritium)

During reactor operation, beta activity (excluding tritium) in liquid effluents was comprised primarily of the radionuclides strontium-90, caesium-134, caesium-137 and sulphur-35. For post-closure conditions, Sr-90 and Cs-137 will predominate due to their longer half-lives. In particular S-35 has a short half-life and therefore, due to radioactive decay, will no longer be present in liquid effluent discharges.

In addition, the small quantities of uranium contamination present on fuel surfaces after the manufacturing process gave rise to fission products, predominantly Cs-134, Cs-137 and Sr-90, which again may have been released to the coolant gas or remained as a contaminant on the fuel element. These radionuclides may have subsequently entered the liquid discharge stream via the cooling ponds when fuel was discharged from the reactors.

Fission products within the fuel element tended to migrate to the outer surfaces of the fuel and, when the elements were stored in the ponds, may have dissolved through any failures in the cladding. Provided the cladding remained intact, no fission products would be released from the fuel to the reactor circuit. In the event of a failure of the cladding, the resultant release of fission products to the reactor circuit would have been minimised through detection by the Burst Can Detection (BCD) system and the prompt removal of the fuel from the reactor. In addition, small quantities of uranium may have been present as contamination on the surfaces of the manufactured fuel elements and consequently, during irradiation, small quantities of fission products may have been produced on the outside surfaces of the elements.

When the reactors were operating, fuel elements discharged from the reactors were held in a cooling pond before being transported to Sellafield for reprocessing. Discharged fuel was held for a minimum of 90 days to allow for the decay heat production rate to reduce before the fuel was transported and to ensure that short lived fission products had decayed before the fuel became available for reprocessing. Following closure, radioactive decay of final core fuel will take place whilst the fuel is in the reactors prior to them being defuelled.

The pond water was chilled to minimise Magnox cladding corrosion. In practice cladding leaks could occur in a very small number of the elements that were discharged, allowing some of the more soluble fission products to be released into the pond water. Fission products have therefore been mainly observed in liquid effluent discharges. Although it is intended that, in future, fuel elements will not be discharged to the cooling ponds, there will continue to be radioactive discharges from pond operations and clean-up.

Review of the Quarterly Bulk Analysis shows that the main fission products will continue to be caesium-134, caesium-137 and strontium-90 (Table 1). In future the caesium radionuclides, being the more soluble, will be the main fission products observed with the longer lived caesium-137 (half-life 30 years) being the principal radionuclide. At present the caesium 137 levels are suppressed by the use of an ion exchange process for the removal of caesium and this system will remain in use until final discharge of pond contents.

Table 1 - Breakdown of Fission Product contributors (% contribution to total beta)

	Sr-90	Cs-134	Cs-137	Other
1996-2004	60.2	1.8	20.7	17.3
2005-2006	53.8	1.5	40.6	4.1

Post operational clean out of the ponds will give rise to continuing liquid discharges of these radionuclides.

4.2.3 Alpha emitting radionuclides

The main source of alpha emitting radionuclides was uranium contamination present on the fuel elements during production. When the irradiated fuel elements were stored in the pond, the alpha activity transferred into the water. The principal alpha radionuclides are americium-241, plutonium-239 and plutonium 240.

Post operational clean out of the ponds will give rise to continuing liquid discharges of these radionuclides.

4.3 Current Discharge Authorisations

The current authorisation for liquid discharges granted by SEPA [Ref.19] are shown in Table 2, below.

Table 2 – Current Liquid Discharge Authorisation (issued 1986)

Radionuclide	Current Annual Limit
Tritium	5.5 TBq
All Alpha Activity	0.1 TBq
All radionuclides excluding tritium and cobalt 60	25 TBq

4.4 Historic Discharges

Table 3 shows the total radioactive liquid discharges in each calendar year since 1996.

Table 3 Total radioactive liquid discharges, 1996-2006

Year	Total Alpha (GBq)	Total Beta (TBq)	Tritium (TBq)
1996	1.00	0.11	0.37
1997	0.30	0.04	0.20
1998	0.40	0.04	0.22
1999	0.20	0.07	0.71
2000	0.60	0.19	0.55
2001	0.07	0.026	0.17
2002	0.10	0.12	0.28
2003	0.80	0.18	0.25
2004	0.03	0.039	0.08
2005	0.01	0.0049	0.033
2006	<0.01	0.0036	0.011

The sum of the individual discharge sample analytical data are used to derive the above figures. For 2006, the gross alpha results have not recorded a result above the limit of detection of 0.01 $MBq.m^{-3}$.

The quarterly bulk samples are subject to gross alpha and gross beta analysis, calibrated to Plutonium-239 and Caesium-137 respectively.

In addition, isotopic analysis for the nuclides shown in **Table 4** is undertaken. The composition of the analysis suite is based on sampling results for 2003, which was the last year during which pond discharges were undertaken.

Table 4 – Nuclides Analysed Routinely In Liquid Quarterly Bulk Effluent Samples.

H3	Cr51	Ru106
Sr90	Cs134	Sb124
C14	Cs137	Sb125
S35	Eu154	Zn65
Ag110m	Eu155	Zr95
Am241	Fe59	Na22
Ce141	La140	Na24
Ce144	Mn54	Sc46
Co58	Nb95	
Co60	Ru103	

Recent annual volumetric liquid arisings by source are described below:

Table 5 – Representative annual volumetric liquid arisings by source since cessation of generation.

Area	Volume (m^3)	Comment
Ponds facilities including strainer cleaning and LLW compactor	4.5	Based on 2004 arisings, this figure is representative of the minor works being undertaken in the period since shutdown up to next planned pond discharge
CXPP	15.4	General arisings related to approximately 4 detention tanks discharged per year since plant closure
Circuit Gas Dryers	None	Since reactor shut-down no replenishment of gas-circuit dryers has taken place. Residual arisings will be removed and processed during planned decommissioning activities
Ground water arisings	980	Based on 2006 figures. Groundwater arisings largely due to ingress into reactor basements following changes in ambient conditions
Reactor Active Drain Tanks	4.5 – 18	Minimal arisings following shutdown
Uranium Store Active Drain Tanks	4.5	General arisings due to activities to recover and transfer packages to Capenhurst
Flask Handling Building	8 - 10	Estimated operational arisings during defuelling
Active Laboratories	1.8	Based on approximately 150 l per month

4.4.1 Tritium

The annual tritium discharges over the last 11 years, illustrated in Figure 5, range from 0.011–0.71 TBq with a mean annual discharge of 0.26 TBq.

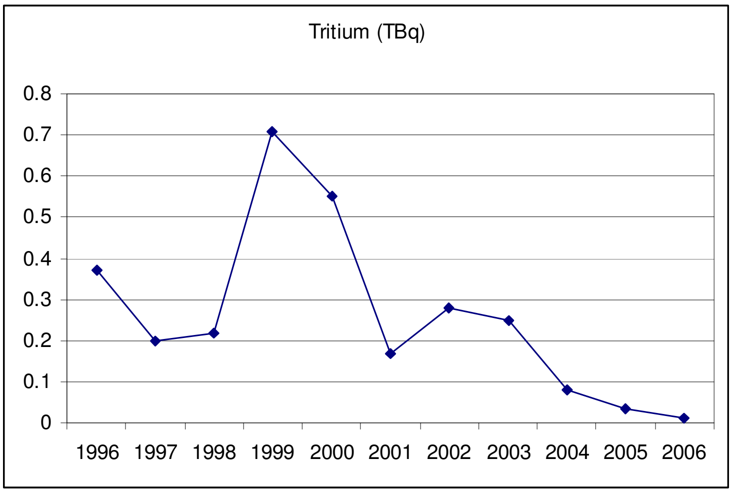

Figure 5 Historic discharges of tritium, 1996 to 2006

These figures include years when there were discharges of reactor humidrier tritiated water, routine pond emptying and decontamination operations. Excluding years in which there were humidrier liquor discharges, the mean annual tritium discharge was ~ 0.3 TBq. CXPP discharges are also included in these figures, but are normally small compared with pond operation arisings. Over this period the mean annual CXPP discharge, excluding years when humidrier liquors were discharged, were ~ 0.05 TBq.

The last time a Pond was emptied and refilled was 2003 and since then site annual tritium discharges have reduced by an order of magnitude from a few 100 GBqs to ~11 GBq in 2006.

4.4.2 Beta emitting radionuclides other than tritium

In the period 1996 to 2006 total ‘other beta’ discharges have been in the range 0.0036–0.19 TBq (see Figure 6). Discharges of the short-lived radionuclides such as S-35 in particular have reduced with cessation of power generation. The peak discharges in 2000 and 2003 are due to the discharge of pond water to enable cleaning of the pond.

When the reactors were operating S-35, Sr-90 and Cs-137 were the radionuclides present in the greatest quantities.

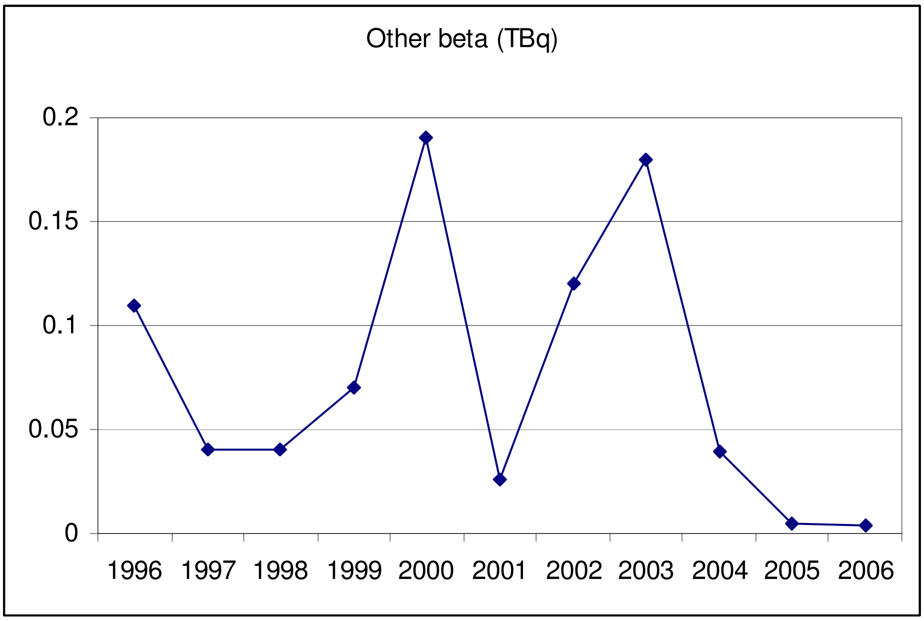

Figure 6 Historic discharges of 'Other Beta Activity', 1996 to 2006

The variation in annual total beta discharges has largely been dependent on the phasing of pond water emptying, some years a pond may not have been discharged or both ponds were emptied, for maintenance purposes. In most years one pond was emptied, the last time being 2003.

Beta emitting radionuclides (excluding tritium) present in liquid discharges comprise both fission and activation products. Although the site does not routinely declare discharges of individual radionuclides (other than tritium) in liquid effluent, it does currently undertake analysis of bulked effluent samples for a range of radionuclides on a quarterly basis. Although plutonium-241 is not included in this analysis, annual discharges of this radionuclide have been estimated from the mean ratio of Pu-241 to Cs-137 activities in discharges of liquid effluent from other Magnox Sites. The annual discharges of these radionuclides are included within the reported annual discharges of beta emitting radionuclides (excluding tritium) which are limited in the current certificate. Table 6 gives the annual discharges of the principal beta emitting radionuclides from 1996 to 2006.

Table 6 - Principal beta radionuclides in liquid discharges, 1996-2006

Year	Liquid Discharge (GBq)					
	S-35	Co-60	Sr-90	Cs-134	Cs-137	Pu-241 [1]
1996	21.0	1.9	42.0	1.4	17.0	0.76
1997	6.9	1.1	13.0	0.4	4.9	0.22
1998	8.9	1.7	15.0	0.4	4.9	0.22
1999	11.0	0.4	24.0	0.3	3.8	0.17
2000	12.0	0.7	88.0	1.3	17.0	0.76
2001	2.2	0.3	8.0	0.3	4.2	0.19
2002	7.6	0.3	53.0	2.1	20.0	0.89
2003	6.7	1.6	81.0	3.2	36.0	1.6
2004	<0.4	0.059	10.3	0.51	7.6	0.34
2005	<0.02	0.026	1.2	0.051	1.3	0.058
2006	<0.02	0.031	1.2	0.016	0.52	0.023

(1) Pu-241 discharges estimated from the mean ratio of this radionuclide to Cs-137 in discharges from other Magnox Sites

4.4.3 Alpha emitting radionuclides

Chapelcross is required currently to declare total alpha activity in its effluent discharges. Monthly declarations within this category are usually below the limit of detection of and are reported as 'less than' values. The only time that measurable levels of such activities are observed is when the site undertakes pond water replenishment. Alpha discharges are reduced by operating a settling tank principle in the 2 detention tanks to achieve BPM.

Total alpha discharges from 1996 to 2006 are given in **Table 3** and represented graphically in Figure 7. These range from <0.01 to 1.0 GBq with a mean of 0.32 GBq (see Figure 7). The peak discharges in 2000 and 2003 were due to the discharge of pond water to enable cleaning of the pond.

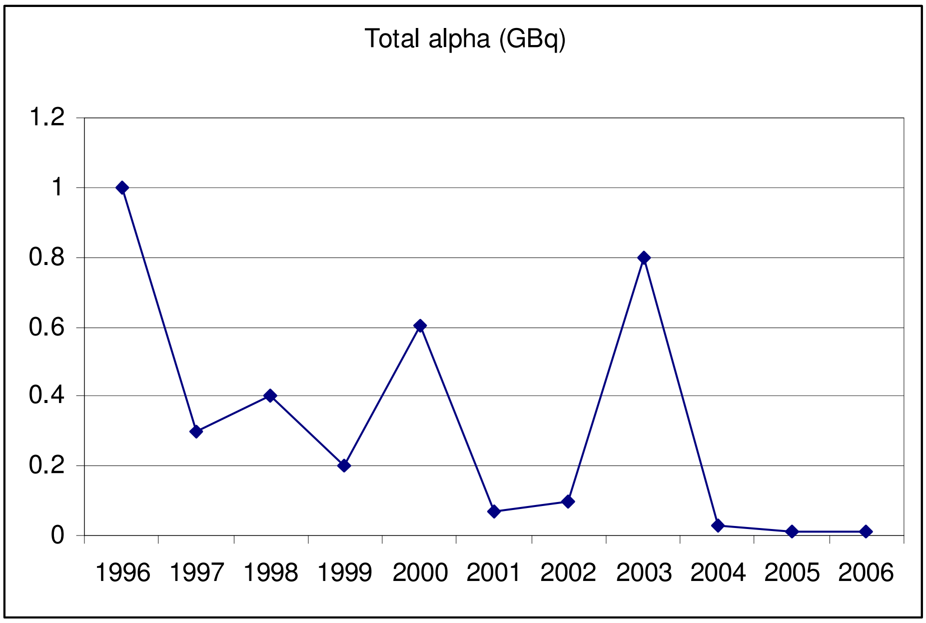

Figure 7 Historic discharges of alpha activity, 1996 to 2006

The level of alpha discharges during recent pond operations up to Reactor shut-down have reduced considerably since the 1980s, with the present pond water total alpha inventory being ~0.1 GBq. However, once the ponds are emptied and decontaminated the detention tanks will also be decontaminated at some stage during the pond decommissioning period, which may give rise to increased alpha discharges. In addition it is proposed to recover and condition the accumulated detention tank sludge for long term ILW storage on site.

Conditioning of the Pond wet ILW and detention tank sludge could start within the period of the next Authorisation and therefore potential discharges have been included in the proposed limits.

4.4.4 Individual alpha radionuclides

As for total beta (excluding tritium) discharges, the site does not routinely declare discharges of individual alpha radionuclides in liquid effluent. With the small alpha concentrations measured in the quarterly bulk effluent samples, the bulk liquid effluent analysis does not include identification of the alpha emitters. Based on a recent analysis of Pond sludge, by Berkeley Labs, the breakdown of the principal alpha radionuclides present as a percentage of the sludge total alpha activity is given in Table 7.

Table 7 – Percentage Contributors to Alpha Sludge Activities

Radionuclide	% Present
Pu 238	5.37
Pu 239	8.61
Pu 240	11.41
Am 241	50.99
Cm 242	0.16
Cm 243	0.27
Cm 244	0.65

Although liquid effluent individual alpha radionuclide annual discharges may be derived from the sludge analysis above, they will only be indicative of actual discharges in the liquid phase due to the variable solubility of the individual alpha emitting isotopes.

4.5 Anticipated liquid effluent arisings 2009- 2014

The main activities likely to give rise to liquid effluents are described in Section 4.1. Anticipated arisings, based on both volume and activity, during the operation period of the discharge authorisation being applied for – 2009 to 2014 – by area are provided in the following sub-sections. It should be noted that the estimates are based on current predictions within the lifetime plan and, as such, are subject to alteration based on revised NDA funding and objectives.

Estimates of activity discharges per nuclide or group of nuclides and proposed new limits for authorisations are given in Section 4.6.

4.5.1 Ponds Facility

Activities within the ponds facility during the initial part of the authorisation period will be essentially the same as those carried out to date following reactor shut-down. These comprise minor decontamination works, pipelines strainer cleaning and LLW compaction[2]. It is assumed that these activities continue until the end of the defuelling period 2009-2012, with anticipated effluent volumes of 4.5 m^3 per annum.

Following completion of defuelling, the next major task will be the POCO and early decommissioning of the Ponds Facility. Arisings during this period are based on the discharge of the contents of one pond per year, estimated to be 1818 m^3 for years 2013 and 2014.

Table 8 – Estimated annual volumetric and activity arisings by principal nuclides for the Ponds Facility.

Years	Vol (m3)	Activity								
		Total beta	Total alpha	H3	Cs 137	Cs 134	Co 60	Sr 90	C14	Am241
2009 - 2012	4.5	0.2 GBq	0.1 MBq	0.4 GBq	30 MBq	2 MBq	0.3 MBq	40 MBq	0.09 MBq	0.43 MBq
2013 - 2014	1818	70 – 500 GBq	40 - 80 MBq	5 - 100 GBq	30 – 40 GBq	1 – 2 GBq		8 – 180 GBq	60 -100 MBq	

Years 2009-2012 activities are based on 2004 sample data. One pond is assumed to be discharged in 2013 with the remaining pond discharged in 2014. Data is based on full ponds effluent contents, with 2013 based on 2006 sample data for Pond 1 and 2014 based on 2006 sample data for Pond 2. It should be noted that although sample analysis does not identify measurable levels of Americium-241, it is considered that this will be a prime contributor to the total measured alpha activity within the pond water.

4.5.2 CXPP

Post closure activities within the CXPP have resulted in the discharge of approximately four detention tanks worth of effluent per annum, equivalent to approximately 15.4 m3 of effluent. Given the predicted programme this is assumed to be a reasonable basis for ongoing estimates of volumetric arisings during the period 2009-2014. However, as the processes for stainless steel recovery, pellet recovery and primary line decontamination have not yet been subject to BPM assessment, these estimates cannot be regarded as definitive and an appropriate conservatism has been included in the process limits requested.

Table 9 provides estimates of arisings from CXPP during the period 2009-2014, based on current data.

Table 9 – Estimated annual liquid effluent arisings from CXPP 2009-2014

Year	Annual Volume (m3)	Activity				
		Total beta	Total alpha	H3	Cs 137	Cs 134
2009 -2014	15.4	0.19 GBq	0.15 MBq	63 GBq	26 MBq	0.4 MBq

[2] The use of low force compaction on site is currently being reviewed – See Section 6.3.1

4.5.3 Gas Circuit Dryers

Now that the reactors have ceased operation, the gas dryers are no longer used and no more dryer liquors will be produced. All the dryer liquors produced when the reactors were operating have been discharged. However, a quantity of tritium will arise during humidrier dismantling and conditioning for ILW storage which will need to be discharged at some time in the future. The peak tritium discharges shown in Figure 5 corresponds to discharges from Gas Circuit Dryers and are of the order of **1 TBq**.

4.5.4 Groundwater arisings

Following shut-down of the four operational reactors, changes in ambient temperature within the reactor basement has lead to an ingress of ground-water into the reactor and turbine hall basement areas.

This ground-water exhibits low-levels of tritium contamination and is, therefore, collected and transferred to the ponds facility for discharge via the existing authorised route. Based on figures for 2006 it is anticipated that 980 m^3 p.a. of such arisings will be generated by this route during the period 2009-2014, however this figure will be wholly dependent on the prevailing meteorological conditions. Chapelcross have given an undertaking to SEPA to investigate means of reducing groundwater ingress into the affected areas.

Table 10 provides estimates of groundwater arisings based on 2006 discharges.

Table 10 – Estimated Annual groundwater arisings 2009 - 2014

Year	Volume (m3)	Activity						
		Total beta	Total alpha	H3	Cs 137	Cs 134	Co 60	Sr 90
2009 - 2014	980	3.50 GBq	10 MBq	1.30 GBq	1 GBq	35 MBq	30 MBq	1.2 GBq

4.5.5 Reactor Active Drain Tanks

During the defuelling period the M2 fuel flasks will be filled in the discharge well of each reactor building. The filling of the flasks will not lead to the generation of significant quantities of liquid effluent and an estimate of up to 4.5 -18 m3 per year is taken to be a conservative estimate of arisings over the period of the authorisation. **Table 11** provides an estimate of likely arisings based on averaged sample data for 2007.

Table 11 – Estimates of Annual arisings from Reactor Active Drain Tanks 2009-2104

Year	Volume (m3)	Activity		
		H3	Cs 137	Cs 134
2009 - 2014	18	0.1 GBq	< 2 MBq	< 2 MBq

The estimated Caesium-137 and Caesium-134 activities are considered to be conservative as the measured activity concentrations are less than the analytical detection level.

4.5.6 Flask Handling Facility

Prior to dispatch of flasks from site, a sample of the flask water is taken for analysis. The flask will be filled with demin. water to a prescribed level within the Reactor Discharge Well and, following transfer to the Flask Handling Facility, approximately 100 l of water will be decanted from the flask and replaced with a nitrogen blanket. A sample will be collected from the decanted water, with the remainder being discharged to the ponds facility detention tanks. During final defuelling of the four reactors at Chapelcross, it is estimated that 80 fuel flasks per year will be filled, generating a total of approximately 10 m^3 of effluent per annum.

This activity will continue for the defuelling period which is anticipated to commence in 2008 and run for 3 years. However, the defuelling programme is dependent on the overall NDA programme and availability of receipt facilities at Sellafield. This may result in defuelling being carried out within the period of the authorisation. It has, therefore, been conservatively assumed that the defuelling programme commences in 2009 and runs for four years. The specific estimates for the period 2009-2012 are provided in **Table 12**, based on averaged analytical data from fuel flask samples over the period 2002 – 2005.

Table 12 – Estimated annual arisings for flask handing during reactor defuelling

Year	Volume (m3)	Activity	
		Cs 137	Cs 134
2009-2012	10	4 GBq	0.3 GBq

4.5.7 Uranium Store

The Uranium Store is currently part way through the programme of recovering and packaging Uranium oxide containers for transfer to BNG Capenhurst for long-term storage. Activities to data have generated approximately 0.85 m3 during the three year programme to date. It is anticipated that it will take a further three years to complete the programme and it is estimated that this will result in approximately 4.5 m3 of effluent being generated per year. During the course of the current programme the dedicated Drain Tank has only accumulated 25% of its volume in effluent. Therefore it is not anticipated that this tank will be filled during the completion of the process.

4.5.8 Analytical Laboratories.

The Chapelcross analytical laboratories are estimated to produce 150 litres per month of active effluent, which is subsequently transferred to the Ponds facility for disposal. The anticipated annual arisings from this facility are, therefore, estimated to be 1.8 m3 per annum.

4.5.9 Summary of Estimated Discharges

Table 13 presents a summary of the estimated annual discharges by both volume and activity for the period 2009-2014.

Table 13 – Summary of estimated total annual effluent discharges for the period 2009-2014

Year	Volume (m3)	Activity									
		Total beta	Total alpha	H3	Cs 137	Cs 134	Co 60	Sr 90	C14	S35	Am241
2009 – 2011	1027.9	3.89 GBq	10 MBq	65 GBq	5 GBq	0.34 GBq	30.3 MBq	1.24 GBq	0.09 Mq	1.36 MBq	0.43 MBq
2012	1027.9	3.89 GBq	10 MBq	1.06 TBq[3]	5 GBq	0.34 GBq	30.3 MBq	1.24 GBq	0.09 Mq	1.36 MBq	0.43 MBq
2013-2014	2831.4	70-500[4] GBq	40 - 80 MBq	5 - 100 GBq	30 – 40 GBq	1 – 2 GBq		8 – 180 GBq	60 -100 MBq	40 - 80 MBq	-

[3] Assuming Gas circuit dryer decommissioning
[4] Range is dependent on which Pond is discharged.

4.6 Future Needs and Proposed Limits for liquid radioactive discharges to 2014

4.6.1 Tritium

Although liquid effluent discharges of tritium arising from the reactors and the ponds would be expected to be lower in future, the quantities which will need to be discharged as a result of CXPP decommissioning are very uncertain, being very dependent on the method used for the process line decontamination. If a wet decontamination process is used to decontaminate the CXPP process line annual tritium discharges could be significant, even with an abatement process to limit discharges.

A study into decommissioning CXPP has taken place. The favoured options will be subject to the BPEO and BPM processes to ensure that both aerial and liquid discharges are reduced. Some of the CXPP plant and pipework will be highly contaminated with tritium, however, it may be possible to take measures to significantly reduce both aerial and liquid discharges of tritium during CXPP plant clean out and decommissioning, for example by cutting and crimping pipework sections in-situ. Alternative options may examine means of reducing aerial discharges at the expense of increased liquid tritium discharges, as the radiological impact of a liquid discharge of tritium is significantly less than that of an aerial discharge of the same quantity. Consequently, measures to reduce aerial discharges at the expense of an increase in liquid discharges could be consistent with the use of BPM.

Following closure of the reactors in 2004 there will be no more boilers leaks but a quantity of tritium will arise during humidrier dismantling and conditioning for ILW storage which will need to be discharged at some time in the future. Based on previous experience the residual humidrier tritium could be of the order of 1 TBq.

Table 13 estimates that the highest annual discharge during the period 2009-2014 will be approximately 1 TBq, due to Post-Operative Clean-Out of the Gas Circuit Dryers. However, if both ponds are discharged in the same year then the tritium discharge from this route could be the order of 0.2 TBq. Taking into account the uncertainly in potential tritium arisings from the reactor humidriers and any plant component decontamination operations during CXPP POCO and decommissioning, it is, therefore, proposed that the current annual limit of 5.5 TBq be reduced to 2 TBq. The proposed discharge limits are given in **Table 14**.

4.6.2 Beta emitting radionuclides (other than tritium)

Annual total beta discharges, since the last batch of irradiated fuel was transferred to Sellafield, have fallen to < 5 GBq, which includes the contribution from CXPP discharges. This takes into account of the use of the molecular sieve to reduce caesium137 pond water activity. If the two ponds are discharged in the same year then the total beta discharge could be the order of 0.5 TBq. Future annual discharges will also be dependent on the methods used for conditioning the wet ILW in the ponds and CXPP POCO and decommissioning.

Post closure, the principal beta radionuclides in liquid effluent will be the fission products Sr-90, Cs-134 and Cs-137, with the long lived isotope of Cs-137 dominating with time. Radioactive decay alone will not significantly reduce the levels of these radionuclides in discharges over the next few years. Hence, it would be expected that liquid discharges of these radionuclides, arising from operational activities which are expected to continue, will be of the same order in future as they have been recently.

No detailed site specific assessment has yet been carried out of the quantities of radioactivity expected in liquid discharges arising from other decommissioning activities planned to take place in the next few years, such as conditioning of pond sludge, ion absorption material, treatment of other miscellaneous ILW items presently stored in the ponds and final pond emptying. The total beta particulate discharges for the period 2009-2014 have been estimated in Table 13 as being a maximum of 0.5 TBq, coinciding with discharge of Pond 2. An assessment of future liquid discharges from Bradwell Power Station suggested that the maximum future annual discharge of all beta radionuclides, excluding tritium, at that site would be 0.78 TBq.

Due to the current uncertainty in predicting future annual discharge arisings from any plant decontamination work during decommissioning and the phasing of the final pond water emptying a suitable contingency is required to ensure that operational activities can be undertaken in the most flexible manner, with the aim of expediting the reduction of site liabilities and risk. On this basis an annual limit of 2.5 TBq for ‘other beta radionuclides’ is recommended (**Table 14**), which is an order of magnitude less than the current respective annual limit.

4.6.3 Alpha emitting radionuclides

Historical discharges of total alpha during the period 1996 to 2006 have ranged from <0.01 to 1.0 GBq with a mean of 0.32 GBq (see **Table 3**). This shows that the site operates well within the current limit value of 0.1 TBq (100 GBq), which would suggest that a significant reduction would be appropriate. This is supported by the initial estimates provided in Table 13, which derives a maximum annual alpha discharge of approximately 0.1 GBq

However, the site must retain sufficient headroom to enable it to carry out the planned preparations for care and maintenance expeditiously. For example, alpha discharges may rise during the recovery and conditioning of the sludge in the pond detention tanks. Although the conditioning of the sludge for long term storage / disposal is currently planned for the period of operation of the new authorisation, actual operations may not commence until the reactors have been successfully defuelled. As such, the sludge conditioning strategy is still to be determined and a conservative annual alpha limit of 20 GBq is recommended (**Table 14**), which is 5 times less than the present limit. As the sludge conditioning strategy is defined it will be subject to BPEO and BPM studies to optimise the environmental benefits of the selected strategy, at which point a more accurate estimate of the likely liquid discharges will be derived.

Table 14 - Proposed liquid discharge limits

Radionuclide	Annual Requirement
Tritium	2 TBq
Other beta emitting radionuclides	2.5 TBq
Alpha emitting radionuclides	20 GBq

4.7 Alternative Options for Managing Radioactive Liquid Waste (BPEO/BPM)

As noted in Section 3.2, a BPEO for the management of liquid waste at Chapelcross has recently been conducted (Reference 9). Some of the measures being considered in the BPEO are outlined below.

All selected options will also be subject to a formal BPM study to ensure that the environmental benefits are optimised.

4.7.1 Tritium

Now that power generation has ceased there is no further production of tritium in the reactors, and now that the reactors have cooled there will be a much lower rate of tritium release from the moderator graphite to the reactor dry air. An increase in the level of moisture in the reactor dry air leads to an increase in the tritium concentration. It is therefore intended to maintaining a low level of moisture in the reactor dry air to minimise the tritium concentration in the dry air and the quantities of tritium in aerial discharges from the reactors.

The aerial discharges of tritium from Chapelcross site will continue to be dominated by discharges from the CXPP All intended operations will be examined to ensure that waste disposals are in the appropriate form and that discharges are kept as low as reasonably practicable.

The subsequent decommissioning of CXPP will involve the dismantling of stainless steel pipework and plant which will contain a large quantity of residual tritium. Detailed plans for decommissioning the CXPP will take account of the BPEO and the BPM of limiting radioactive discharges during the decommissioning. These are still under consideration. The radiological impact per unit volume of tritium discharged from Chapelcross site is much less for a liquid discharge than for an aerial discharge. Consequently, measures to reduce aerial discharges at the expense of an increase in liquid discharges are among the measures being considered.

4.7.2 Beta emitting radionuclides

Preparations for care and maintenance will require the cleaning, emptying and decommissioning of the ponds and the detention tanks. The site already undertakes periodic pond cleaning and emptying and therefore the final pond preparation for the subsequent care and maintenance should not result in enhanced levels of activity in liquid effluent arisings. However, the detention tanks will have some sludge requiring removal and conditioning and the caesium abatement ion exchange skips will require conditioning into ILW containers. These processes may result in additional discharges of beta activity. As these detention tanks are downstream of the pond ion exchange units, those units cannot be used to reduce beta activity arising from the cleaning of the tanks. However, the potential for increased beta discharges is recognized and, before the cleaning begins, there will be a full consideration of BPM to ensure that the discharge is as low as reasonably practicable.

4.7.3 Alpha emitting radionuclides

As detailed above, preparations for care and maintenance will require the cleaning, emptying and decommissioning of the ponds and the detention tanks. The site already undertakes periodic pond cleaning and emptying and therefore the final pond preparation for the subsequent care and maintenance phase should not result in enhanced levels of activity in liquid effluent arisings. However, the detention tanks will have some sludge requiring removal and conditioning and the caesium abatement ion exchange skips will require conditioning into ILW containers. These processes may result in additional discharges of alpha activity. As these detention tanks are downstream of the pond ion exchange units, those units cannot be used to reduce alpha activity arising from the cleaning of the tanks. However, the potential for increased alpha discharges is recognized and, before the cleaning begins, there will be a full consideration of BPM to ensure that the discharge is as low as reasonably practicable.

4.8 UK Strategy for Radioactive Discharges to the Marine Environment

The statement signed on behalf of the UK Government at the Sintra meeting of OSPAR committed the UK to prevent pollution through reductions of discharges, with the ultimate aim of concentrations in the environment close to zero for artificial radioactive substances, taking into account:

- legitimate uses of the sea;
- technical feasibility; and,
- radiological impacts to man and biota.

In order to achieve the requirements of the OSPAR agreement, the Government has published a document entitled 'UK Strategy for Radioactive Discharges 2001-2020'. This strategy recognises that radionuclides differ in their environmental significance and sets targets for different sectors of industry. For nuclear energy production there are targets for annual discharges of tritium (850 TBq) and for total activity excluding tritium (1.5 TBq). These reductions are to be achieved by 2020. National discharges generally, and from the electricity generation sector in particular, are expected to reduce by 2020 as older plants are decommissioned.

4.9 Radiological Impacts

Authorised discharges of radioactivity can result in an increase in public radiation doses as a result of both external exposure and internal exposure due to inhalation and the consumption of foodstuffs within which radionuclides have been incorporated. Public radiation doses and collective doses have therefore been estimated on the basis of the proposed annual discharge requirements for liquid effluents (Table 15). Table 15 also indicates the radionuclide composition assumed in the assessment for beta and alpha activity in liquid.

Table 15 - Proposed discharge limits and radionuclide composition assumed for doses arising from discharge of liquid effluents

Radionuclide	Proposed limit	Radionuclide composition	Radionuclide Used in Assessment*
Tritium[1]	2 TBq	Tritium	Tritium
Other beta emitting radionuclides	2.5 TBq	Sr-90, Cs-134, Cs-137	Cs-134
Alpha emitting radionuclides	20 GBq	Pu-238, Pu-239, Pu-240, Am-241	Pu-239

*Cs-134 and Pu-239 were chosen as they are the most radiotoxic of the components found ensuring that the assessment was conservative

Exposure of the public to discharges of liquid waste were assessed using the PC-CREAM modelling code and accepted assessment methods, using site-specific habits data where available.

For the purposes of the assessment it was assumed that the critical group was comprised of fishermen and their families that are exposed to liquid discharges from the site by spending some time on the intertidal sediments in the area and consuming high levels of locally caught fish and shellfish. Local habit survey results were used to determine the occupancy and food intakes of the members of this group. The basis for the dose calculations is described in Appendix 1.

4.9.1 Critical Group dose

At the limits proposed, the highest dose from marine discharges was 6 μSv/y to an adult fisherman (**Table 16**). The majority of this dose arises from the handling of fishing nets contaminated with beta emitting radionuclides .

Table 16 - Individual Doses to Candidate Critical Groups arising from liquid discharges at the proposed limits

Candidate Critical Group	Age Group	Dose (μSv/y)
local fisherman (high marine exposure)	Adult	6
	Child	2
	Infant	<1

These figures are significantly below the single source dose constraint of 300 μSv per annum and the Basic Safety Objective of 20 μSv per annum recommended by the Nuclear Installations Inspectorate..

4.9.2 Collective dose

Table 17 gives the calculated collective doses (truncated to 500 years) from one year's aquatic discharge at the proposed discharge limits and the radionuclide composition given in Table 15 for the beta and alpha activity in liquid effluent. The collective doses have been calculated for the UK, for Europe and for the World. The basis for the dose calculations is described in Appendix 6. The predicted collective doses are considered to represent a negligible societal risk.

Table 17 - Collective dose from one year's liquid discharges at the proposed limits

Radionuclide	Collective Dose (man.Sv)		
	UK	Europe	World
Tritium	1.02E-06	4.36E-06	8.73E-05
Beta activity	0.015	0.035	0.04
Alpha activity	0.0016	0.003	0.003
Total	0.02	0.04	0.04

5. DISCHARGE OF GASEOUS RADIOACTIVE WASTE

This section provides information in support of the application of Magnox North Ltd. for an authorisation of gaseous radioactive waste from the Chapelcross Site during decommissioning.

5.1 Sources of Radioactive Releases to Atmosphere

Historically there have been three main sources of radioactive gaseous discharges from the site to the environment. These arose from the reactor coolant circuits, from the reactor shield cooling air and from the CXPP. In addition there have been minor discharges from contamination ventilation plants associated with work areas. Details of all outlets are shown in Table 18. Suitable methods have been agreed with SEPA for determining the quantities of the specified radionuclides in the gas discharged. The concentrations of tritium and sulphur-35 in the reactor coolant are measured routinely as a requirement of the existing authorisation. The Site also measures the quantity of carbon-14 released.

Table 18 - Gaseous outlets

[a] Main Outlets

Outlet	Discharge height	Filtration
Reactor 1 – 4 shield cooling air	Discharge at 60 m	None
Reactor 1 – 4 gas circuit blowdown ducts	Discharge at 60 m via shield cooling air	Ceramic candle filter
Reactor 1 – 4 heat exchanger	Discharge at 30 m	Ceramic candle filter
CXPP	Discharge at 37 m	HEPA filters

[b] Other Reactor Outlets

Outlet	Location	Filtration
Reactor 1 – 4 discharge wells	Discharge at 20 m	HEPA filter
Reactor pile cap local extract during defuelling and maintenance	Discharge at 26 m	HEPA filter
Reactor pile cap graphite crusher flask local extract	Discharge at 60 m via shield cooling air	Ceramic candle filter
Reactor boron ball safety mechanism local extract	Discharge at 60 m via shield cooling air	None

[c] Other Outlets

Outlet	Location	Filtration
Pond building LLW Sorting and Compaction area	Discharge at 15 m	HEPA filter
Pond building Active Grab Workshop[5]	Discharge at 5 m	HEPA filter
Pond building natural leakage	Ground level	unfiltered
Analytical Laboratories	Discharge at 20m	HEPA filter
Uranium Store	Discharge at 10 m	HEPA filter

5.1.1 Reactor circuits

During normal operation each reactor contained about 26 tonnes of reactor coolant. The reactor coolant contained small amounts of radioactivity in gaseous and particulate form. After the cessation of electricity generation, the coolant pressure was reduced to slightly above atmospheric pressure.

[5] This outlet may not be required to support future operations

This situation continued until the safety case had been made for the reactor coolant to be replaced with dry air. Some release of radioactivity will continue to occur due to normal leakage of dry air and any purging from the reactors. In addition, some release of contaminated air is inevitable during defuelling, whilst further but smaller releases will occur after the reactors have been defuelled.

At present, the quantity of each of the radionuclides discharged from leakage is determined from the known reactor dry air make-up rate and the measured concentrations of those radionuclides in the reactor coolant.

5.1.2 Shield cooling air

The reactors at Chapelcross have steel pressure vessels surrounded by a concrete biological shield. During reactor operation the shield was cooled by the shield cooling air (SCA) which was a forced flow of air between the pressure vessel and the shield. Neutron activation of argon naturally present in the air produced Ar-41 which was then discharged with the SCA to the atmosphere. Now that the power generation has ceased, there is no further production of Ar-41 and hence no further discharge of Ar-41. In future the use of the SCA will be limited to periods of defuelling. The discharged air will contain small quantities of tritium, C-14 and particulate-borne activity arising from coolant leakage.

5.1.3 Processing plant

The extraction of tritium in the CXPP leads to the gaseous release of tritium. When operating, this was a batch process, however, removal of the isotope cartridges from the reactors and the processing of tritium from these isotope cartridges in the CXPP have been completed. As outlined earlier, the role of this plant will now move to the handling and treatment of ILW. Such processes will lead to some release of gaseous wastes, mainly tritium.

Gaseous discharges of tritium from the CXPP are determined from continuous sampling of both the extract ducts and on-line monitoring. The use of ion chambers gives a collective assessment of both elemental and oxidised forms of tritium. Such activity assessment methods will continue post closure.

5.1.4 Other plant

In addition to the above, there are various minor outlets primarily associated with the ventilation of individual work areas some of which will continue in operation post reactor closure. These are shown in Table 18 (b) and (c).

In the ponds building low level waste handling facility ventilation extract systems will only be in use during waste sorting and compaction operations. In addition there is also a potential discharge route, via the pond roof air vents, for some radionuclides from evaporation of pond water and during periodic pond decontamination and maintenance operations.

Most of the reactor minor outlets were operated intermittently during defuelling operations and had the potential to give rise to small discharges of particle borne radioactivity.

The Graphite Handling Facility was formerly used for the physical testing of irradiated graphite, but is no longer in use. Removal of this facility is planned as part of the North Site clearance programme. A small discharge of particle borne activity could occur during this work which is expected to have been completed before reactor defuelling begins.

The Uranium Store has been over-clad and a filtered and monitored ventilation extract installed to facilitate the work associated with over packing the drums in preparation for their transfer to another site. The measured uranic discharge[6] is negligible and below the detection threshold. A small discharge of tritium, associated with the presence of some CXPP ILW, including pellet waste, which is currently held in Temporary Storage Vessels in this building, has also been measured.

Based on the level of radioactivity associated with the environmental and site samples analysed in the Technical Building laboratory facilities any aerial discharges from ventilated fume hoods and glove boxes will be negligible. Similarly for the irradiated Flask Handling Building, which will be used for final flask decontamination, monitoring assessments and lid seal testing, any aerial discharge will be negligible.

5.2 Principal Nuclide Contributors to Aerial discharges

The named radionuclides in the gaseous discharge authorisation IPB/4/1/2/3 are:

- Tritium;
- Carbon-14;
- Sulphur-35; and,
- Argon-41;

Although included within the discharge authorisation, no limit is currently stipulated for carbon-14. The new authorisation seeks limits for beta particulate.

5.2.1 Tritium

Tritium is a radioactive isotope of hydrogen that emits very low energy beta radiation with a half life of 12.3 years. Tritium was the major radionuclide in the coolant gas and arose from tertiary fission followed by diffusion through the fuel pin cladding into the gas circuit and neutron activation and subsequent decay of the of lithium present as an impurity in the graphite moderator; from where it was released to the reactor coolant due to graphite oxidation. Some tritium, produced by fission in the fuel, may also have diffused through the fuel cladding to the coolant.

Now that power generation has ceased, there is no further production of tritium in the reactors, and now that the reactors have cooled there will be a much lower rate of tritium release from the moderator graphite to the reactor dry air. An increase in the level of moisture in the reactor dry air leads to an increase in the tritium concentration. It is intended that maintaining a low level of moisture in the reactor dry air will minimise the tritium concentration in the dry air and the quantities of tritium in aerial discharges from the reactors. However, once defuelling activities commence, the level of moisture and, therefore, the level of tritium discharges are likely to increase over the period of defuelling.

Tritium was also produced in the isotope cartridges irradiated in two of the Chapelcross reactors. Subsequent processing of the isotope cartridges in the CXPP to extract the tritium resulted in significant tritium in gaseous discharges.

5.2.2 Carbon-14

Carbon-14 was produced by neutron activation of the natural isotopes carbon-13, nitrogen-14 and oxygen-17 by the following reactions :

$^{17}O(n,\alpha)^{14}C$, $^{14}N(n,p)^{14}C$ and $^{13}C(n,\gamma)^{14}C$.

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[6] The term "uranic discharge" means the discharge of compounds of uranium.

Nitrogen and oxygen were present as an impurity in reactor coolant and in the graphite moderator and could have been a significant contributor to the production of C-14. In an operating Magnox reactor, C-14 is produced in the graphite moderator from where it is released to the coolant by graphite oxidation reactions. Carbon-14 was also produced directly by neutron activation of the coolant.

The quantity of C-14 produced in the moderator was proportional to the integrated quantity of power generated by the reactor. During operation, the rate at which C-14 from the moderators was released into the coolant depended on the graphite oxidation rate. This was controlled through the application of reactor operating rules that governed the chemical composition of the coolant gas..

Although the production of C-14 in Chapelcross reactors has now stopped, there will be no significant reduction of the quantity in the reactor during the period of interest because of its long half-life (5,730 years).

Experience at other stations shows that after a Magnox power station ceases power generation, C-14 discharges fall initially while preparations are made to defuel the reactors. This is because the principal mechanisms whereby C-14 enters the coolant (radiolytic moderator oxidation and resuspension) have ceased. Before defuelling, the primary release mechanism will be due to the gradual diffusion of residual coolant from the graphite moderator and reactor internals. This pattern can be seen in the summary of airborne discharges from Calder Hall presented in Section 5.4.6.

Once defuelling starts, there may be an increase from these lower levels as operations within the core are reinstated. However, experience indicates that such levels do not attain those experienced during operation and based on information supplied by Calder Hall, a station of similar design and operation, it is estimated that a four-fold increase on current discharge levels may be seen.

5.2.3 Sulphur-35

The principal source of sulphur-35 in an operating Magnox reactor was the neutron activation of chlorine and sulphur impurities in the graphite moderator and the subsequent release to the coolant due to graphite oxidation. Most of the S-35 released to the reactor coolant was deposited on circuit surfaces with a small fraction remaining gas-borne. With the cessation of power generation, there is no further production of this radionuclide and the quantities present in the graphite moderators and deposited on internal reactor surfaces are reducing continuously due to the short radioactive half-life of S-35 (87 days). Now that the reactors have cooled the rate at which S-35 is released to the coolant is also greatly reduced. Consequently, the levels of S-35 in the reactor dry air, and the quantities of S-35 in aerial discharges from the site, are greatly reduced and will become close to zero before the end of defuelling.

5.2.4 Argon-41

Argon-41 was produced mainly by neutron activation of argon-40, which was present as a contaminant in the biological shield cooling air. With cessation of power generation no Ar-41 is being produced and, as this radionuclide has an extremely short half-life (1.83 hours), future discharges will effectively be zero.

5.2.5 Particulate-borne activity

Each of the reactor gas circuits contained small quantities of particulate material, principally as graphite particulate from the moderator surfaces. Particulate could also have been produced during oxidation of heat exchanger and other surfaces and may have been transferred by the coolant gas and become activated in the core and deposited principally in regions of the circuit where the gas velocity was low. Following cessation of power generation the release of any beta particulate will be dependent on changes to reactor gas circuit characteristics. However, once defuelling starts, disturbances in the reactor vessels similar to those during refuelling may lead to the resuspension of particulate material in the gas circuit.

Radioactive particulate matter can become airborne in any area where radioactive materials are handled, in particular maintenance on contaminated fuel and reactor components, and can also occur in discharges of coolant gas. At Chapelcross, most of the activity associated with particulate consists of the beta emitters Mn-54, Fe-55, Co-60, Zn-65, Sr-90 and Cs-137. Particulate emissions are minimised through HEPA and ceramic candle filtration on discharge routes. For accounting purposes, activities of beta radionuclides discharged to air will be collated and reported together under the 'beta emitting radionuclides associated with particulate matter' category.

The radionuclide of most significance within such particulate is cobalt-60, which has a half-life of 5.27 years). There will therefore continue to be arisings of beta particulate, although at decreasing levels. Cobalt-60 is the major radionuclide present in irradiated graphite and steel (Table 9).

Other potential sources of particulates is their suspension resulting from work carried out during the decontamination and maintenance of the ponds following the routine periodic discharge of pond water. In addition, the potential exists for aerial discharges from the ponds facility via evaporative transfer from the ponds surface and subsequent leakage from the facility by natural ventilation. Further particulate arisings may be generated in other active work areas such as the active workshop and decontamination areas.

The breakdown of beta particulate contributors is detailed in Table 19 - Beta Particulate contributors.

Table 19 - Beta Particulate contributors

Radionuclide [1]	Percentage contribution [2]
Co-60	89
Mn-54	0.2
Ni-63	10
Zn-65	0.02

1. Excludes Fe-55 and H-3
2. Based on a 2001 Graphite sample decay corrected to 2006

5.3 Current Authorisations for Gaseous Discharges

The Current Gaseous discharge authorisations for Chapelcross are:

Table 20 - Current Gaseous discharge limits (Authorisation issued 1986)

Nuclide	Authorised Limit
Argon 41	4500 TBq
Sulphur 35	0.05 TBq
Carbon 14	no limit
H3 elemental	1000 PBq
H3 (other)	5 PBq
Beta particulate	no limit

5.4 Historic Discharges

Table 21 - Radioactive gaseous discharges, 1996 to 2006 shows the gaseous discharges in each calendar year since 1996. It has not been a requirement of the current discharge authorisation to monitor discharges of beta particulate and data on historical discharges of such material is not, therefore, available.

Table 21 - Radioactive gaseous discharges, 1996 to 2006

Year	Ar-41 (TBq)	C-14 (GBq)	S-35 (GBq)	H-3 (TBq)
1996	3200	389	28	1100
1997	2700	332	23	1000
1998	2800	314	22	1300
1999	2800	385	27	1400
2000	2600	358	24	1500
2001	2100	343	20	840
2002	1200	280	7	760
2003	750	153	4	410
2004	69	35.5	0.8	594
2005	0	0.65	0.023	300
2006	0	0.095	<0.041	121

5.4.1 Argon-41

The current gaseous discharge limit for Argon-41, which is only associated with reactor coolant, is 4500 TBq. Figure 8 shows the reduction in Ar-41 discharges as a result of reduced electricity generation between 1996 and 2006.

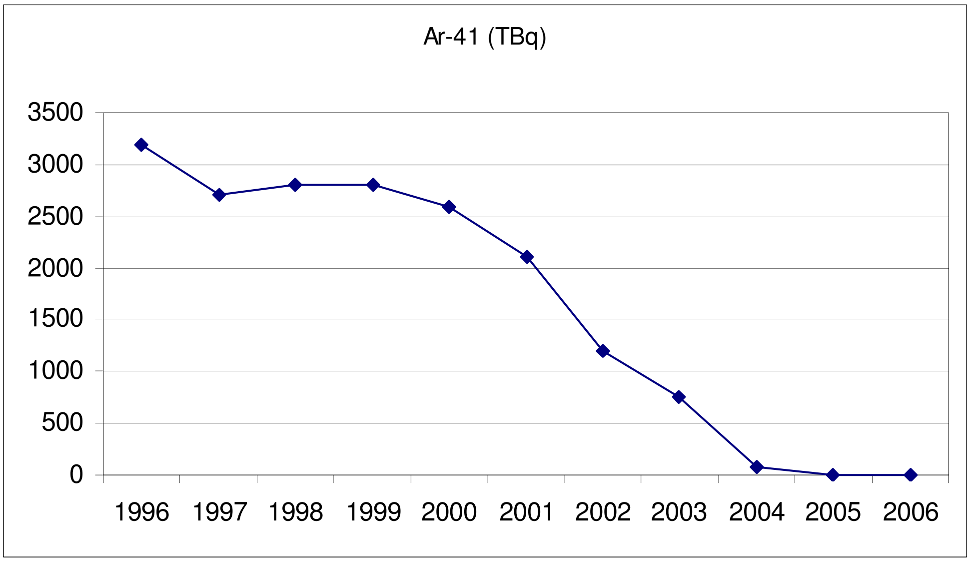

Figure 8 Historic discharges of argon-41

5.4.2 Carbon-14

Currently there is no limit on the quantity of C-14 discharged from Chapelcross and there has, therefore, been no requirement for the site to declare such discharges. However, the site has undertaken measurements of the C-14 released since 1990. Figure 9 shows a decline in C-14 discharges over the period 1996 to 2006.

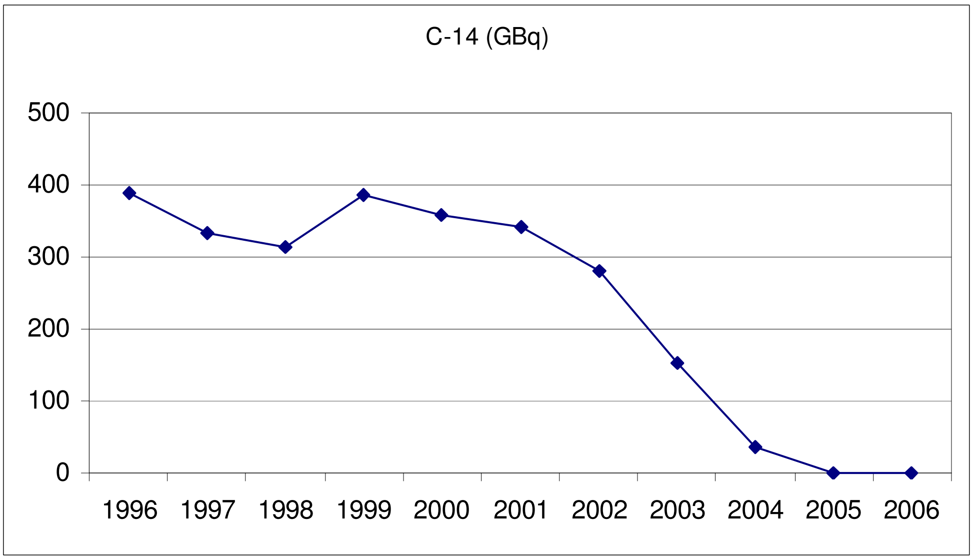

Figure 9 Historic discharges of carbon-14

Current measurements of C-14 are predominantly below the detection threshold of the approved analysis method and current assessments are based on the assumption of limit of detection values. An alternative sampling technique, utilising a new sampling point and analysis methodology has been trialled. Based on the gaseous concentrations derived and the annual reactor make-up volumes an estimate of the C-14 discharge can be made and is shown in **Table 22**, below:

Table 22 – Revised estimate of C14 discharges from Reactors R1-R4 for 2006

2006	R1	R2	R3	R4
Dry air make up (m^3)	$4.6\ 10^4$	$1.5\ 10^5$	$1.6\ 10^5$	$6\ 10^5$
C14 conc ($Bq.m^{-3}$)	737.5	125	1213	1388
Estimated discharge (Bq)	33.9 MBq	18 MBq	0.19 GBq	83.6 MBq
Estimated total Annual discharge	0.33 GBq			

The alternative estimate of 0.3 GBq for 2006 is of the same order as the assessment made by the approved method and supports the conclusion that C-14 discharges have fallen significantly following cessation of reactor operations. This data is supported by the data provided by Calder Hall, as summarised in Section 5.4.6.

5.4.3 Sulphur-35

The current gaseous discharge limit for sulphur-35 is 50 GBq. Over the last 10 years S-35 discharges have significantly reduced (Figure 10) and, since power generation ceased, discharges of S-35 have reduced to almost zero.

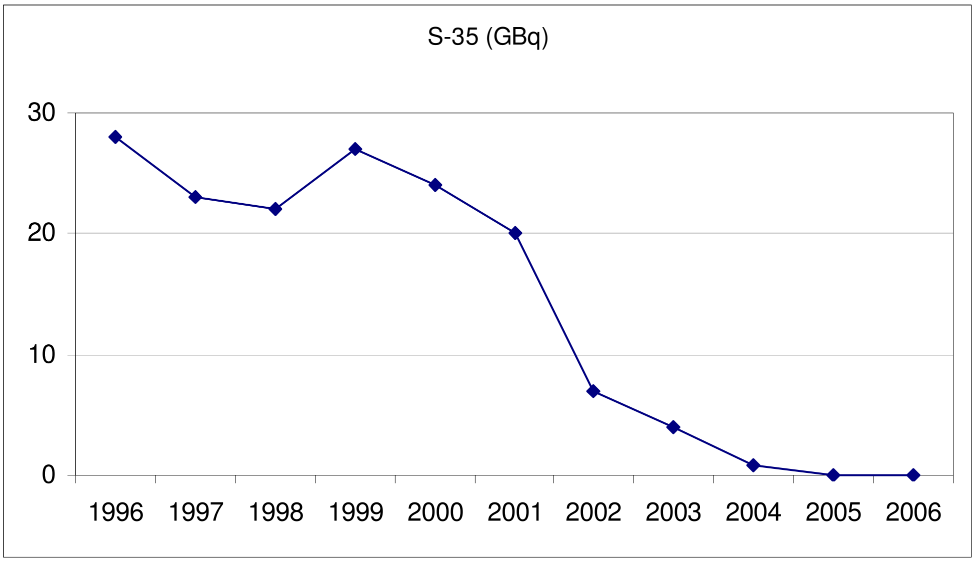

Figure 10 Historic discharges of sulphur-35

For full reactor operation between 1986 and 2000 the range of annual discharges of S-35 was 0.0097-0.0282 TBq, with a mean of 0.0197 TBq

Based on experience with other magnox type reactors discharges of sulphur 35 fall to relatively low levels shortly after generating ends. For instance, annual discharges at Bradwell reduced from around 60 GBq, during operation, to ~ 0.09 GBq (~0.2% of operating level) in the first year following closure and ~0.03 GBq (~0.05% of operating level) in the second year, post operation.

With the progressive closure of the Chapelcross reactors, between 2001 and 2004, sulphur-35 annual discharges reduced from around 20 GBq, during 4 reactor operation, to 0.76 GBq in 2004. The annual average discharge since final reactor closure in 2004 has ranged from 0.02 to 0.04 GBq (up to ~0.2% of the operating level).

Since concentrations of sulphur-35 in the reactor cores are now at the analytical detection limit, recent annual discharges should be regarded as un upper limit.

Reactor core sulphur 35 concentrations will have reduced by at least 20 half lifes (87 day ½ life) before the new Authorised limits takes effect, which should be in 2009. By this time sulphur 35 discharges should be effectively zero. On this basis it is suggested that a sulphur 35 discharge limit is not considered appropriate, for post reactor closure operations.

5.4.4 Tritium

The current authorisation places separate annual limits on aerial discharges of elemental tritium and of other forms of tritium ("tritium-other than elemental"). The annual limit for discharges of "tritium-other than elemental" is much lower than the limit on elemental tritium (5000 TBq and 1000 PBq respectively). With the agreement of SEPA, all gaseous tritium discharges are reported as "tritium other than elemental". The annual limit for discharges of "tritium-other than elemental" is then effectively a limit on the total gaseous discharge of tritium.

During CXPP operation, in the period 1986 to 2005 the site annual discharges ranged from 300 -1935 TBq, with a mean of 1109 TBq.

Tritium discharges were dominated by CXPP during the reactor operating period. For comparison the total reactor tritium discharges were generally less than 3 TBq per year during reactor operations. Annual CXPP tritium discharges from 2000 have fallen from around 1500 TBq to 300 TBq in 2005, the final year of operation. In 2006 discharges were ~ 120 TBq, principally due to general plant gassing off and the start of the campaign to recover the stainless steel ILW for transfer to Sellafield MBGWS.

In addition there will be a minor discharge of tritium due to any leakage from the tritium ILW pellet waste currently stored in the Uranium Store. Based on the stack bubbler tritium monitoring annual tritium discharges are of the order of 6 GBq, which will continue until the pellet waste is transferred to the CXPP for conditioning.

An estimate of the potential tritium discharges through evaporation from the ponds and natural leakage from the building fabric is presented in Appendix 3. This estimate is based on the highest tritium concentrations in Pond Water Samples for 2007 and takes the volume of pond make-up water for 2004 as being representative of the total evaporation from the ponds. The estimated value is less than 10 GBq of tritium released and this is deemed conservative as the ambient pond water temperature has decreased significantly since the removal of spent fuel. This discharge path is not considered significant for the future life of the ponds facility.

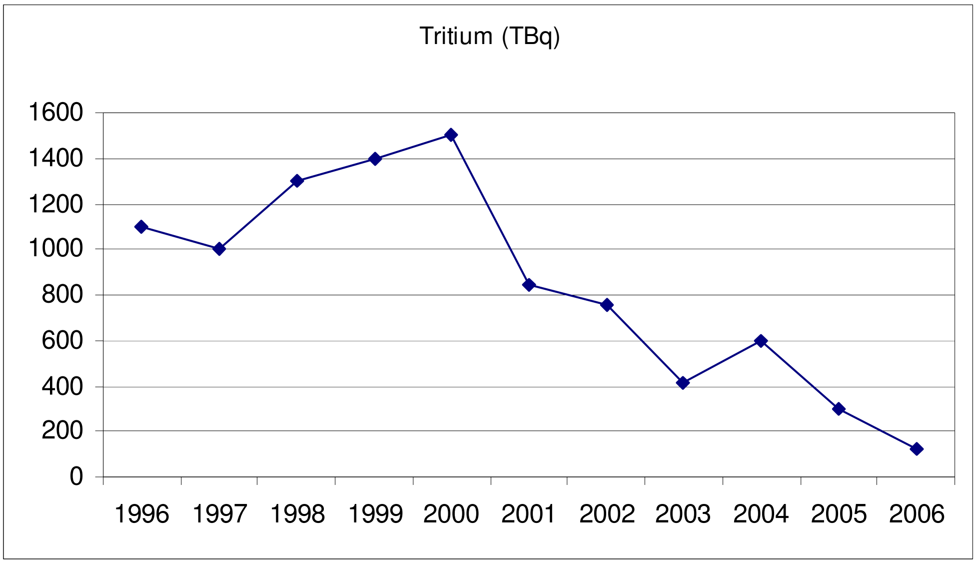

Figure 11 Historical discharges of tritium

5.4.5 Beta particulate

Discharges from Major Outlets

In the past there has been no requirement to report to the regulator any aerial discharges of radioactivity associated with beta particulate material from Chapelcross. However, at all other Magnox Power Station sites including Calder Hall there is an annual limit on aerial discharges of beta-emitting radionuclides associated with particulate. Although the limits apply only to beta emitting radionuclides, they have the effect of limiting all discharges of beta particulate borne radioactivity.

Shortly before the reactors ceased operation, an attempt was made to evaluate the levels of beta particulate that were released from the Chapelcross reactors, based on cobalt-60 activity measurements on samples taken from the reactor shield cooling air stacks. A comparison of these measurements with Calder Hall data indicated that, during operation, beta particulate releases from Chapelcross were probably comparable with those observed at Calder Hall.

Calder Hall and Chapelcross power stations were both built in the mid 1950's to the same reactor design criteria.

Data presented in Section 5.4.6 shows that during the last few years of operation the annual discharge of beta particulate from Calder Hall reactors was of the order of 80 MBq. Cobalt-60 was observed to be the predominant radionuclide present. Following closure these discharges figures have dropped steadily, currently standing at approximately 0.3 MBq.

Discharges from Minor Outlets

The annual beta particulate discharge from the reactor minor outlets listed in Table 18 (b) is estimated to be around 2-3 MBq. As with the reactor stack beta discharge the principal radionuclide present will be cobalt-60. Other radionuclides which could be present are manganese-54, nickel-63 and zinc-65.

It is recognised that an unmonitored discharge route related to the discharge of material entrained in evaporate from the cooling ponds and adventitious leakage from the ponds building exists. A conservative estimate of the beta particulate discharge via this route is presented in Appendix 4. The assessment is based on air sample data from a comprehensive study undertaken between 1982 and 1984, when pond water activity is likely to have been significantly higher. Evaporation rates from the pond will also have been higher due to the increased ambient temperature generated by the cooling fuel rods. Recent air sample data indicates that expected airborne activity levels will be significantly lower than the data assumed. However, as this data is not decay corrected for radon daughter activity it has not been used in this assessment. The conservative estimate, not accounting for any particulate deposition within the building or decontamination from the intact structure, derived in Appendix 4 is an annual discharge of 2.4 MBq via this pathway.

Based on particulate air sampling of the Uranium Store aerial discharge outlet, the discharge of particulate borne activity from this Store is negligible.

Fume hoods and glove boxes in the active laboratories of the Technical Laboratories are ventilated and filtered before discharge but not monitored. . However, the activity associated with the site and environmental samples, analysed in this facility, is such that the potential discharge from this outlet will be negligible.

The Graphite Handling facility may be removed during the reactor defuelling period. During these operations the facility's general work area ventilation system, which is filtered but not monitored, was operated. With the additional secondary containment to be used within the facility during the decommissioning process, the beta particulate discharge is likely to have been negligible.

A flask handling facility has been built to carry out the irradiated fuel flask lid seal test before transfer of the fuel to Sellafield. During this process the flask will be provided with a local ventilation extract which is filtered but not monitored. Based on experience elsewhere any beta particulate discharge will be negligible.

The Uranium Store has been over clad and a building ventilation system, with HEPA filters and discharge monitoring installed. Monitored discharges during current overpacking operations are negligible.

Table 23 - Minor discharge outlets and estimated discharges

Plant	Outlet	Discharge height and Filtration	Radionuclides	Estimated Annual Discharge
Reactors	Pile cap local extract (intermittent use)	- 26m - HEPA filter	β particulate Cobalt 60	2.5 MBq 1.2 MBq
Pond	Pond top general (natural ventilation)	~15m - None	Tritium β particulate Caesium 137 Strontium 90 α particulate Americium 241	10 GBq 2.4 MBq <0.1 MBq < 0.1 MBq < 0.1 MBq <20 KBq
	Active Workshop	~15 m - None	β particulate	Negligible
	LLW sorting area fume hood (intermittent use)	~15m - HEPA filter	β particulate Cobalt 60 Chromium 51 Iron 59	Negligible Negligible Negligible Negligible
Uranium store	General building	~10 m - HEPA filter	Tritium Uranic isotopes	6 GBq Negligible
Technical Labs	Active fume hoods	~10 m - HEPA filter	Tritium	< 1.0 MBq

5.4.6 Data supplied by Calder Hall

Calder Hall and Chapelcross power stations were both built in the mid 1950's to the same reactor design criteria. Calder Hall Reactor 1 was shut down on the 20th March 2003, Reactor 2 on the 14th October 2001, Reactor 3 on the 13th September 2001 and Reactor 4 on 28th October 2001. Subsequently, the reactors have been in a dormant condition awaiting the commencement of defuelling activities. Data form Calder Hall therefore forms a useful reference in support of gaseous discharges from the Chapelcross Reactors.

Table 24 – Calder Hall Annual Aerial Discharges - 5 Year Summary

	2002	2003	2004	1 Jan 05- 31 Mar 05	1 Apr 05- 31 Mar 06	1 Apr06- 31 Mar 07
Tritium	1.5 TBq	0.6 TBq	61 GBq	8.2 GBq	87 GBq	91 GBq
Carbon-14	53 GBq	34 GBq	0.5 GBq	68.5 MBq	0.6 GBq	0.37 GBq
Total Beta particulate	6.5 MBq	2 MBq	0.3 MBq	0.03 MBq	0.3 MBq	0.34 MBq

Table 25 – Calder Hall Aerial Discharge by Year 1997 - 2001

Nuclide	Aerial Discharge by Year with % of current authorised limit shown in parenthesis				
	1997	1998	1999	2000	2001
H3	4.42 TBq (40.18%)	4.02 TBq (36.55%)	3.79 TBq (34.45%)	4.26 TBq (38.73%)	3.22 TBq (29.32%)
C-14	0.32 TBq (67.87%)	0.33 TBq (71.06%)	0.34 TBq (73.62%)	0.34 TBq (71.91%)	0.29 TBq (62.32%)
S-35	88.3 GBq (42.05%)	0.15 TBq (73.33%)	99.5 GBq (47.38%)	0.12 TBq (55.71%)	0.12 TBq (55.00%)
Ar-41	2.53 PBq (68.38%)	2.52 PBq (68.11%)	2.58 PBq (69.73%)	2.55 PBq (68.92%)	1.94 PBq (52.46%)
Co-60	61.4 MBq (6.67%)	51.9 MBq (5.64%)	37.4 MBq (4.07%)	32.9 MBq (3.58%)	25.8 MBq (2.8%)
Total Beta	0.11 GBq (0.55%)	94.7 MBq (0.47%)	71.1 MBq (0.36%)	80.5 MBq (0.40%)	50.7 MBq (0.25%)

5.5 Future Needs and Proposed Limits to 2014

It is appropriate that the authorisations for gaseous discharges from Magnox reactors continue to place limits on individual activation products. In the past, limits have been placed on those radionuclides which are of the greatest radiological significance, which are likely to be discharged in the greatest quantities or which are indicators of plant performance. It is proposed that this continues to be the case during the post generation period.

5.5.1 Argon-41

No further discharge of Ar-41 is anticipated now that power generation has ceased. The Company therefore suggests that no annual argon 41 discharge limit will be required for the final reactor defuelling, programmed to start during 2008.

5.5.2 Carbon-14

There is no more production of carbon-14 in the Chapelcross reactors now that they have ceased power generation and, since the reactors are now relatively cool, the release of C-14 from the graphite moderator into the coolant due to graphite oxidation is greatly reduced. However, some C-14 will continue to diffuse out of the graphite pores.

In the first full calendar year after closure, the annual discharges from Bradwell and from Hinkley Point A, both Magnox Stations, were each about 2% of the general level experienced during operation of those stations. At Hinkley Point A the annual discharge was reduced to about 0.2% after 3 years. Data presented for Calder Hall in Section 5.4.6 indicates that following closure of the final reactor in 2003, the 2004 discharge figures had fallen by 99% and continued to fall in the subsequent years.

Therefore, should the arisings of C-14 at Chapelcross reflect the experience at the other sites, it would be expected that the annual discharge might be reduced to about 4 GBq during the first full calendar year after closure, reducing to less than 1 GBq within 3 years. Measurements in 2005, the first full year after reactor closure, indicated that the C-14 discharges were less than 1 GBq. However, once defuelling starts it is possible C-14 discharges could increase from these low levels due to the mechanical disturbances associated with defuelling however, it is not anticipated that discharges will reach the levels experienced during reactor operations.

Table 21 indicates that the average discharge from the reactors during the period 1996 to 2002 was 343 GBq from all four reactors. Assuming that two reactors are defuelled simultaneously, it is proposed that any annual limit should be based on an annual discharge requirement of 100 GBq of C-14, similar to other closed Magnox Sites. It should be noted that defuelling activities are planned to commence during 2008 and should continue for approximately three years.

5.5.3 Sulphur-35

Radioactive decay will result in continuing natural reduction in the levels of S-35 in the reactors. Indeed, significant decay will already have occurred, particularly in the reactors that were not at power in the period leading up to the declared site closure date of June 2004 and the intended post closure modifications to the fuel routes will extend the period of decay before defuelling begins.

This is supported by experience from other Magnox Sites. At Hinkley Point A annual discharges reduced from about 60 GBq during operation to 1.1 GBq in the year 2000, effectively the first year after the cessation of generation, and 0.49 GBq the following year. At Bradwell annual discharges reduced from the order of 50 GBq during operation to less than 0.1 GBq in the first full calendar year after closure. On the basis of the discharge data from the other sites, it is expected that the total annual discharge of S-35 from Chapelcross during the year 2005 will be less than 1% of the typical annual discharge when the Site was operating. This has been confirmed based on 2005 discharges. The discharges would then be expected to reduce progressively each year.

Reactor core sulphur 35 concentrations will have reduced by at least 20 half lifes (87 day ½ life) before the new Authorised limits takes effect in 2009. By this time sulphur 35 discharges should be effectively zero. On this basis it is suggested that a sulphur 35 discharge limit is not considered appropriate, for post reactor closure operations Magnox North Ltd. therefore suggests that there is no benefit in regulatory limitation of this radionuclide following March 2007.

5.5.4 Tritium

Reactor tritium discharge during the defuelling period will remain relatively small compared with the CXPP tritium discharges. Experience to date for other closed magnox stations suggests that the tritium discharges during defuelling activities can fall to ~40% of the operating level in the first year, post closure, and ~15% in the second year. If the tritium discharges are assumed to be ~15% of the operating level in the early years of defuelling, a typical annual tritium discharge for 4 reactors could be up to ~0.5 TBq. Currently Chapelcross annual reactor tritium discharges are around 0.01 TBq but very little in core work is taking place at present. Discharges are likely to rise during final defuelling but will still be insignificant in comparison to CXPP tritium discharges.

Based on the current proposed work programme in the period 2006-2008/09, the stainless steel ILW will continue to be recovered from the storage matrix and transferred to Sellafield Miscellaneous Beta/Gamma Waste Store (MBGWS). In addition the uranium furnaces, including the PU pots, may be decontaminated and conditioned for the proposed on site ILW store, in the period 2009/11, followed by the pellet waste recovery either for ILW site storage or transfer to Sellafield MBGWS. During this period the potential aerial annual discharges, based on the estimated tritium inventories, could be up to ~ 400 TBq, inclusive of the typical plant outgassing of ~100TBq. This pessimistically assumes that the full pellet waste tritium inventory is displaced during its conditioning.

Decommissioning of the process line may begin as early as 2009 and continue to 2015, during the plant POCO period. Other work which may also take place during this period is conditioning of the tritiated pump oil, the remaining product containers and accumulated in cave tritium contaminated soft waste. Annual potential tritium discharges during this period, based on the tritium inventory could be up to ~ 900 TBq, inclusive of general plant off gassing.

The above estimated potential aerial tritium discharges take no account of any abatement measures which may be used to limit aerial discharges during plant POCO and early decommissioning. For instance the present strategy for decommissioning the process line is simply to flange and plug the pipework and not attempt to decontaminate the pipework internal surfaces. Apart from initial relatively short increase in aerial discharges from outgassing, each time the pipework is cut, discharges should be maintained at relatively low levels compared with when the plant was operating. If for example, around 25% of the estimated process line tritium inventory was discharged during decommissioning, then the highest annual discharge during this period could be ~500 TBq.

With the uncertainties in the estimated plant component inventories and the timing of plant decommissioning operations a headroom of 50% is suggested in determining the required annual discharge limit. On this basis a future annual discharge limit of 750 TBq (HTO) is recommended for the plant POCO and decommissioning period. This represents 15% of the present annual discharge limit.

5.5.5 Beta particulate

It is currently intended that the majority of damaged graphite will not be removed from the core during final defuelling which should significantly reduce beta particulate discharges during that period. However, no benefit has been made of this in substantiating the annual requirement. At present the effect of such damage on discharges has not been quantified but it would not be unreasonable to assume that discharges might double.

In the absence of any accurate beta particulate discharge information for Chapelcross reactors the Calder Hall annual discharge data, shown in Section 5.4.6 has been used for the basis of the proposed annual discharge limit. For the Calder Hall reactor operating period 1997 to 2001 the annual range of beta particulate discharges was 50.7 to 110 MBq, with a mean of 81.4 MBq and the predominant radionuclide present, based on gamma spectrometry, being Cobalt 60.

Assuming Chapelcross beta particulate discharges are similar to Calder's, for reactor operations, the annual total beta discharge could have been around 80 MBq.

Analysis of Calder Hall's beta particulate discharges indicate that, during defuelling, they could be about a factor of 4 times higher, than the operating total beta discharge of ~20 MBq/reactor. If it is assumed that defuelling takes place on 2 reactors simultaneously, the estimated annual beta particulate discharge could be about 160-170 MBq. With a 50% headroom to accommodate the uncertainty in the estimated beta particulate discharge, an annual limit of 250 MBq is recommended. This will accommodate any beta particulate discharges from minor outlets outlined in Section 5.1.

Gamma spectroscopy analysis of the Reactor stack sampling filter papers indicates that the predominant radionuclide present is cobalt 60. Other radionuclides which may be present, based on recent graphite analysis, include manganese 54, nickel 63 and zinc 65, totalling less than 20% of the beta gamma activity present.

5.5.6 Summary of Proposed Limits

As a result of the predicted discharge profile for gaseous discharges from Chapelcross, Magnox North Ltd. proposes the following annual limits to be applied to future operations (Table 26).

Table 26 - Proposed gaseous discharge limits

Radionuclide	Proposed limit	Radionuclide composition	Radionuclide Used in Assessment*
Carbon -14	100 GBq	Carbon-14	Carbon-14
Tritium	750TBq	Tritium	Tritium
Beta Particulate	250 MBq	Mn-54, Fe-55, Co-60, Zn-65, Sr-90 and Cs-137	Co-60

*Co-60 was chosen as it is the predominant component of beta activity in particulate material – see **Table 19**.

5.6 Alternative Options for Managing Radioactive Gaseous Waste (BPEO/BPM)

5.6.1 Tritium

With the exception of tritium discharges arising from decommissioning the CXPP, it has been argued that current measures will continue to represent BPM for limiting aerial discharges from the site. Detailed plans for decommissioning the CXPP are currently being developed. Appropriate means of limiting tritium discharges will be incorporated into those plans. Nevertheless, even using BPM, there will be some aerial discharge.

Per unit discharge, the dose resulting from aerial emissions of tritium from Chapelcross is greater than that from discharges to the marine environment. Consequently, during CXPP decommissioning activities, measures to reduce aerial discharges of tritium at the expense of increased aquatic discharges would be beneficial in reducing the doses to individuals exposed to these discharges.

5.6.2 Carbon-14

Virtually all carbon-14 released from the moderator remains gas-borne. Consequently, measures to reduce the coolant losses would have no effect on the quantity of C-14 discharged, but would only effect the timing. It is argued in Reference 9 that there are no practical means of removing C-14 from aerial discharges at operating Magnox Sites because the C-14 is chemically indistinguishable from non-radioactive carbon and the reactor coolant is carbon dioxide. In principle, this would be less impracticable at a shutdown Site when the reactors are air-filled. However it would require the chemical treatment of the aerial discharges to remove carbon dioxide and other carbon compounds which could contain C-14.

The application of BPM does not require measures to be taken to reduce discharges if time, money or trouble involved is disproportionate to any potential benefit. It is argued that within a few years of closure, the annual aerial discharge of C-14 from Chapelcross will be below 1% of the level experienced during operation.

Critical group dose and collective dose to the World truncated to 500 years are low and, based on the principles of BPM, the provision of equipment intended to remove carbon compounds from aerial discharges would be disproportionate to the likely benefits.

5.6.3 Beta particulate

At Chapelcross three of the four reactors have sleeved channels which can be damaged during defuelling. The majority of the beta particulate discharged when the reactors were operating came from the removal of damaged graphite during defuelling. It is currently intended that the majority of damaged graphite will not be removed from the core during final defuelling. This should significantly reduce beta particulate discharges during that period and will be a significant factor in ensuring that particulate discharges from the reactors are ALARP during the period of defuelling. However the magnitude of the reduction is uncertain.

In principle, aerial discharges of particulate in the Shield Cooling Air could be reduced by the installation of particle filters in each of the eight shield cooling air stack discharge routes (2 per reactor). In Section 4.4.5 it is estimated that an annual limit of 250 MBq on the aerial discharge of beta emitting radionuclides associated with particulate would provide sufficient headroom given the estimated total discharge from the site.

As detailed below, critical group doses for the proposed discharge limits are well within the site constraint. Based on the principles of BPM, the installation of particulate filters in each of the eight shield cooling air stack discharge routes would be disproportionate to the likely benefits and would delay the defuelling capability to such an extent that the site would not be able to meet the operational window necessary to enable the reprocessing plant at Sellafield to cease operation in the required timescale. It is concluded that this engineering modification would not be justified.

Arisings of airborne particulate in the pond area are minimized by maintaining wet surfaces and by the hosing down of any equipment removed from the ponds. During pond emptying all surfaces are washed down. Measures to limit the levels of activity in the pond water, such as the appropriate use of the ion exchange skips, reduce the potential for the aerial release of such material.

5.7 Radiological Impacts

Authorised discharges of radioactivity can result in an increase in public radiation exposure as a result of external exposure and internal exposure due to inhalation and the consumption of foodstuffs within which radionuclides have been incorporated. Modelling can be used to assess the impact of discharges through the estimation of critical group doses and collective doses.

Radioactive doses to the most exposed group of individuals in the vicinity of Chapelcross discharges of gaseous waste at the proposed limits have been assessed using the PC-CREAM modelling code and accepted assessment methods. Site-specific habits data were utilised where available.

For the purposes of this assessment, the candidate critical group has been conservatively assumed to be a family (adults, children and infants) that lives in the nearest habitation to the site. It is assumed that members of this family spend most of their time at home, some of which is spent outside. They get their green vegetables, root vegetables and fruit from their garden or other local source (within 1 km from the site) and milk and meat from local farms close to the site and small amounts of local fish and shellfish caught from the Solway. Local habit survey results were used to determine the occupancy and food intakes of the members of this group. The basis for the dose calculations is described in Appendix 1.

5.7.1 Prospective Critical Group dose

At the limits proposed, the dose from atmospheric discharges is 49 μSv/y (Table 27) to local residents consuming locally produced beef cattle and sheep meat. This is below the Source Constraint of 0.3 mSv/y and 5% of the Basic Safety Limit recommended by the NII. Of the three age classes considered (adult, 10 year child and 1 year old infant) the highest doses were received by the infant and arose predominantly from tritium. The inhalation, including absorption through the skin accounted for the majority of the dose predicted from the aerial discharges.

Table 27 - Annual Critical Group dose for gaseous discharges at the proposed limits

Candidate Critical Group	Age Group	Dose (μSv/y)
Local resident (high rate terrestrial food consumer)	Adult	41
	Child	43
	Infant	49

5.7.2 Collective dose

Table 28 gives the calculated collective doses (truncated to 500 years) from one year's aerial discharge at the proposed discharge limits given in Table 26.

Table 28 - Collective dose from one year's aerial discharges at the proposed limits

Radionuclide	Collective Dose (man.Sv)		
	UK	Europe	World
Tritium	0.75	1.65	1.95
Carbon-14	0.028	0.24	1.8
Beta particulate	0.0011	0.0018	0.0018
Total	0.78	1.89	3.75

The collective doses have been calculated for the UK, for Europe and for the World. The basis for the dose calculations is described in Appendix 6.

6. TRANSFER OF WASTE FOR INCINERATION

This section provides information in support of the application of Magnox North Ltd. for an authorisation to dispose of low level radioactive waste from Chapelcross Site by transfer to the premises of Onyx Environmental Services plc for incineration at their Fawley plant at Hythe in Hampshire.

6.1 Description of Waste

There are several categories of low level radioactive waste (LLW) for which incineration at a specialist off-site incinerator is either the only practicable disposal option or is preferable to disposal by the routes addressed elsewhere. These are considered below:

6.1.1 Oil and other organic liquids

There are three types of contaminated waste oil and two other organic liquids requiring disposal:

- Used gas circulator lubricating oil arising from routine oil changes;
- Other waste oil from active plant, principally from motor and pump maintenance, that is collected in active waste oil tanks;
- Oil from oil/water separation;
- Solvents; and,
- Scintillants (used in the measurement of radioactivity).

6.1.2 Combustible solid waste

Some combustible solid waste is also produced at Chapelcross that is not readily accepted at the National Low Level Waste Repository. This includes oily pads and other oily contaminated material and activated charcoal. Some paint tins and grease containers may also be sent for incineration. In addition there may be the requirement to send contaminated putrescible waste for incineration.

6.2 Sources and Production

6.2.1 Oil and other organic liquids

The principal historic source of liquid combustible waste at Chapelcross was waste lubrication oil from the reactor blowers and from motors and pumps in areas of the plant where the oil could potentially be contaminated with radioactivity. For example, it would be expected that radioactivity in the reactor gas could contaminate the oil in the gas blowers. Forced coolant circulation continues to be required for some time after Magnox reactors have finally ceased operation. However, now that the decay heat from the spent fuel remaining within the four reactors has reduced sufficiently, forced circulation is no longer required and the gas circulators have been switched off. Oil from the gas circulators can now be removed for disposal. As other motors and pumps cease to be required, the oil from these will also be removed and disposed of in compliance with extant authorisations and third party conditions for acceptance..

In addition to contaminated oil, there are two other sources of liquid combustible waste: liquid scintillant and organic solvents.

The Site undertakes reassurance monitoring for staff working in the CXPP to demonstrate that containment measures remain effective and that committed doses to plant operators remain ALARP. This monitoring is undertaken by liquid scintillation analysis of urine samples provided by the appropriate members of staff. Liquid scintillation analysis is also undertaken on plant and environmental samples for the determination of tritium and other low beta energy radionuclides. The technique involves the addition of a liquid scintillant to prepared samples and hence results in small quantities of such waste that requires disposal. The majority of the activity in the liquid scintillant waste is attributed to tritium, with only small quantities of C-14 and S-35.

In addition to organic liquid scintillant, some maintenance, inspection and repair activities require the use of small quantities of organic solvents, which will become contaminated during their use.

During decommissioning these are expected to be the main sources of contaminated oil and organic liquids.

6.2.2 Combustible solid waste

Activated charcoal was used in reactor re-circulation filters and in void air filters so that, in the event of a reactor fault, the charcoal beds could be used to remove radioactive iodine from the reactor gas or from the void air to prevent its release to the environment. As the iodine removal efficiency of charcoal reduces as the charcoal ‘ages’, it was necessary to periodically replace the charcoal in these filters with fresh charcoal. Charcoal removed from the filters is stored in 205 litre drums in secure on-site storage.

In addition to activated charcoal waste oil pads have also been generated that require disposal by incineration. These are pads that have become soaked and impregnated with oil.

6.3 Management of Waste

6.3.1 Oil

All active waste oil generated is transferred to double lined plastic holding tanks in a designated area on the site, at Hanger 55 base slab. Chapelcross does not currently have a transfer authorisation for contaminated oil. All arisings to date are therefore stored on site awaiting disposal. A letter of agreement is in place with Onyx Environmental Services (formerly Veolia Environmental Services Ltd.) an authorised disposal facility to receive this waste for incineration in compliance with their extant authorisation for the receipt and incineration of radioactive waste and a copy of this letter is attached as Appendix 8.

6.3.2 Other organic liquids

The site currently has an authorisation to dispose of liquid scintillant waste by transfer to Onyx Environmental Services, an industrial waste contractor. Annual disposal volumes have generally been less than 200 litres, although two disposals can occur within a twelve month period. The activities in the samples and their volumes result from optimised programmes of work agreed with SEPA.

6.3.3 Combustible solid waste

Currently Chapelcross does not have a transfer authorisation for combustible solid waste. Active waste oil pads are collected in drums and are stored on site awaiting disposal. Similarly, slightly contaminated activated charcoal is stored in drums contained in ISO containers on site awaiting disposal.

6.4 Historic Arisings

6.4.1 Oil

Chapelcross currently has an inventory of approximately 4 m^3 of slightly contaminated waste oil which is currently stored on site. A further 100 m^3 will be removed from the reactor gas circulators during reactor POCO. Recent radionuclide analysis of oil wastes indicates they contain small amounts of tritium, carbon-14 with lower concentrations of other beta activity.

At present there is no authorisation for the disposal of contaminated oil from Chapelcross. At other sites, representative samples are taken from each storage container and a radiochemical analysis is carried out by a specialist laboratory in order to determine the radionuclide concentrations in the samples. Where appropriate, for radionuclides which are below the limit of detection, theoretical estimates are provided based on knowledge of the potential origins of those radionuclides and the measured concentrations of other radionuclides expected to be associated with them. From these assessments, the quantities present in each waste consignment from the site are determined. The same procedure would be used at Chapelcross. However, a programme of radiochemical analysis of waste oil was carried out in 2001, which provides indicative values for the activity concentrations associated with the current inventory of waste oil stored on site. Overall the total level of activity in the oil was found to be very low. The maximum total activity from all radionuclides was less than 8 Bq ml^{-1}. **Table 29** gives the bounding concentrations of each radionuclide in the waste oil[7] (Reference 12).

Table 29 - Maximum radionuclide composition of waste oil at Chapelcross

Nuclide	Maximum Concentration (MBq/m^3)
Tritium	6.3
Carbon-14	<0.17
Sulphur-35	<0.09
Gross alpha activity	0.006
Gross beta activity[(1)]	0.611
Manganese-54	<0.02
Iron-55	<0.3
Cobalt-60	<0.03
Niobium-95	<0.02
Zinc-65	<0.3
Caesium-137	<0.03
Europium-154	<0.07
Europium-155	<0.2

(1) "Gross beta activity" does not include radionuclides which emit low energy beta particles, such as tritium, C-14 and S-35. The figure given for iron-55 is indicative, based on data from other Magnox sites.

Table 30 gives the estimated radionuclide inventory of the waste oil awaiting disposal based on maximum activity concentrations (**Table 29**) assuming that any radionuclide concentration less than the detection level is taken to be positive. A detailed characterisation of the waste oil is being undertaken to confirm the radioactive and non radioactive parameters.

[7] The highest quoted detection limit is shown for those radionuclides which were not detected in any of the samples.

Table 30 - Total estimated radionuclide inventory in waste oil at Chapelcross

Nuclide	Quantity (MBq)
Tritium	1100
Carbon-14	48.6
Sulphur-35	27
Gross alpha activity	1.4
Gross beta activity	51
Manganese-54	3.6
Iron-55	90
Cobalt-60	6.0
Zinc-65	25
Niobium-95	3.6
Caesium-137	4.2
Europium-154	11
Europium-155	19

6.4.2 Other organic liquids

Chapelcross was granted authorisation to transfer contaminated liquid scintillant to Onyx Environmental Services in 1990. The current transfer limits are detailed in **Table 31**. .

The majority of the activity in liquid scintillant waste is attributed to tritium, with only small quantities of carbon-14 and sulphur-35. Recent disposals of tritium have been less than 10 MBq. However, the greater quantities have corresponded with larger volumes being disposed of following years when no disposals had been undertaken. Generally, the records indicate that the annual arisings of tritium are less than 5 MBq, in a volume approaching 200 litres.

The disposals of the carbon/sulphur category again reflect the volumes being sent to Onyx Environmental Services, with the maximum being when larger shipments are undertaken following years when none were undertaken. Typically, the records indicate an annual arising of 0.25 MBq.

Table 31 - Current transfer limits for liquid scintillant

Radionuclide	Activity (MBq)
Tritium	10
Carbon-14 & Sulphur-35	0.8
Volume (m3)	None

6.4.3 Combustible solid waste

Chapelcross has an inventory of around 18,000 kg (32 m^3) of slightly contaminated activated charcoal that is currently stored in drums on site awaiting disposal. A further estimated 12,000 kg (22 m^3) of charcoal will be removed from the reactor recirculation and void filters during reactor POCO.

Based on recent analysis of activated charcoal samples, the only radionuclides present are tritium, cobalt-60 and caesium-137. The estimated total activities are 1.8 GBq H-3 (based on a mean activity of 60 $kBq.kg^{-1}$), 3.5 MBq Co-60 (based on a mean activity of 136 Bq kg^{-1}) and 0.25MBq Cs-137 (based on a mean activity of 9.52Bq kg^{-1}).

The site also has a current inventory of around 100 m^3 of oil pads, which are stored in secured containers awaiting disposal. A detailed characterisation of the oil pads is being undertaken to confirm the radioactive and non radioactive parameters.

6.5 Consideration of BPEO and BPM

6.5.1 Liquid combustible waste

As with other materials, the Site procedures include measures to minimise the quantities of oil and other liquids which could potentially become contaminated. Now that the reactors have ceased operation, and once the reactor gas circulator oil has been removed, there should be very little additional arisings of contaminated oil on the site, although small arisings of liquid scintillant will continue while the site remains manned and analysis of environmental monitoring samples is undertaken.

The Site procedures ensure that the arisings of liquid combustible waste requiring disposal as radioactive waste are minimised by keeping waste which should not be contaminated separate from potentially contaminated waste, so that, after appropriate confirmatory checks have been made, the non-contaminated waste can be dealt with as normal non-radioactive material.

In principle, there are a number of possible means of dealing with contaminated liquid combustible waste.

- The waste can be incinerated. As Chapelcross does not have an incinerator, this requires the liquid combustible waste to be transferred to another location for incineration, as is currently already the case for liquid scintillant waste.
- The waste could be treated chemically to remove the radioactivity in solid form, allowing the oil to be sold for re-use and remaining radioactive solid radioactive waste to be sent for disposal at Drigg.
- The liquid waste could be treated to fix the liquid in a solid matrix, and the resulting waste could be encapsulated for disposal at Drigg as solid LLW.

Waste cannot be sent to Drigg for disposal in liquid form and obviously this liquid waste cannot be discharged to the marine environment.

A number of studies, within the Company, have been carried out to determine the best option for dealing with this type of waste. Decontaminating the waste oil to allow it to be re-used is an initially attractive option, since it should lead to an overall reduction in the quantity of radioactive waste requiring disposal and would allow otherwise waste material to be reused. However, most of the radioactivity in the oil is tritium and it would be expected that most of the tritium would be lost during processing and discharged to the atmosphere. Although it appears to be technically feasible to “fix” the liquid waste so that it can be encapsulated and sent to Drigg as solid LLW or for incineration, it is clear that this would result in a very large increase in the total volume of the waste, since a relatively small amount of oil could be included in the encapsulated material. There are, furthermore, uncertainties about the long-term retention of oil in the encapsulated solid matrix.

Previous studies have concluded that incineration of this waste is the best environmental option. At other Magnox Sites, liquid combustible waste is either:

- incinerated on site[8];
- sent for incineration at a neighbouring power Site[9]; or,
- sent for incineration at an appropriate industrial waste incineration facility[10].

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[8] Bradwell, Dungeness A, Oldbury, Sizewell A and Wylfa have authorisations to incinerate liquid organic waste on site.
[9] Hinkley Point A and Sizewell A have authorisations to send liquid organic waste to the neighbouring B Station for incineration.
[10] Berkeley, Trawsfynydd and Wylfa have authorisations to send liquid organic waste to the specified contractor for incineration.

In each case, other disposal options were considered and incineration was considered to be the best option. Recently, a study has been carried out to investigate whether the current means of disposal of all radioactive waste from Magnox Sites in England and Wales continues to be the best environmental option . This study included the options for disposal of combustible liquid waste and concluded that incineration was the best option. As liquid combustible waste contains only small quantities of radioactivity, the quantities of radioactivity discharged to the atmosphere during incineration would be small. It is not practicable to extract the oil which is soaked in to the oil pads. Incineration is the best disposal option for these pads. The Company intends to transfer the combustible liquid waste (and the oil pads) to an authorised receiver for incineration. Several other Magnox Sites have been granted authorisations to transfer waste of this type to Onyx Environmental Services Limited at Hythe for incineration and this would be the preferred option for Chapelcross..

6.5.2 Activated charcoal

The charcoal contains very low levels of activity. The only options are disposal as solid LLW at Drigg or incineration. A recent report on whether the current means of disposal of all radioactive waste from Magnox Sites in England and Wales continue to be the best environmental option (Ref. 8) concluded that incineration of combustible solid LLW was the best option because it provided waste volume reduction and waste form stabilisation. It is proposed that the charcoal should be sent for incineration at an appropriate facility.

6.6 Future Management Strategy

If the application to dispose of combustible waste to Onyx Environmental Services is granted, the future management strategy would be:

- transfer of waste oil (including oily pads) to Onyx Environmental Services for incineration;
- transfer of other organic liquid wastes (liquid scintillant) to Onyx Environmental Services for incineration;
- transfer activated charcoal to Onyx Environmental Services for incineration.

6.7 Future Needs and Proposed Limits to 2014

6.7.1 Liquid incinerable wastes

It is a site licence condition (SLC32) “Accumulation of Radioactive Waste” that adequate arrangements should be made to minimise the generation and accumulation of radioactive waste at the site. Consequently, it is suggested that an authorisation for disposal of radioactive liquid combustible waste should not contain conditions or limits which would unnecessarily delay the transfer of waste oil from the site for incineration.

On the basis of the estimated quantities of organic liquid waste currently on site, it is suggested that an appropriate annual limit on the volume of organic liquid waste sent for incineration would be 200 m3 with annual radionuclide limits of 3 GBq for tritium, 10 MBq for alpha emitting radionuclides and 3 GBq for all other radionuclides. This is summarised in

Table 32. The proposed limits take into account the current authorised transfer limits for liquid scintillant. Although there may be additional arisings of waste oil during the preparations for Care and Maintenance, they are not expected to represent more than a small fractional increase in the total.

Table 32 - Proposed annual transfers of combustible liquid waste from Chapelcross

Radionuclide or Group of Radionuclides	Annual Requirement [1] (GBq)	Annual Volume Requirement (m^3)
Tritium	3	200
Total alpha	0.01	
Other radionuclides	3	

(1) The scintillant requirements are included within these proposed limits

6.7.2 Activated charcoal

As for combustible liquid waste, it is suggested that an authorisation for disposal of activated charcoal granules should not contain conditions or limits which would unnecessarily delay the transfer of the waste from the site for incineration.

It is suggested that an appropriate annual limit on the quantity of charcoal granules sent for incineration would be 40 tonnes (representing approximately 110 m^3), with an annual limit of 3 GBq for tritium and 50 MBq on the total quantity of other radionuclides in the waste. This is summarised in **Table 33**. Both of these suggested activity limits are well within the consignment limits within the authorisation to receive radioactive waste issued to Onyx (formerly Veolia) Environmental Services Ltd as shown in Appendix 8.

Table 33 - Proposed annual transfers of activated charcoal granules from Chapelcross

Radionuclide or Group of Radionuclides	Annual Requirement	Annual Mass Requirement, (tonnes)
Tritium	3 GBq	40
All radionuclides	50 MBq	

6.8 Radiological Impacts

It is understood by Magnox North Ltd. that waste transferred under the proposed authorisation would be incinerated under the existing authorisation of Onyx Environmental Services (Appendix 8), granted by the Environment Agency, and that the transfer of this waste would not require disposal limits to be changed. Appendix 8 identifies that Onyx (Formerly Veolia) Environmental Services facility utilises a rotary kiln with afterburner, wet quenching system and a wet packed absorber for gas cleaning and wet electrostatic precipitators. Ash is collected and removed from the kiln by a deslagger. After satisfactory analysis the slag is sent to landfill. Magnox North Ltd. believes that with these arrangements in place the processing of incinerable wastes from the Chapelcross site Onyx Environmental Services would therefore present a negligible hazard to the public.

Radioactive waste can give rise to a small radiation dose to members of the public whilst in transit. Issues associated with the transport of radioactive wastes are addressed under the Transport Regulations.

7. DISPOSAL OF LOW LEVEL WASTE TO THE NATIONAL LOW LEVEL WASTE REPOSITORY.

Magnox North Ltd. is applying for an authorisation to transfer solid low level wastes (LLW) to the national Low Level Waste Repository (LLWR) near Drigg. In addition, an authorisation is being sought to transfer some LLW to UKAEA Winfrith for conditioning prior to disposal at the LLWR near Drigg (see Chapter 6).

7.1 Description of Waste

Chapelcross generates solid radioactive wastes as part of its normal operations and, whilst the site takes all reasonable steps to minimise the amount of waste produced, the arisings, which are primarily LLW, need to be dealt with. LLW contains radioactive materials other than those suitable for disposal with ordinary refuse, but not exceeding 4 GBq/tonne of alpha or 12 GBq/tonne of beta /gamma activity. Solid waste arisings are segregated at source into non-radioactive and that which is potentially radioactive (LLW). However, all waste arising from work within the inner security area and contamination controlled areas is deemed potentially radioactive unless confirmed otherwise. There are two types of solid LLW requiring disposal at Chapelcross:

- Compactable routine LLW arisings; and,
- Uncompactable routine LLW arisings;

7.1.1 Compactable wastes

Waste is deemed to be compactable if it can be readily size reduced under high force compaction. Typical examples of compactable wastes include:

- Polythene, either as wrappings or temporary tenting, which cannot be removed outside Contamination Controlled Areas;
- Rubber, which is largely in the form of rubber gloves or Wellington boots used as personal protective equipment (PPE) in Contamination Controlled Areas, which get damaged over time;
- PVC suits (PPE) used in Contamination Controlled Areas;
- Paper and cardboard;
- Cloth in the form of old coveralls and overshoes (PPE) that are no longer fit for purpose; and,
- High Efficiency Particulate Air (HEPA) filters from the contaminated heating and ventilation system where the filters trap airborne particulates.

7.1.2 Uncompactable wastes

Waste is deemed to be uncompactable if it cannot be readily reduced in size under high force compaction or wastes that can become airborne and either cause a danger to the health of the operator of the plant (e.g. soft asbestos) or cause a radiological release to the atmosphere (e.g. tritium contaminated material). Typical examples of uncompactable wastes include:

- Large metal items, normally in the form of redundant plant items such as pumps and valves that are taken out of service, but can also include metal scaffolding that is no longer fit for purpose and large sheets of metal;
- Bricks and rubble from any areas where the plant has been altered or removed;
- Large metal filters; and,
- Large pieces of wood.

7.2 Sources and Production

7.2.1 Compactable and uncompactable wastes

Normal operation and maintenance of the plant and equipment associated with reactor coolant circuits, refuelling equipment, fuel storage ponds, uranium drum stores, various handling and storage areas and the CXPP has generated compactable and uncompactable LLW.

During operation, structural and fuel element components within the reactors were activated by neutron irradiation which resulted from the fission of uranium oxide fuel during electricity generation. These activated radioactive materials became associated with metallic and graphite dusts. During refuelling operations and during periods of entry to the pressure vessels for maintenance work or statutory inspections, some of these dusts were removed and were therefore available to contaminate other materials or items. When no longer useful these materials, items and equipment become LLW.

The radionuclide composition within any waste arising is characteristic of the type and location of work being undertaken. Since waste is characterised by its radionuclide 'fingerprint', which is specific to particular waste streams, it can be segregated according to its origin. Fingerprints are periodically reassessed (Reference 13) to ensure the best estimate of radioactivity is made in each case. The current identified waste streams are detailed below and summarised in Table 35..

- The CXPP plant areas where tritium was extracted from the lithium pellets and purified; Nirex Identifier 2C10 (tritiated waste).
- The Reactor plant areas including the charge face, refuelling/defuelling equipment and heat exchangers and CXPP plant areas where the isotope cartridges were broken down and the pellet containers removed for processing; Nirex Identifier 2C11 (Reactor CXPP non tritiated).
- The Ponds plant areas including in pond operations, equipment maintenance areas, decontamination area and the Irradiated Fuel Flask handling Plant; Nirex Identifier 2C12 (Pond).
- The Reactor plant areas from which large irregular uncompactable items originate; 2C13 (Reactor Irregular).
- The Pond plant areas from which large irregular uncompactable items originate; 2C14 (Pond Irregular).
- Uranium Store work areas; Nirex Identifier 2C16 (Uranium Store).

Although all reactors at Chapelcross have ceased power generation, the processes leading to solid waste arisings have not changed significantly. Waste will still arise during defuelling in much the same way as during refuelling. Subsequently, when all the fuel has left the site, moves will be made to prepare the site for its subsequent period of care and maintenance prior to ultimate decommissioning. The Company has examined the post generation work programme to identify the impact of the various projects on waste creation. The work to be undertaken post generation to prepare the site for care and maintenance may well lead to increased quantities of LLW that will require removal from the site.

For example, the site will need to dispose of the exhausted ion exchange units currently held in the ponds and the pond related sludge. Also, the stainless steel cans held in the CXPP will need to be dealt with as will any miscellaneous in-core reactor components either currently held on site or removed during the defuelling of the reactors.

7.3 Management of Waste

7.3.1 Low Level Waste

The disposal of all LLW from the Chapelcross site is managed from a dedicated compound located on the North Site where all processing and temporary storage of solid LLW is undertaken. As well as providing temporary storage for waste materials, the LLW facility makes provisions for:

- loading of drums into ISO-containers for high force compaction prior to disposal;
- processing for the removal of contaminated sections of waste items;
- processes for the decontamination of large waste items; and,
- loading of drums and miscellaneous waste items into ISO-containers.

It is planned that a new LLW handling facility will be constructed at the north end of site by 2008. This facility will process all of the LLW arisings from decommissioning activities, which will be significantly higher in volume from those during normal site operations.

All wastes are minimised as far as possible by segregation and monitoring of waste at source to ensure no unnecessary items are taken to the LLW compound for processing as waste. Low level waste is batch processed and is therefore stored on site after processing prior to dispatch to the LLWR. All items of LLW are tagged, listed on drum inventories and placed in LLW drums or bins prior to transfer to the LLW compound.

The only disposal option for solid LLW from Chapelcross is to send the waste to the LLWR near Drigg and this is therefore Magnox North Ltd. Company strategy. Disposal of LLW to the LLWR are managed by Magnox on behalf of all sites across the fleet, based on activity and volume requirements specified by individual sites and the LLWR With the establishment of separate companies to manage the LLWR and Sellafield Sites it will be necessary in the future to establish separate contracts between Magnox and the LLWR Operating Company and this will be managed as a central function with inputs from the individual sites.

The operator of the LLWR facility, imposes Conditions of Acceptance with which Chapelcross has to comply before waste can be despatched from site.

Compactable waste

All waste generators are responsible for segregating waste at source. Compactable waste is bagged, tagged and placed into wheelie bins. All waste items are listed on the waste inventory. Currently, bins for the collection of compactable LLW are stored in dedicated areas within the buildings in which wastes are generated. Once full, either physically or because it has reached an external radiation limit of 2 mSv h^{-1} beta gamma, the bin is closed and locked prior to transfer to the Pond hardstanding area.

Most wastes are sent to the LLWR in 205 litre drums for further compaction. Soft LLW is therefore transferred from bins to drums within the Pond building LLW facility where low force compaction is carried out. This typically results in reduction factors of three or four to enable further waste to be added to drums. The drums of low force compacted waste are then transferred to North Site and temporarily stored in an ISO Container or within the Rubb building which is a dedicated LLW processing facility.

Once filled, all drums suitable for high force compaction are monitored and transferred to ISO transport containers for transfer to the Waste Assay, Monitoring and Compaction (WAMAC) high force compaction facility at Sellafield. All suitable LLW, with the exception of the CXPP tritiated waste, is subjected to high force compaction.

The use of low force compaction on site is currently being reviewed and the option to place suitable bagged waste into specific ISO Freight Containers, prior to shipping directly to WAMAC for High Force Compaction is being assessed.

All containers are monitored prior to dispatch to ensure dose rates are in compliance with the regulations for the safe transport of radioactive material. Following high force compaction at WAMAC, compacted drums are transferred to half height ISO containers and grouted in situ prior to disposal at the LLW

Uncompactable waste

Disposal of non-compactable waste at Chapelcross is conducted by loading into an appropriate sized ISO-container and transferring to the LLWR for direct grouting and disposal.

The identification of routine uncompactable LLW arisings (by source) is maintained through on-site handling and processing routes. Uncompactable wastes are usually subject to a preliminary survey at its collection point. Subsequently wastes are transferred in either sealed drums or in bagged form to the North Site where waste is stored until enough uncompactable waste arises to make a half height ISO container disposal feasible.

Where appropriate, decontamination techniques are used to reduce waste by cleaning items for reuse or disposal as non-radioactive scrap. Such techniques could be used to reduce the levels on an item to bring it into a lower category. However, it is recognised that decontamination produces secondary wastes that can be chemically and radioactively unacceptable as LLW and could result in an increase in the total mass or volume of waste requiring disposal. This, together with operator dose implications, must be taken into account before such techniques are applied.

Some large items may be cut up so that they fit into drums or transport containers. Cutting of contaminated items is undertaken in a contamination controlled area under controlled conditions with suitable provision for the collection of swarf, dust or other particulate. The application of ALARP may limit the cutting of heavily contaminated items.

Waste is loaded into the ISO freight containers and, when full, the lid sealed and the outside monitored for contamination. Decontamination is undertaken if necessary prior to transport by road to the LLWR.

At Drigg, containers are filled with a low viscosity grout and allowed to cure. The cured ISO is then placed within the LLWR.

7.4 Historic Arisings

Since the Site was commissioned in 1959/1960, Chapelcross has been routinely sending LLW to the LLWR. Disposal volumes from Chapelcross have been variable due to the time taken to accumulate LLW, but have generally been reducing as a result of on-site waste minimisation initiatives and improved volume reduction techniques.

7.4.1 Volume

Examination of records of waste movements over the lifetime of the current waste transfer certificate shows that annual transfers of LLW for disposal at Drigg have ranged from 13 m^3 to 150 m^3. Disposals in this period are shown graphically in Figure 12. A review of the site waste characterisation to meet the conditions for acceptance for the disposal of LLW to Drigg precluded any waste transfers in 2000 and 2001.

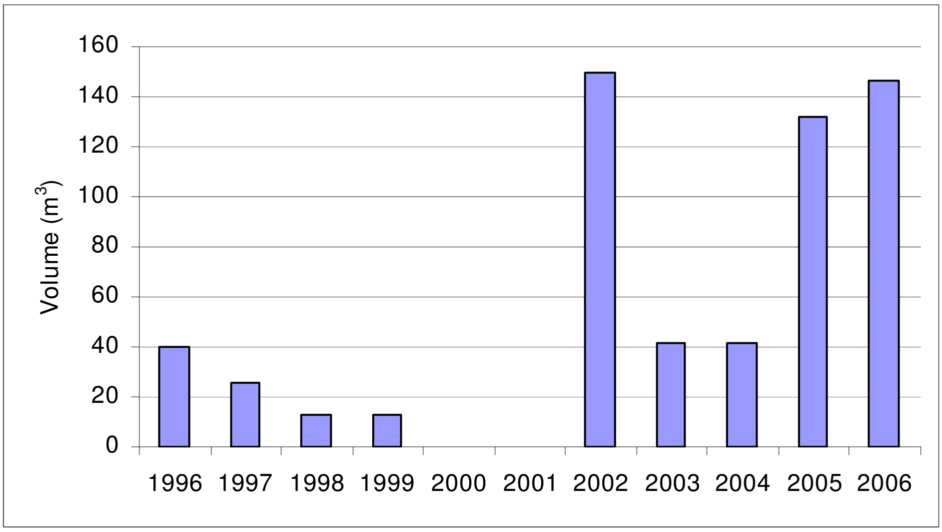

Figure 12 Disposal volumes of LLW from Chapelcross sent to the LLWR near Drigg

7.4.2 Activity

In order to overcome the inherent difficulties in providing detailed data concerning the radionuclide content of solid waste, “fingerprints” are employed at Chapelcross. Radionuclide fingerprints for the waste streams are established by collecting and assaying samples of radioactive contamination, usually on swabs, from plant areas in which the waste is generated. Waste stream fingerprints are used to determine the individual radionuclide content of waste arisings from relatively simple measurements.

Activity “fingerprints” have been established for each of the representative low level waste streams produced on the site. Details of the activity fingerprints are provided in Appendix 0. The approach assumes that the radionuclide inventory of the waste can be assessed from measurement of gamma emitting radionuclides and knowledge of the ratios of these to other non-gamma emitting radionuclides. As the waste is segregated into individual waste streams only one “fingerprint” is applicable per drum. This enables the determination of radioactivity to be assessed from measurements of certain gamma activities within the waste. Appropriate fingerprints to each of the waste streams identified in Table 20 have been determined in agreement with the LLWR management.

All waste drums sent to the LLWR are assessed for activity prior to dispatch. Twelve separate measurements of gamma dose rate at defined points on the surface around the drum are taken and the average calculated. This average dose rate is used in combination with the drum weight and information on the waste stream that it came from to calculate

the activity for that drum from the waste streams fingerprint.

For items too large to be drummed, the activity is assessed from direct measurements of surface contamination or from a comparison of dose rates at various distances. Knowledge of dose rates, contamination probe measurements, gamma spectrometry of swabs, dimensions and weight of the object, the origin of the waste and the appropriate fingerprint are employed to determine isotopic activities that are not measured directly. The most suitable measurement techniques are discussed with a suitably qualified expert prior to the characterisation exercise to ensure that the activity assessment utilises ‘best practicable means’.

As LLW is being sent to the LLWR for disposal, it is considered more appropriate for limits in the authorisation to reflect those imposed on the LLWR itself. This would result in limits being set on a number of additional radionuclides. To reflect this Table 34 shows the activity arisings since 1996 from Chapelcross reported against the current LLWR authorisation categories.

Table 34 - Annual solid LLW disposals, 1996-2006 (Proposed Definitions)

Year	Volume (m^3)	Activity (GBq)							
		U	Ra-226/ Th-232	Other Alpha	C-14	I-129	H-3	Co-60	Others
1996	40.0	0	0	0.007	0.085	0	47	2.2	2.2
1997	26.0	0	0	0.005	0.070	0	120	1.9	1.9
1998	13.0	0	0	0.002	0.020	0	62	0.65	0.63
1999	13.2	0	0	0.001	0.015	0	48	0.48	0.46
2000	0.0	0	0	0	0	0	0	0	0
2001	0.0	0	0	0	0	0	0	0	0
2002	150.0	0	0	0.050	0.12	0	390	3.1	9.5
2003	42.0	0	0	0.010	0.03	0	49	0.6	2
2004	42.0	0	0	0.003	0.0064	0	0.58	0.49	6.5
2005	132.1	0	0	0.0061	0.023	0	1.2	3.2	46.5
2006	146.8	0	0	0.008	0.02	0	1.01	1.74	24.7

(1) Only activities for those radionuclides specified in the solid waste disposal Authorisation i.e. other alpha, tritium, cobalt-60 and other beta, for 1996 to 1999 were reported in the Company annual reports on Discharges and Monitoring of the Environment. Data for the other radionuclide groups in this period have been included for comparison with later years.

7.5 Consideration of BPEO and BPM

Disposal options for solid LLW arising on nuclear sites are set out in Government Policy Cm 2919. Currently, the only site available for solid LLW arisings from Chapelcross that comply with Cm 2919 is the LLWR near Drigg.

The BPEO study recommended that, where appropriate and practicable, materials should be decontaminated or size reduced to permit disposal under the Substances of Low Activity Exemption Order. This process has been successfully applied at Chapelcross, resulting in a significant reduction in volumes consigned to LLWR.

7.5.1 Compactable and uncompactable Wastes

The volume of radioactive wastes produced at Chapelcross is dominated by routine LLW arisings. In order to maintain nuclear safety and comply with the Site Licence it is necessary to dispose of the LLW as it arises to the LLWR near Drigg. Chapelcross uses BPM to ensure that waste arisings are minimised, taking into account British Nuclear Groups CFA requirements. The BPEO for LLW is for land burial at Drigg as this complies with the Governments preferred strategy of 'concentrate and contain' as set out in Government Policy Cm 2919.

7.6 Future Needs and Proposed Limits to 2014

7.6.1 Volume

As noted in section 6.4.1, annual transfers of LLW to the LLWR near Drigg have been variable, ranging from 13 m^3 to 150 m^3. As stated in Section 3.6.2, as part of the preparation for decommissioning, Chapelcross have prepared a Baseline Decommissioning Plan which has derived initial estimates of waste volumes associated with identified projects within the Life Time Plan. Comparison with the extant programme has allowed estimates of predicted arisings by year to be made. The data and description of LLW streams are presented in Table 35.

With the present proposals for reactor defuelling, plant post operational clearance operations and early decommissioning, the annual volume and radionuclide activity arisings have been estimated to range from a minimum of 130 m^3 during reactor defuelling to a maximum of 2300 m^3 during early site decommissioning. However, these future annual volume arisings will be heavily dependent on the final methods adopted for decommissioning each of the sites' plants and the degree of waste decontamination and conditioning undertaken for disposal. In addition, a proportion of the predicted waste arisings may only be trace active and may be retained on site for recycling purposes.

Table 35 – Anticipated LLW Arisings to 2018

Stream No.	Stream Description	Stocks (m3) at 01/04/07	Arisings (m^3) 07/08 to 08/09	08/09 to 09/10	10/11 to 17/18	Total Volume (m^3)	Description
OPERATIONAL WASTE FOR ROUTINE DISPOSAL TO THE LLWR							
2C10	CXPP Tritiated Waste	4	0	0	0	4	Mainly soft waste (clothes, gloves, tissues etc.), but also plastic, rubber, paper, wood, small metal items. Stored in alkathene containers in 205 l drums. Not suitable for supercompaction due to potential for H3 release.
2C11	Reactor and Associated Areas LLW	32	10.5	31.5	10.5	74.0	Soft waste (PPE and fabric), but also Plastic, rubber, paper, wood, small metal items stored in 205 l drums. Until end of defuelling phase 2011/12
2C12	Cartridge cooling ponds LLW	4.2	0.6	1.6	0	6.4	Soft Waste arising from flask cleaning (wipes etc), but also plastic, rubber, paper, wood, small metal items Principal contaminant Cs-137, Cs134. Peak expected to correspond to repackaging of waste from ponds. Stored in 205 l drums.
2C13	Large Items from Reactor Areas	712	45	135	0	892	Comprises Steel plant and equipment (primarily various grades of steel and some lead) including contaminated charge baskets, redundant flasks (PRDO), grabs, BCGDs (cast steel). Not expected to be activated or contaminated with PCBs. Wrapped and stored in HHISO. Also Bulky items e.g. HEPA filters, metal components, wood, concrete, redundant plant items
2C14	Large items from cooling ponds	13.3	0.6	1.7	0	15.6	Comprises grabs, pumps, lights, scaffold boards, HEPA filters, wood, concrete, Wrapped and loose stored in HHISO.
2C16	UO3 contaminated LLW	6.4	2.4	7.2	0	16.0	Soft waste and plywood boards also Plastic, rubber, paper, wood, small metal items stored in 205 l drums
CARE AND MAINTENANCE PREPARATION – FOR ROUTINE DISPOSAL TO THE LLWR							
2C920	Reactor LLW	364.2	364.2	728.3	2913.4	4370.1	Comprises large plant components including: defuelling machines, turbo generators, heat exchanger pipework, blowers, building fabric, iron ductwork, transformers, generators, large lead acid batteries, MMMF, switch gear scaffolding poles. Materials include cast steel, cement bound asbestos, brickwork and reinforced

Stream No.	Stream Description	Stocks (m3) at 01/04/07	Arisings (m^3)			Total Volume (m^3)	Description
			07/08 to 08/09	08/09 to 09/10	10/11 to 17/18		
							concrete. Not suitable for super compaction. *This anticipated volume is based on the assumption that the reactor structure and building slabs are left intact and that the rail an related structures remain. Revised estimates of LLW indicate up to 32,869.6 m^3 of activated reactor structures. However, the majority of these structures will remain in place, under safe store, until final site clearance. The principal contributor to the activity associated with this material is Co-60, With a half-life of 5.24 years, this activity will have undergone approximately 20 half-lives prior to anticipated final demolition and should, therefore, not require regulation as LLW at this point.
2C921	Ponds LLW	194.2	194.2	388.3	6859.8	7636.5	Comprises full ponds structure (assuming walls are contaminated to depth including the walls, redundant flasks, furniture and concrete. Not suitable for super compaction
2C922	Pipeline Concrete						
2C93	Pipeline Steel						
2C924	North Site LLW	22.5	22.5	45	991.9	1081.9	This material is currently in temporary storage building and is expected to be removed prior to C&M preparations. Not suitable for super compaction.
2C925	CXPP Dismantling	0	81.3	162.5	1170.2	1414	This category relates to the containment of the process line not including building structure. It comprises tritiated equipment (pumps, valves etc) of largely metal construction. Not suitable for super compaction.
Annual Total (m^3)		**1352.8**	**721.3**	**1501.1**	**11945.8**	**15510.5**	

In view of the uncertainties in the final annual LLW conditioned volumes, derived from the post generation operations, an annual waste volume limit of 1200 m^3 is proposed. Although this is significantly higher than the present annual limit of 600 m^3, any reduction in value could lead to a restriction in the site's ability to move forward efficiently towards care and maintenance due to its inability to move LLW away from site. The current limit and proposed future limit are summarised below (Table 36).

Table 36 - Proposed solid LLW disposal volume limits

	Volume (m^3)		
	Current Limit Cert.305/95	Predicted Annual Volume Range (yr^{-1})	Proposed Limit
Compactable and uncompactable	600	720 - 1400	1200

7.6.2 Activity

The Company's preparation of its forward work programme for the post generation period has enabled a determination of the activity requirements for wastes to be disposed of by transfer off-site. They are based on the present waste stream radionuclide activity finger prints and an annual disposal volume of 1200 m^3 with suitable headroom to allow for future amendments in the characterisation for individual waste streams. Although nil activities for uranium, radium-226/thorium-232 and iodine-129 are included in Table 37, trace amounts of these radionuclides are present in the waste streams, therefore, a small allowance needs to be included in the required authorised annual limits. The radioactivity levels proposed are based on other Magnox sites typical requirements.

As discussed previously, the waste being sent off-site is going to the LLWR and it is therefore considered appropriate that the limits in the authorisation reflect those imposed on the LLWR itself. This would lead to limits being set on a number of additional radionuclides and a slight change to the 'other beta' category. LLW annual volume and radionuclide activities are shown in Table 37 on the basis of the 'new' set of disposal categories.

Table 37 - Proposed solid LLW radioactivity limits

Radionuclide or Radionuclide Group	**Current Limit (GBq)**	**Proposed Radioactivity Annual Limit (GBq)**
Uranium		1
Radium-226/Thorium-232		0.2
Other Alpha	18 (alpha)	0.5
Carbon-14		2
Iodine-129		2
Tritium	500	5200
Cobalt-60	32	35
Other beta/gamma	70	400

7.7 Radiological Impacts

It is understood by Magnox North Ltd. that the LLW it would transfer under the proposed authorisation would be disposed of under the existing authorisation of the LLWR, granted by the Environment Agency.

Radioactive waste can give rise to a small radiation dose to members of the public whilst in transit. Low Level Waste is transported to the LLWR/Sellafield in approved ISO containers by road in compliance with the requirements of the appropriate Transport regulations. The low external dose rate from the transport packages ensures that the radiological impact from the transport of this material is very low. The latest study of the potential radiological implications resulting from the transport of radioactive materials by road and rail (Reference 14), undertaken by the HPA, concluded that the estimated collective dose was less than 0.02 man.Sv to members of the public. The majority of this was from the movements of radioactive materials by road. Since these estimates took account of all UK transport activities they bound the contribution from any one site (such as Chapelcross) which would be only a fraction of this value. HPA assessed the maximum annual dose to a member of the public from road transport, including irradiated fuel, as less than 20 μSv y^{-1}. Transport of radioactive waste would contribute only a small proportion of this.

8. TRANSFER OF LOW LEVEL WASTE TO WASTE MANAGEMENT TECHNOLOGY WINFRITH

Magnox North Ltd. is applying for an authorisation to transfer some of the low level waste (LLW) streams from Chapelcross Site to Waste Management Technology (WMT) Winfrith for conditioning. The conditioned LLW will be then transferred to the Low Level Waste Repository (LLWR) near Drigg.

8.1 Description of Waste

Chapelcross generates solid radioactive wastes as part of its operations and, whilst the site takes all reasonable steps to minimise the volume of the waste produced, there may be a requirement to volume reduce by compaction or pre-treatment by a specialist waste contractor.

8.2 Sources and Production

Asbestos LLW may be generated during the removal of lagging materials and others from the Heat Exchangers, Turbine Hall, Reactor associated plant and other site buildings.

Due to the large volumes associated with asbestos lagging waste there is a requirement to size reduce the asbestos material by high force compaction, so that the LLWR can accept the material.

The asbestos waste material will have a radionuclide composition characterised by the 2C11 fingerprint (see Table 35).

8.3 Management of Waste

The disposal of asbestos LLW from the Chapelcross Site will be managed from a dedicated facility, where initial processing and interim storage of the asbestos waste will take place.

All asbestos LLW will be minimised in volume by high force compaction at an approved facility at WMT Winfrith. After compaction WMT will consign the asbestos LLW to the LLWR on behalf of Chapelcross Site.

8.4 Limits

The LLW transferred to WMT for high force compaction and onward shipment to the LLWR near Drigg will be included as part of the proposed solid LLW disposal volume limit for the Chapelcross Site (see Table 36).

9. TRANSFER OF INTERMEDIATE LEVEL WASTE TO BNG, SELLAFIELD

Magnox North Ltd. is applying for an authorisation to continue transfer some of the Intermediate Level Waste (ILW) streams from Chapelcross site to Sellafield Miscellaneous Beta Gamma Waste Store (MBGWS). The conditions and limitations relating to the transfer of ILW to Sellafield are set out in the present solid waste authorisation. The Company assumes that if the Regulator approves this authorisation application the ILW annual volume requirements will continue be included in the revised solid waste authorisation transfer certificate for LLW to Drigg or Sellafield. For the purposes of this application the ILW future requirements are set out in following sections.

9.1 Description of Waste

Some wastes will continue to be produced from routine and maintenance operations in the Reactors and CXPP which, because of its activity content, is classified as Intermediate Level Waste. This is defined by Magnox North Ltd. as waste which is not heat producing, has activity levels above 4 GBq te^{-1} alpha and 12 GBq te^{-1} beta/gamma and meets the MBGWS at Sellafield conditions for acceptance. The current ILW waste streams, characterised by their type and source are given in Table 38.

Table 38- Solid Intermediate Level Waste stream descriptions

Identifier	Description
2C01	Ion exchange materials (zeolite) from Pond water decontamination currently stored in the Ponds
2C02	Miscellaneous activated components currently stored in the CXPP
2C03.1	Miscellaneous reactor components currently stored in the Ponds
2C03.2	Miscellaneous reactor components transferred to Sellafield MBGWS
2C05	Pond sludge currently stored in the Ponds
2C06	CXPP ceramic pellets currently stored in building B141
2C07	CXPP contaminated plant components transferred to Sellafield MBGWS
2C15	Tritium contaminated rotary pump oil currently stored in the CXPP
2C18	Miscellaneous CXPP wastes including Magnox and aluminium transferred to Sellafield MBGWS

9.2 Sources and Production

Refuelling operations have led to production of some ILW. This is principally graphite that had been found to be damaged during the post defuelling exercise prior to refuelling the reactor. Some minor quantities may arise during the core defuelling exercises. Additionally, fuel element thermocouples present to monitor fuel can temperatures in the core need to be removed during the defuelling exercise.

Fuel element thermocouples and any graphite debris, removed during final defuelling will continue to be transferred routinely to Sellafield MBGWS. Any other in core activated ILW components arising during final defuelling may be transferred to the Ponds for interim storage.

During reactor operation moisture levels in the reactor coolant gas were controlled to prevent corrosion. This was achieved by periodically passing the coolant gas through humidriers containing an alumina desiccant. Tritiated water was routinely removed from the humidriers for disposal. During Reactor POCO the alumina will be removed, characterised and conditioned for disposal potentially as ILW.

Pond operations also result in the production of some ILW. Radionuclides in discharges of pond water have been controlled by ion exchange units which have led to skips of exhausted ion exchange resins needing to be disposed of by transfer away from site. Also, the site holds some pond sludge material resulting from pond operation.

ILW is also produced during operations within the CXPP, including Magnox cartridges, aluminium liners from the isotope cartridges and the pellet residues. The higher neutron absorption cross section stainless steel cans that contained the lithium pellets are retained in the CXPP.

The Magnox cartridges and aluminium liners, produced from the breakdown of the isotope cartridges during the final tritium production, have all been transferred to MBGWS following closure of the plant in 2005. Transfer of the stainless steel inner cans to MBGWS has started and should be completed before the new solid waste Authorisation comes into force. The lithium pellet waste, containing residue quantities of tritium currently held in the Uranium Store, is programmed to be recovered and conditioned in the CXPP for potential transfer to MBGWS as part of the plant POCO process.

9.3 Management of Waste

ILW is transported in flasks approved by the Department for Transport (DFT) to the Miscellaneous Beta Gamma Waste Store (MBGWS) at Sellafield. However, the site is examining the possibility of local storage of ILW during the care and maintenance period and decommissioning.

9.4 Historic Arisings

9.4.1 Waste volumes

The site is currently limited on the amount of ILW that it can dispose of by transfer to Sellafield. In the period 1996 to 2006, the lifetime of the current solid waste transfer certificate, the site has operated well within the current volume restriction of 30 m^3 (Table 39).

Table 39 - Intermediate Level Waste transfer volumes to MBGW, 1996-2006

Year	Volume (m^3)				
	Graphite	Aluminium	Magnox	Misc.	Total
1996	3.22	0.68	2.34	1.45	7.7
1997	1.56	0.77	2.61	1.28	6.2
1998	1.53	0.85	2.71	0.78	5.9
1999	2.63	0.85	3.36	0.95	7.8
2000	2.63	0.85	2.60	0.85	6.9
2001	1.06	0.68	3.32	0.59	5.7
2002	1.38	0.77	1.77	0.63	4.5
2003	0.53	0.26	1.75	0.74	3.3
2004	0.00	0.94	2.47	0.00	3.4
2005	0.16	0.60	1.96	0.58	3.3
2006	1.1	0	0	0.35	1.45

9.4.2 Activity content

Presently there is no requirement to seek annual radionuclide activity limits for ILW transfers to MBGWS Sellafield as no activity limits are specified in the facilities conditions for acceptance. The activity content of each waste consignment is limited by the relevant ILW road transport flask design safety report, which is approved by the Department for Transport.

9.5 Consideration of BPEO and BPM

A BPEO study [Ref. 9] has been conducted into management options for both LLW and ILW. Waste conditioning and interim on-site storage, pending availability of a final disposal route was the highest scoring option for all categories considered. For ceramics, magnox and graphite materials, transfer to Sellafield was considered to be an equally high scoring option.

9.5.1 Volume minimisation of solid waste

Magnox North Ltd. has an Environment, Health and Safety Policy which, for waste operations, states that it “will strive to prevent pollution and minimise waste and the use of natural resources as part of our contribution to sustainability and environmental improvement” (Reference 3). In compliance, Chapelcross pays particular regard to waste minimisation through staff training, its operating procedures and volume reduction (Reference 8).

9.5.2 Reduction techniques

All ILW graphite arising from graphite sleeve and distance pieces goes through a crusher. Thermocouples are wound around a reel to aid packing.

The volume of ILW is optimised by the BPM considerations examined earlier. A component part of a BPM assessment exercise is the consideration of secondary wastes. For example, solid ILW can result from an abatement process to remove activity from a specific waste stream. Thus, it may not be appropriate to further reduce the activity of an already low activity fluid if it results in the creation of ILW.

9.6 Future Management Strategy

Chapelcross site has started work on an ILW strategy. This strategy is looking at the initial optioneering and characterisation of specified ILW streams with a view to holistic design and build for the recovery, processing and storage of the ILW that will remain on site during the care and maintenance phase.

9.7 Future Needs and Proposed Limits to 2014

9.7.1 Volume

As stated above, Chapelcross site has operated well within the current volume restriction of 30 m^3. However, the preparations to move the site forward into care and maintenance could see the need to undertake additional transfers of ILW away from site. This could include H-3 pellet waste (19 m^3), stainless steel waste (1.4 m^3), CXPP decommissioning (30 m^3), reactor final defuelling (3.4 m^3), recovery of ponds sludge (16 m^3), ion exchange resins (150 m^3 conditioned) and miscellaneous wet ILW (14 m^3). As stated in Section 3.6.2, as part of the preparation for decommissioning, Chapelcross have prepared a Baseline Decommissioning Plan which has derived initial estimates of waste volumes associated with identified projects within the Life Time Plan.

Comparison with the extant programme has allowed estimates of predicted arisings by year to be made. The data and description of ILW streams are presented in Table 40 .Predicted annual volume arisings range from 9.5 to 47.5 m^3. However, currently only ILW from three of these waste streams are routinely transferred to Sellafield.

For the present programme of post closure plant operations the estimated annual arisings (Reference 8) of conditioned ILW, with established transfer routes to the MBGWS Sellafield, ranges from about 13 m^3 during the reactor defuelling and the CXPP plant POCO period, to under 2 m^3 during early decommissioning activities. However, if the ILW arisings from the decommissioning of the CXPP and some of the waste presently stored in the Ponds can be conditioned for acceptance and transfer to MBGWS Sellafield, then the annual volume transfers could increase during the early plant decommissioning period up to 46 m^3.

9.7.2 On site ILW store

As stated above, the Company has undertaken a preliminary examination of the work programme for the post generation period and the impact on the ILW arisings of the various operations necessary to be undertaken has been assessed (Reference 8) An on site ILW store has also been proposed for some of the ILW, for which currently there is no established disposal route to the MBGWS at Sellafield. Based on the present waste strategy for moving to care and maintenance the majority of ILW annual arisings, suitable for transfer to MBGWS, will initially be associated with the POCO activities of the CXPP and reactor defuelling operations. This will be followed by CXPP decommissioning including the plant process line which could give rise to an estimated 30 m^3 of ILW, possibly over a period of 3 years.

Table 40 – Anticipated LLW Arisings to 2018

Stream No.	Stream Description	Stocks (m3) 01/04/07	Arisings (m^3) 2006/07	07/08 to 09/10	10/11 to 17/18	Total Volume (m^3)	Description
OPERATIONAL WASTE FOR STORAGE ON-SITE OR AT SELLAFIELD PENDING DISPOSAL							
2C01	INX Resin AW500 (Zeolite)	47.8	1	0	0	48.8	48 spent resin components in storage and up to another 12 in use. **Location: Ponds Facility**
2C02	MAC, Activated liners	1.5	0	0	0	1.5	Activated components including stainless steel compacted liners dry stored in stainless steel compacted liners dry stored in stainless steel containers, shield plugs and couplings. Various components will be left in the reactor including: control rods, boron balls and neutron sources (which may be LLW). No Fuel Element Debris (FED) is present. **Location: Reactors & Ponds**
2C03	Misc. Reactor Components	20.4	4.6	13.7	0	38.7	Activated components include reactor furniture (2-3 m^3), holding down weights, support struts and thermocouples. Mainly steel but some magnox and aluminium cladding and graphite materials. Stored in skips (wet and dry). **Location: 90% Reactors, 10% Ponds**
2C05	Sludge	6.1	0.5	1.4	0	8	Sludges containing corrosion products from the ponds. Approximately 2 m^3 in pond skips with remainder in detention tanks. **Location Ponds Facility.**
2C06	Ceramic Pellets CXPP	9.7	0	0	0	9.7	Dry stored in 2020 bottles and stainless steel cans in temporary storage vessels.
2C07	Contaminated Plant Components	3.6	0	0	0	3.6	Including tritium contaminated steel plant (pipes, valves etc) and graphite. Stored in disposable flask liners. **Location: CXPP**
2C15	Rotary Pump Oil	0.3	0	0	0	0.3	Tritium contaminated oil. Stored in Stainless steel cans. **Location: CXPP**
2C18	Misc. β/γ waste	15.1	2.6	7.7	0	25.4	
2C19	Fuel skips in Pond R1	0	0	10.5	0	10.5	190 skips of mild steel with surface contamination present in the paint (mainly Cs137).
2C20	Fuel skips in Pond R2	0	0	189.5	0	189.5	
2C21	Pond skip	0	0	0	0.2	0.2	

Stream No.	Stream Description	Stocks (m3) 01/04/07	Arisings (m^3) 2006/07	07/08 to 09/10	10/11 to 17/18	Total Volume (m^3)	Description
	decontamination sludge Pond R1						
2C22	Pond Skip decontamination sludge Pond R2	0	0	0	3.8	3.8	
2C23	Desiccant	4	0	0	0	4	
PREPARATION FOR C & M: FOR ON-SITE STORAGE PENDING FINAL DISPOSAL							
2C26	CXPP Dismantling ILW	0	0	118.5	118.5		
Total annual arisings (m^3)		108.5	8.7	341.3	122.5	344	

Intermediate Level Waste currently stored in the irradiated fuel ponds, which may not be acceptable for long term storage at MBGWS Sellafield, may be conditioned for safe storage in the proposed ILW facility at Chapelcross. These waste streams include the ion exchange resins and miscellaneous reactor core activated components. Methods for conditioning these waste streams will be developed after the remaining irradiated fuel held in the ponds has been transferred to Sellafield for reprocessing.

9.7.3 Proposed limits

With the uncertainties in the establishment of acceptable transfer routes to MBGWS, for some of the CXPP decommissioning ILW and ILW stored in the Ponds, it is proposed that the current annual volume limit of 30 m^3 for ILW transfers to the MBGWS be retained during the preparations for site care and maintenance (Table 41). Only the waste streams in Table 41 will routinely be transferred to Sellafield, any transfers for material in other waste streams identified in Table 35 will be the subject of a separate application for minor authorisations.

Table 41 - Proposed solid ILW volume disposal limits

Identifier	Description	Proposed Annual Limit (m^3)
2C02, 2C03.2, 2C06, 2C07 and 2C18	Miscellaneous Reactor, CXPP, contaminated and activated plant components	30

9.8 Radiological Impacts

Intermediate Level waste is transported by road to Sellafield in flasks approved by the Department of Transport. The low external dose rate from the transport packages ensures that the radiological impact from the transport of this material is very low. The latest study of the potential radiological implications resulting from the transport of radioactive materials by road and rail (Reference 14), undertaken by the HPA, concluded that the estimated collective dose was less than 0.02 man.Sv to members of the public. The majority of this was from the movements of radioactive materials by road. Since these estimates took account of all UK transport activities, the contribution from any one site (such as Chapelcross) would be only a fraction of this value. HPA assessed the maximum annual dose to a member of the public from road transport, including high activity irradiated fuel, as less than 20 μSv y-1.

10. ENVIRONMENTAL IMPACT

10.1 Landscape and Ecology

Chapelcross site is situated in Dumfries and Galloway and is surrounded by agricultural farmland. Radioactive liquid effluent is discharged by pipeline to the inner regions of the Solway Firth.

The Solway Firth is one of the largest, least populated and least industrialised natural sandy estuaries in Europe and supports one of the largest continuous areas of intertidal habitat in Britain. The area has received designation as a site of national and international conservation importance for supporting a range of nationally and internationally important habitats and species. Species of particular conservation interest include:

- Whooper swan, barnacle geese, golden plover and bar-tailed godwit that are protected under Annex I of the Birds Directive;
- Pink-footed geese, pintail, scaup, oystercatcher, knot, curlew, redshank, dunlin and ringed plover that are present in internationally important numbers as defined by Article 4.2 of the Birds Directive;
- Natterjack toads and great-crested newts that are protected under the Wildlife and Countryside Act 1981, the Conservation (Natural Habitats, &c.) Regulations 1994 and the Ramsar Convention; and,
- River lamprey and sea lamprey, which are species of importance under the Habitats Directive, but are not primary qualifying features for the area.

In addition to particular species, the estuary supports a total of more than 20, 000 wintering waterfowl, which qualifies the area as of international conservation importance under both the Birds Directive and Ramsar Convention.

As a result of the species, populations and habitats present, the following designations are in place:

- Upper Solway Flats and Marshes Site of Special Scientific Interest (SSSI);
- Upper Solway Flats and Marshes Special Protection Area (SPA);
- Upper Solway Flats and Marshes Ramsar site;
- The Solway Firth Special Area of Conservation (SAC); and,
- Royal Ordnance Powfoot SSSI.

10.2 Impact of Activities on Environmentally Sensitive Areas

Historically, radiological protection has focused on the protection of man on the basis of the recommendations of the International Commission on Radiological Protection (ICRP) that *'The Commission believes that the standards of environmental control needed to protect man to the degree currently thought desirable will ensure that other species are not put at risk'* (Reference 16). However, in recent years, there has been an increasing emphasis on environmental protection issues and in 2000 the ICRP set up a Task Group to consider the issue of environmental protection in more detail.

In response to the increasing awareness of the need to demonstrate protection of the environment in its own right a number of assessment methods have been developed both at a national and international level. Such methods include the Environment Agency and English Nature R&D 128 assessment methodology, which was released in 2001 (Reference 17), and the EC ERICA assessment tool that is due to be released in March 2007.

As previously noted (Section 2.1), liquid effluent discharges from Chapelcross site are to the Solway Firth, an area designated as of conservation importance both nationally and internationally. To date, no specific assessment has been conducted on the impacts of radioactive discharges from the Chapelcross site on these designated sites. However, a screening assessment has been conducted to determine the potential impacts of radioactive substances in aquatic environments around Scotland that are subject to authorised discharges as part of SEPA's commitment to the Water Framework Directive (Reference 18). The screening assessment was conducted on the basis of environmental monitoring data and two sets of screening levels for radionuclides in water.

Measured activity concentrations in seawater around the Chapelcross discharge point were within the screening levels derived by the Environment Agency in conjunction with English Nature (Reference 17).

10.3 Concentrations and Accumulation of Radionuclides in the Local Environment from Past and Future Discharges

Magnox North Ltd. carries out an extensive programme of environmental monitoring around its nuclear sites in order to assess the quantities of wastes released to the environment and demonstrate compliance with the authorisations issued under RSA93. The monitoring programme at Chapelcross began before the power station was built and has continued ever since. In addition, an extensive independent programme of environmental monitoring is carried out, with data published by the Centre for Environment, Fisheries and Aquaculture Sciences (CEFAS) on behalf of the Environment Agency, Environment & Heritage Service, Food Standards Agency and SEPA.

Measurements, such as gross beta activity and gamma spectrometry of environmental samples, taken from within the site boundary, are undertaken in the site's own laboratories. Radiochemical analysis and gamma spectrometry for environmental samples, taken from beyond the site boundary, are undertaken by Westlakes Scientific Consulting in Whitehaven, Cumbria and RadioCarbon Dating in Oxfordshire.

The data given in the Tables below are taken from the Company Annual Reports of Discharges and Monitoring of the Environment and supplemented with data from the routine reports to SEPA in compliance with the Aerial and Marine Discharge Authorisations.

Activity concentrations measured within terrestrial environments and agricultural produce have varied with time, but have remained low. No accumulation within the environment is evident. Activity concentrations will decline following the cessation of electricity generation.

Activity concentrations in the Solway as a result of discharges from Chapelcross are difficult to decipher from those resulting from the Sellafield site. Activity concentrations within the Solway have varied over time and some accumulation of radionuclides within sediments and other indicator species is evident. However, this is primarily the case for radionuclides such as Cs-134 and Cs-137 for which discharges from the Sellafield site are up to 3 magnitudes higher than those for Chapelcross. It is therefore probable that the Sellafield discharges have the largest influence over measured activity concentrations in the inner Solway. Contributions to measured activity concentrations within the Solway Firth arising from discharges from Chapelcross are anticipated to decline now that power generation has ceased.

10.3.1 Marine

The current sampling programme agreed between SEPA and the Company under the current authorisations includes the following;

- Fish;
- Crustacea;
- Silt and seaweed;
- Foreshore Gamma Dose Rate measurements (stake nets and strandline); and,
- Pipeline gamma Dose Rate measurements.

Seafood Radioactivity Concentrations

Samples of flounder, salmon/sea trout and shrimp, obtained from local fisherman, on a quarterly basis when available have been analysed for a number of radionuclides including strontium-90, caesium-134 and caesium-137. The annual average seafood activities, for the principal radionuclides, over the last ten years are given in Table 42. No particular trends for strontium-90 activity in seafoods are evident with Chapelcross discharges. Both caesium-134 and caesium-137 seafood concentrations have decreased significantly during this period, following a steady decrease in both Chapelcross and Sellafield caesium-137 discharges.

Table 42 - Activities (Bq/kg wet weight) Reported in Flounder and Salmon/Sea Trout

Year	Flounder(1)			Salmon/Sea Trout			Shrimp(2)		
	Sr-90	Cs-134	C-137	Sr-90	Cs-134	Cs-137	Sr-90	Cs-134	Cs-137
1996	0.10	<0.1	22.0	0.10	<0.1	2.2	0.10	<0.1	8.0
1997	0.70	<0.1	23.0	0.10	<0.1	0.90	0.30	<0.1	9.8
1998	0.10	<0.1	25.0	0.20	<0.1	0.60	0.45	<0.1	5.5
1999	0.10	<0.1	23.0	0.10	<0.1	0.40	0.30	<0.1	7.1
2000	0.20	<0.1	20.0	0.10	<0.1	0.40	0.30	<0.1	5.8
2001	-	-	-	<0.1	<0.1	0.30	<0.1	<0.1	4.5
2002	0.10	<0.2	12.0	0.10	<0.1	0.40	0.25	<0.1	4.0
2003	<0.1	<0.1	12.0	<0.1	<0.1	0.20	-	-	-
2004	-	-	-	<0.1	<0.1	0.30	-	-	-
2005	-	-	-	<0.2	<0.1	0.20	-	-	-
2006	<0.1	<0.1	14.0	<0.1	<0.1	0.30	-	-	-

Table Note: (1) No Flounder were available for analysis in 2001, 2004 and 2005.
(2) No Shrimp were available for analysis from 2003.

Indicator Radioactivity Concentrations

Samples of seaweed, from the vicinity of the pipeline outfall and sediment samples, from the highest measured dose rate area around the stake nets, are taken periodically through the year. Total beta and gamma spectrometry analyses are routinely undertaken, but only a limited number of radionuclides have been routinely reported in the Company annual reports of Discharges and Monitoring of the Environment over the last ten years. The annual average activities for these radionuclides in seaweed and foreshore sediments during this period are given in Table 43.

Although caesium-137 activities in seaweed have shown a general decrease over this period caesium-137 activities in sediments samples have shown a greater variability. There has been little variation in cobalt-60 activities in seaweed and sediment samples, reported from 1999 onwards. Other radionuclide concentrations reported in seaweed in the last three years are, technetium-99 ranging from around 2000 to 5000 Bq. Kg^{-1} and americium-241 concentrations which have been less than 5 Bq. Kg^{-1}. Although both Chapelcross and Sellafield caesium discharges have generally decreased over this period, Sellafield discharges are considered to have the largest influence on the indicator activity levels in the inner Solway.

Table 43 - Activities (Bq/kg wet weight) reported in seaweed and silt.

Year	Seaweed(1)				Sediments(2)				
	Co-60	Ru-106	Cs-134	Cs-137	Co-60	Ru-106	Cs-134	Cs-137	Am-241
1996	-	<6.6	<0.4	10	-	<4	<3	104	-
1997	-	<0.6	<0.3	11	-	<7	<2	350	-
1998	-	<0.8	-	10	-	<5	<1	91	-
1999	0.9	<0.8	-	10	<2	<7	<1	74	32
2000	0.8	<0.8	-	8.0	<2	<6	<1	92	57
2001	0.6	<0.8	-	7.0	<2	<5	<1	110	55
2002	0.6	<0.8	-	5.0	1.5	<6	<1	130	65
2003	0.5	<0.8	<0.1	8.0	<2	<6	<1	180	79
2004	0.6	<0.6	<0.1	6.0	2.7	<8	<2	160	147
2005	0.8	<1.0	<0.1	6.0	3.3	9.0	<1	302	173
2006	0.6	<0.9	<0.1	7.0	2.0	<7	<1	190	140

Table Notes: (1) Cobalt-60 activity concentrations were reported in the Company Annual Reports on Discharges and Environmental Monitoring from 1999 onwards. Ruthenium-106 and caesium-134 activity concentrations have been taken from SEPA quarterly reports.

(2) Only caesium-137 activity concentrations have been reported in the Company Annual Reports on Discharges and Monitoring of the Environment over this period. Cobalt-60 and americium-241 activity concentrations were reported from 1999 onwards. Ruthenium-106 and caesium-134 activity concentrations have been taken from SEPA quarterly reports.

Foreshore Gamma Dose Rates

Gamma dose rates have been measured in the vicinity of up to 10 stake nets, when placed on the foreshore. In recent years there has been a significant reduction in the number of stake nets set up on the foreshore during the fishing season, with only three in place in 2006. During the last calendar quarter of the year gamma dose rates and beta gamma contamination measurements are made in the net store when all the stake nets have been removed for maintenance and storage over the winter period. The mean of up to five stake nets, with the highest measured gamma dose rates, are given in Table 44. In recent years there has been little change in foreshore dose rates in the vicinity of stake nets which have averaged at around 0.08 $\mu Gy.h^{-1}$, slightly higher than natural background.

Stake net store gamma dose rates have ranged from 0.11 $\mu Gy\ h^{-1}$ to 0.15 $\mu Gy\ h^{-1}$ over this period. With the change in the instrument calibration in 2000, stake net store dose rates are currently around 0.13 $\mu Gy\ h^{-1}$. No significant beta gamma contamination levels above background have been measured on the stored nets. These data are taken from the routine reports to SEPA as they are not routinely included in the Company annual reports on Discharges and Monitoring of the Environment.

Table 44 - Stake Net area Gamma Dose Rates

Year	Stake Nets Gamma Dose Rates ($\mu Gy.\ h^{-1}$) (1)
1996	0.08
1997	0.08
1998	0.08
1999	0.09
2000(2)	0.091
2001	0.11
2002	0.088
2003	0.082
2004	0.076
2005	0.072
2006	0.078

Table Notes:
(1) Average of up to five stake nets with the highest measured dose rates.
(2) Radiation dose rate instrument calibration changed from radium-226 to caesium-137

Strandline Gamma Dose Rates and Foreshore Contamination Monitoring

Gamma dose rates measurements and random beta contamination monitoring of the foreshore strandline over a distance of up to about 100 m, either side of the pipeline outfall, are undertaken once per quarter. The average annual gamma dose rates over the last ten years, inclusive of natural background, East and West of the pipeline outfall has shown little change averaging about 0.11µGy h^{-1}. This figure is based on the routine reports to SEPA as it has not routinely been included in the Company Annual Reports on Discharges and Monitoring the Environment. During this period no beta contamination above the general background levels has been detected along the strandline.

In addition, foreshore contamination monitoring is also undertaken in the vicinity of the pipeline outfall area on a regular basis to detect any particles of contaminated lime scale which may have come from the inside of the pipeline. Following the detection of these particles in 1992 a strainer was developed and installed in 1993 at the end of the pipeline to prevent the migration of lime scale onto the foreshore. Several modifications were made to the strainer arrangements over the following three years to improve its efficiency. Any particles of lime scale detected, during the routine foreshore surveys and strainer maintenance operations, have been removed for activity analysis. The number of particles detected annually, has varied and has ranged from one to a few tens with measured beta gamma activity up to a few thousand Bq of caesium-137, which is the dominant radionuclide present. None have been found more than few metres from the outfall area and therefore the potential risk to a member of the public coming into contact with one is considered to be very small.

Pipeline Gamma Dose Rates

A cast iron pipeline carried a continuous discharge of overflow Turbine Hall condenser cooling water, when the reactors were producing electricity, and intermittent discharges of active liquid effluent from the Pond building and CXPP to the Solway. Gamma dose rates are measured, generally fortnightly, in contact with and up to 2 m from the above ground sections of the pipeline at ten pipe intervals. Only the annual average 2 m gamma dose rates, inclusive of natural background over the last ten years, are given in Table 45. The average dose rate over this period has been of the order of 0.19 µGy h^{-1}.

Table 45 - Annual mean Pipeline Gamma Dose Rates at 2m

Year	External Gamma Dose Rate ($\mu Gy.\ h^{-1}$)
1996	0.17
1997	0.20
1998	0.20
1999	0.20
2000	0.20
2001	0.18
2002	0.18
2003	0.18
2004	0.22
2005	0.21
2006	0.19

Marine Pathway Doses

The measured annual critical group doses for the stake net fisherman and the two secondary groups, wildfowlers and a walker in the vicinity of the pipeline, are reported in the Company Annual Reports on Discharges and Monitoring of the Environment. There has been reduction in the sea food consumption adult annual dose, in recent years, from less than 5 µSv to around 1 µSv partly due to the decreasing trend in flounder and salmon/sea trout caesium-137 activity levels and the difficulty in obtaining flounder and shrimp.

Similarly, recent years there has been a reduction in the external dose contribution to the stake net fisherman's dose from around 38 µSv to less than 10 µSv, and from 15 µSv to less than 1 µSv for the wildfowlers . Prior to the introduction of the CEFAS 2000 habits survey data the assessed annual dose for a person walking the pipeline was relatively constant averaging about 14 µSv. Since 2002 it has averaged about 7 µSv.

10.3.2 Terrestrial

The current sampling programme agreed between SEPA and the Company under the current authorisations includes the following:

- Milk, and,
- Green Vegetables

Milk Radioactivity Concentrations

Over the period of the current gaseous discharge authorisation milk samples from up to 12 farms, within 6 km of Chapelcross, have been analysed fortnightly for tritium and sulphur-35, although the latter will decay significantly in the period post generation and therefore will become inappropriate for future measurement. These measurements are supplemented by the more detailed radiochemical analysis of quarterly bulked samples from up to 6 farms within 3 km of Chapelcross (inner zone) and up to 6 farms within 3 and 6km (outer zone). The more detailed analysis examines samples for tritium, organically bound tritium, carbon-14 (both gross and net above natural background), sulphur-35, strontium-90 and caesium-137.

The mean annual activities, in inner and outer zone farms, for those radionuclides reported in the Company annual reports over the last ten years are shown in Tables Table 46 and Table 47. For most of the period of interest the tritium concentrations in milk from the inner zone farms are higher than those measured in the outer zone farms, indicating that the sites' discharges are the principal source of tritium in milk. Organically bound tritium concentrations, although not normally reported to SEPA, are around 10% of the total tritium levels, for the inner and outer zone farms. Milk tritium concentrations should decrease in future years with the anticipated reduction in aerial tritium discharges during plant decommissioning.

The levels of carbon-14 in milk, from the inner and outer zone farms, as indicated by the activity concentrations net of natural background, are not significantly different for most of the period and have remained relatively constant as did the discharges of carbon-14. With the cessation of electricity generation, in 2004, milk carbon-14 concentrations should be less than in previous years.

Sulphur-35 milk concentrations for both inner and outer zone farms, although very variable over the period of interest, appeared to show little correlation with sulphur-35 discharges over most of the period. Following reduction in reactor power from 2001 onwards and final reactor shutdown in 2004, sulphur-35 concentrations in milk have been less than detection level.

Similarly both strontium-90 and caesium-137 milk concentrations, from the inner and outer zone farms, although not significantly different show a general decreasing trend over the period.

Table 46 - Activities ($Bq.l^{-1}$) Reported in Inner Farm Milk (0-3 km from Chapelcross).

Year	Tritium	C-14 [(1)] (gross)	C-14 [(2)] (net)	S-35	Sr-90	Cs-137
1996	80	18	0.43	0.76	0.055	0.031
1997	75	16	0.35	1.2	0.056	0.046
1998	87	13	0.05	0.75	0.061	0.029
1999	58	254	0.13	0.94	0.047	<0.027
2000	64	250	0.23	0.43	0.062	<0.03
2001	63	250	0.10	0.42	0.047	<0.02
2002	66	250	0.33	<0.6	0.056	<0.03
2003	25	240	0.13	<0.4	0.041	<0.03
2004	27.7	242	0.00	<0.4	0.032	<0.03
2005	24.9	243	0.15	<0.4	0.030	<0.02
2006	12.8	243	0.10	<0.4	0.034	<0.03

Table Notes: (1) Carbon-14 gross (inclusive of natural background) activity units in the Company Annual Reports on Discharges and Monitoring of the Environment are Bq/kg carbon from 1999 to 2006.
(2) Carbon-14 net of natural background activity concentrations are taken from routine reports to SEPA

Table 47 - Activities ($Bq.l^{-1}$) Reported in Outer Farm Milk (3-6 km from Chapelcross)

Year	Tritium	C-14 (1) (gross)	C-14 (2) (net)	S-35	Sr-90	Cs-137
1996	61	18	0.43	1.1	0.060	0.023
1997	51	16	0.30	1.2	0.051	0.033
1998	46	13	0.15	0.74	0.058	0.030
1999	53	250	0.13	0.8	0.054	<0.025
2000	74	250	0.18	0.41	0.053	<0.03
2001	67	250	0.40	0.42	0.034	<0.02
2002	55	250	0.10	<0.7	0.030	<0.04
2003	24	250	0.28	<0.4	0.033	<0.04
2004	26.5	243	0.075	<0.4	0.038	<0.03
2005	19.2	243	0.23	<0.5	0.030	<0.03
2006	10.9	241	0.15	<0.4	0.034	<0.03

Table Notes: (1) Carbon-14 gross (inclusive of natural background) activity units in the Company Annual Reports of Discharges and Monitoring of the Environment are Bq/kg carbon from 1999 to 2006

(2) Carbon-14 net of natural background activity concentrations are taken from routine reports to SEPA as these data are not included in the Company Annual Reports.

Green Vegetable Radioactivity Concentrations

Locally grown green vegetables are taken during the growing season when available from within 2km of Chapelcross. These are currently analysed for both tritium and sulphur-35 although the latter will decay significantly post generation due to its relatively short half-life. As with milk sample analyses the monthly vegetation examinations are supplemented by a more comprehensive programme with quarterly samples being analysed for both total and organically bound tritium, carbon-14, (gross and net of natural background), sulphur-35, strontium-90 and caesium-137. A quarterly comparative study is also undertaken with vegetables purchased from a supermarket over 8km from Chapelcross, to provide an indication of the equivalent background activity levels. They are referred to as 'control' vegetables. Annual average activity levels for the identified radionuclides for locally grown and controlled green vegetables are given in Table 48 and Table 49.

Both tritium and organically bound tritium activity levels in locally grown green vegetables are higher than for the controlled vegetables. Organically bound tritium concentrations, although not normally reported to SEPA, are around 10% of the total tritium levels, for local green vegetables. The comparatively large variability in tritium concentrations does not show any particular correlation with the tritium discharges in the early years of this period. Although the observed variations in tritium concentrations may be associated with the changing weather patterns in the growing season, there should be a general decrease in tritium concentrations in future years following closure of the CXPP in 2005.

Carbon-14 (net of natural background) activities, in local green vegetables, are higher than in the control vegetables and appear to have some correlation with the carbon-14 discharges in this period, particularly from 2001 onwards.

Annual sulphur-35 activity levels in local green vegetables show some variability and are greater than control samples. Again there is little correlation with the discharges, in the early years of the period of interest, but since reactor shutdown sulphur-35 green vegetable concentrations have decreased to less than detection level.

Strontium-90 and caesium-137 activity levels in local vegetables have generally decreased over this period and are generally higher than in the control samples. Although there are no measured discharges, there is the potential for a small discharge of strontium-90 and caesium-137 via the Pond building's natural ventilation system.

Table 48 - Activities (Bq.kg^{-1} fresh weight) Reported in Local Green Vegetables (0-2km from Chapelcross Site)

Year	Tritium	C-14[1] (gross)	C-14 (net)	S-35	Sr-90	Cs-137
1996	1400	13	0.94	4.3	1.9	1.4
1997	940	12	0.95	5.9	1.1	0.6
1998	670	16	0.65	7.3	1.2	0.2
1999	1500	260	0.47	14	1.2	0.1
2000	1900	270	1.25	6.0	1.8	0.2
2001	480	250	0.35	2.5	0.80	0.2
2002	620	250	0.27	<0.9	0.38	<0.2
2003	120	250	0.25	<2	0.73	0.2
2004	1160	242	0.0	<1.3	0.48	<0.1
2005	326	240	0.23	<1.5	0.40	<0.1
2006	122	240	0.0	<2	0.60	<0.2

Table Notes: (1) Carbon-14 gross (inclusive of natural background) activity units in the Company Annual Reports of Discharges and Monitoring of the Environment are Bq/kg carbon from 1999 to 2006.
(2) Carbon-14 net of natural background activity concentrations are taken from routine reports to SEPA as these data are not included in the Company Annual Reports.

Table 49Activities (Bq.kg^{-1} fresh weight) Reported in Control Green Vegetables[1]

Year	Tritium	C-14[1] (gross)	C-14 (net)	S-35	Sr-90	Cs-137
1996	49	10	0.25	1.5	0.20	<0.5
1997	2.8	11	0.04	3.0	0.20	<0.1
1998	3.0	10	0.04	3.0	0.20	<0.1
1999	8.0	-	0.00	3.0	0.20	<0.2
2000	4.0	-	0.00	2.0	0.30	<0.1
2001 [2]	3.0	-	-	1.0	0.10	<0.1
2002	6.0	-	-	<1	0.10	<0.3
2003	3.0	-	-	<1	0.10	<0.1
2004	3.0	-	-	<1	0.10	<0.1
2005	14.0	-	-	<1	0.10	<0.1
2006	3.0	-	-	<1	0.10	<0.1

Table Notes: (1) Data from 1999 to 2006 for control green vegetables are taken from routine reports to SEPA as these data are not reported in the Company Annual Reports. Only carbon-14 net of natural background activity concentrations are reported in the routine SEPA reports.
(2) Carbon-14 analyses were not undertaken in control green vegetables from 2001 onwards.

Terrestrial Pathways Doses

The annual critical group doses for the milk and green vegetable dose pathways, are reported in the Company annual reports on Discharges and Monitoring of the Environment reports. In recent years the annual critical group dose for the consumption of milk and green vegetable pathways has generally been less than 15 µSv for an infant and less than 10 µSv for an adult.

11. CONCLUSIONS

Following closure of the reactors the site has moved to preparation for defuelling the reactors and decommissioning of the site's facilities. Future aerial and liquid discharges and solid waste disposals have been determined from the proposed reactor defuelling work programme, the site's Baseline Decommissioning Plans for the reactors, Chapelcross Processing Plant and other site facilities, and the site Life Time Plan.

Best Practical Means (BPM) for minimising radioactive discharges and waste disposals are discussed and radiological assessments of the gaseous and liquid discharges, at the required annual limits, have been made for the most exposed members of the public. The resulting radiation doses are less than the statutory annual dose limit of 1 mSv and the recommended annual Source Constraint of 0.3 mSv. A review of the terrestrial and marine dose pathways have shown a general downward trend in recent years, reflecting the reduced annual gaseous discharges from site and liquid discharges from Sellafield.

The required waste discharge and disposal limits are given in tables below.

AERIAL EMISSIONS

Table 50 - Proposed gaseous discharge limits

Radionuclide	Proposed Annual Limits
Carbon -14	100 GBq
Tritium	750TBq
Beta Particulate	250 MBq

LIQUID EFFLUENTS

Table 51 - Proposed liquid discharge limits

Radionuclide	Annual Requirement
Tritium	2 TBq
Other beta emitting radionuclides	2.5 TBq
Alpha emitting radionuclides	20 GBq

COMBUSTIBLE WASTE

Table 52 - Proposed annual transfers of combustible liquid waste from Chapelcross

Radionuclide or Group of Radionuclides	Annual Requirement [1] (GBq)	Annual Volume Requirement (m^3)
Tritium	3	200
Total alpha	0.01	
1Other radionuclides	3	

(1) Scintillant requirements are included within these proposed limits

Table 53 - Proposed annual transfers of activated charcoal granules from Chapelcross for incineration

Radionuclide or Group of Radionuclides	Annual Requirement (MBq)	Annual Mass Requirement, (tonnes)
All radionuclides	50	40

SOLID WASTE

Table 54 - Proposed solid LLW radioactivity and volume limits

Radionuclide or Radionuclide Group	Proposed Radioactivity Annual Limit (GBq)	Volume compactable and uncompactable LLW (m^3)
Uranium	1	1200
Radium-226/Thorium-232	0.2	
Other Alpha	0.5	
Carbon-14	2	
Iodine-129	2	
Tritium	5200	
Cobalt-60	35	
Other beta/gamma	400	

Table 55 - Proposed solid ILW volume disposal limits

Identifier	Description	Proposed Annual Limit (m^3)
2C02, 2C03.2, 2C06, 2C07 and 2C18	Miscellaneous Reactor, CXPP, contaminated and activated plant components	30

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13. GLOSSARY OF TECHNICAL TERMS

Activation products	Radionuclides produced by the interaction of neutrons with stable radionuclides, for instance, cobalt-60 which is an isotope of cobalt.
Alpha activity	Radionuclides that decay by emitting an alpha particle. The latter consists of two protons and two neutrons.
ALARA (As Low as Reasonably Achievable)	Radiological doses from a source of exposure are ALARA when they are consistent with the relevant dose or target standard and have been reduced to a level that represents a balance between radiological and other factors, including social and economic factors. The level of protection may then be said to be optimised. In the UK the term ALARP, As Low as Reasonably Practicable, is used which is effectively synonymous with ALARA
Authorisation	Permission given by regulatory authority under the Radioactive Substances Act or Environmental Protection Act to dispose of respectively radioactive and non-radioactive waste, subject to conditions.
Becquerel	The SI unit of radioactivity equal to one transformation per second.
Beta-Particulates	Small particles of solid material containing radioactive isotopes that emit beta particles when they decay. A beta particle is an electron or positron.
BPEO (Best Practicable Environmental Option)	A concept developed by the Royal Commission on Environmental Pollution. It implies that decisions on waste management have been based on an assessment of alternative options evaluated on the basis of factors such as the occupational and environmental impacts, the costs and social implications.
BPM (Best Practicable Means)	Within a particular waste management option, the BPM is that level of management and engineering control that minimises as far as practicable, the release of radioactivity to the environment whilst taking account of a wider range of factors including cost-effectiveness, technological status, operational safety, and social and environmental factors.
CEFAS	The Centre for Environment, Fisheries and Aquaculture Science is a scientific research and advisory centre for fisheries management and environmental protection. It is an Agency of the UK Government's Department for Environment, Food and Rural Affairs (Defra). It was formed in 1997 from the Fisheries Research Laboratory of MAFF and its Lowestoft laboratory carries out habit surveys and monitoring of radioactivity in the environment on behalf of the Food Standards Agency.
Collective dose	Collective dose is the quantity obtained by summing the individual doses of the people in a population over a defined period (e.g. 500 years). It is reported in units of man-Sieverts (man Sv).
Contamination Controlled Areas	Parts of the site's facilities where radiological conditions require protection against inhalation or ingestion of radioactive material.

Critical group	A group of members of the public whose radiation exposure is reasonably homogeneous and is typical of the people receiving the highest *dose* from a radiation source. The critical group dose is calculated as the mean effective dose to members of the group.
Dose	A measure of radiation received. In this document it is used primarily to mean the 'effective dose' received by members of critical groups.
Dose constraint	A restriction on annual dose to an individual from a single source, applied at the design and planning stage of any activity in order to ensure that when aggregated with doses from all sources, excluding natural background and medical procedures, the dose limit is not exceeded.
Dose limit	For the purpose of discharge authorisations, the UK has (since 1986) applied a dose limit of 1 mSv (1000 µSv) per annum to members of the public from all man-made sources of radiation (other than medical exposure). This limit is now incorporated into UK law in the Basic Safety Standards Directive.
Effective dose	The sum of the equivalent doses in all tissues and organs of the body from internal and external radiation multiplied by the tissue weighting factor (e.g. skin = 0.01, thyroid = 0.05, red bone marrow = 0.12, gonads = 0.20). It allows the various equivalent doses in the body to be represented by a single number giving a broad indication of the detriment to the health of an individual from exposure to ionising radiation, regardless of the energy and type of radiation. For comparison with dose limits, the term takes on a specific meaning.
Fingerprint	The contaminated controlled areas have a characteristic mixture of radionuclides. The area fingerprint defines the radionuclides present and the ratio between the quantities of each radionuclide.
Fission products	Nuclear fission is the splitting of a heavy atomic nucleus such as uranium into (usually) two nuclei spontaneously or under the impact of another particle, with resulting increase of energy. The two nuclei are called fission products.
Giga Becquerel (GBq)	10^9 Bq
Graphite Moderator	The central part of the reactor system in which the graphite assembly slows down neutrons to allow the nuclear chain reaction to proceed. The nuclear fuel is inserted into the moderator and the fuel and moderator together form the reactor core.
Gray (Gy)	The SI unit of absorbed dose. This is the mean energy imparted by ionising radiation to matter in a given volume divided by the mass of the matter. Dose rates measured in the environment are usually expressed in the units of µGy, a millionth of a Gray.
Half-life	The time for the radioactivity of a radionuclide to decrease by radioactive decay to one half of its initial value. Half-lives range from fractions of a second to millions of years. The effective half-life in the human body of a quantity of ingested radioactivity is a function of the radioactive half-

	life and biokinetic behaviour.
Health Protection Agency (HPA)	Formerly the NRPB National Radiological Protection Board. An independent statutory body set up by the Radiological Protection Act 1970 to advance the acquisition of knowledge about the protection of mankind from radiation hazards and to provide information and advice on matters relating to radiological protection and radiation hazards.
Individual dose	Individual dose distinguishes the radiation exposure of a single individual from the collective dose to the population.
Intermediate Level Waste (ILW)	Waste with radioactivity levels exceeding the upper boundaries for low level waste and which requires special handling facilities or systems and cannot be disposed of to the LLWR near Drigg. Some Intermediate Level Waste from Chapelcross is routinely transferred to Medium Active Beta Gamma Waste Store (MBGWS) at British Nuclear Group Sellafield Limited.
Ion-Exchange Units	Ion exchange units contain zeolite material which can remove ions such as caesium-137 from the irradiated fuel Pond water.
ICRP	International Commission on Radiological Protection. An independent group of experts founded in 1928 which provides guidance on principles and criteria in the field of radiological protection. The recommendations are not legally binding, but are generally followed by the UK in legislation.
Ionising Radiation Regulations 1999 (IRRs 1999)	These regulations under the Health and safety at Work Act 1974 in part implement the European Basic Safety Standards Directive of 1996.
Liquid Scintillation Counting and Gamma Spectrometry	Two techniques for accurate measurement of radioactivity.
Low Level Waste (LLW)	Waste containing levels of radioactivity greater than those acceptable for dustbin disposal but not exceeding 4 GBq per tonne of alpha-emitting radionuclides or 12 GBq per tonne of beta-emitting radionuclides.
Magnox	A magnesium/aluminium alloy that is used in the manufacture of the canister for uranium fuel metal (‘Magnox fuel’) used in a type of nuclear reactor (‘Magnox reactor’).
Mega Becquerel (MBq)	10^6 Bq. Typically 200 kg of super phosphate garden fertiliser contains 1 MBq of natural radioactivity.
Micro Sievert (µSv)	10^{-6} Sv. A typical chest X-ray gives a dose of about 20 µSv and an aeroplane flight from the UK to Spain gives a dose of about 10 µSv.
Milli Sievert (mSv)	10^{-3} Sv
Natural background	Includes cosmic rays from outer space; gamma rays from the ground, floors and walls; and radon gas seeping from the rocks and soil.
NII (Nuclear Installations	Part of the Health and Safety Executive. It is responsible for enforcing legislation relating to nuclear safety under

Inspectorate)	the Nuclear installations Act 1965.
Nuclear fuel	The nuclear fuel in a Magnox reactor, consists of metallic uranium sealed in magnox alloy cans to form fuel elements.
Peta Becquerel (PBq)	10^{15} Bq
Radiation	Radiation, in this context, refers to ionising radiation. This may consist of subatomic particles or electromagnetic waves with sufficient energy to break chemical bonds.
Radioactivity	The spontaneous disintegration of atomic nuclei. Radioactive substances or the radiation they emit (e.g. alpha particles, beta particles, gamma rays). The rate of radioactive decay. Measured in the standard international (SI) unit, Becquerels (Bq) or their multiples or sub-multiples.
Radioactive decay	Radioactive decay is the process whereby some atoms may change, usually by emitting ionising radiation and eventually become non radioactive. There are many naturally occurring materials that undergo radioactive decay, in addition to those that may be produced by man.
Radioactive Substances Act (RSA) 1960, 1993	Statutory legislation to control the keeping and use of radioactive substances and the accumulation discharge or disposal of radioactive waste.
Radioactive waste	Material that contains radioactivity above the appropriate levels specified in the Radioactive Substances Act 1993 and which meets the definition of waste given in the Act.
Radionuclide	A radioactive isotope of an element.
Ramsar	Is an intergovernmental treaty which provided the framework for national action and international co-operation for the conservation and use of wetlands and their resources, signed in Ramsar, Iran, 1971.
SEPA	Scottish Environment Protection Agency.
Sievert	The Sv is the internationally approved unit of effective dose equivalent and is a measure of the degree of exposure to ionising radiation. It takes account of the harmfulness of different types of radiation. Frequently this unit is too large so that fractions of the unit are commonly used.
Stack	A stack is a chimney through which gaseous discharges are directed. The discharge point is usually some way above the adjacent building and ground level and ensures that the discharges are dispersed effectively in the air.
Tera Becquerel	10^{12} Bq

14. LIST OF ABBREVIATIONS AND ACRONYMS

ALARA	As Low As Reasonably Achievable
ALARP	As Low As Reasonably Practicable
AWS	Automatic Weather Station
BPM	Best Practicable Means
BDP	Baseline Decommissioning Plan
BPEO	Best Practicable Environmental Option
CXPP	Chapelcross Processing Plant
EAS	Environmental Assessment Software
EH&S	Environment Health and Safety
EHS&Q	Environment Health Safety and Quality
EIAP	Emergency Iodine Adsorption Plant
HEPA	High Efficiency Particulate Air
HPA	Health Protection Agency
HSE	Health and Safety Executive
HSWA	Health and Safety at Work etc Act 1974
ICRP	International Commission on Radiological Protection
ILW	Intermediate Level Waste
IRR99	Ionising Radiation Regulations 1999
ISO	International Standards Organisation
LLW	Low Level Waste
MAFF	Ministry of Agriculture, Fisheries and Food
m^3	Cubic metre
μSv	Microsievert
$\mu Sv\ y^{-1}$	Microsievert Per Year
MBGWS	Medium Active Beta Gamma Waste Store
mSv	Millisievert

$mSv.y^{-1}$	Millisievert Per Year
MW	Megawatt
NDA	Nuclear Decommissioning Authority
NII	Her Majesty’s Nuclear Installations Inspectorate
POCO	Post Operational Clean Out
REPPIR	Radiation Emergency Preparedness and Public Information Regulation
RSA93	Radioactive Substances Act 1991
SAC	Special Area of Conservation
SEPA	Scottish Environment Protection Agency
SPA	Special Protection Area
SSG	Site Stake Holders Group
SSSI	Site of Special Scientific Interest
Tera	10^{12}
UK	United Kingdom
WAMAC	Waste Monitoring and Compaction

APPENDICES

APPENDIX 1 SUMMARY OF QUARTERLY BULK EFFLUENT SAMPLES FOR 2003

Analysis type / Nuclide	1st Quarter		2nd Quarter		3rd Quarter		4th Quarter	
	Bq/m3	% cont	Bq/m3	% cont	Bq/m3	% cont	Bq/m3	% cont
Alpha	1.40E+05		1.40E+05		1.30E+05		8.30E+04	
Beta	6.30E+07		7.80E+07		2.10E+07		1.10E+07	
H3	7.20E+07	**60%**	9.00E+07	**69%**	1.60E+07	**56%**	5.80E+06	**42%**
Sr89		0%		0%		0%		0%
Sr90	2.90E+07	**24%**	2.60E+07	**20%**	6.70E+06	**24%**	2.40E+06	**18%**
Y91		0%		0%		0%		0%
C14	3.00E+04	0%	4.20E+04	0%	1.50E+04	0%	8.80E+03	0%
S35	3.10E+06	**3%**	2.00E+06	**2%**	2.50E+05	**1%**	1.20E+05	**1%**
Ag110m	1.70E+04	0%	1.90E+04	0%	3.70E+03	0%	6.00E+03	0%
Am241	5.30E+05	0%	6.40E+05	0%	3.60E+05	**1%**	2.20E+05	**2%**
Ce141	*3.00E+03*	0%	*3.60E+03*	0%	*1.50E+03*	0%	*1.50E+03*	0%
Ce144	5.20E+04	0%	*6.30E+04*	0%	4.40E+04	0%	1.00E+05	***1%***
Co58	*5.10E+03*	0%	1.40E+03	0%	*2.60E+03*	0%	8.70E+02	0%
Co60	3.50E+05	0%	4.80E+05	0%	3.30E+05	**1%**	2.90E+05	**2%**
Cr51	*1.20E+05*	0%	*2.70E+04*	0%	*2.10E+04*	0%	*8.90E+04*	**1%**
Cs134	1.30E+06	1%	8.80E+05	**1%**	3.00E+05	**1%**	2.50E+05	**2%**
Cs137	1.30E+07	**11%**	1.00E+07	**8%**	4.10E+06	**14%**	4.10E+06	**30%**
Eu154	5.80E+04	0%	*5.50E+03*	0%	3.40E+04	0%	4.50E+04	0%
Eu155	4.00E+04	0%	4.00E+04	0%	2.70E+04	0%	3.80E+04	0%
Fe59	*1.90E+04*	0%	*3.30E+03*	0%	*1.40E+04*	0%	*9.20E+02*	0%
La140	*7.90E+02*	0%	*4.50E+02*	0%	4.00E+03	0%	*3.00E+03*	0%
Mn54	5.40E+04	0%	2.40E+04	0%	1.10E+04	0%	1.10E+04	0%
Nb95	1.50E+04	0%	*1.40E+03*	0%	*9.80E+02*	0%	*1.10E+03*	0%
Ru103	*4.10E+03*	0%	*3.50E+03*	0%	*2.10E+03*	0%	*9.50E+03*	0%
Ru106	*2.20E+05*	0%	*1.10E+05*	0%	9.70E+04	0%	1.60E+05	**1%**
Sb124	2.60E+04	0%	*2.00E+03*	0%	5.90E+03	0%	*8.10E+03*	0%
Sb125	1.00E+05	0%	1.30E+05	0%	4.20E+04	0%	2.40E+04	0%
Zn65	1.20E+04	0%	*1.40E+04*	0%	5.20E+03	0%	9.20E+03	0%
Zr95	*4.40E+03*	0%	3.60E+04	0%	*2.40E+03*	0%	2.20E+03	0%
Na22	1.30E+03	0%	2.50E+04	0%	*1.10E+03*	0%	*1.10E+03*	0%
Na24	2.60E+03	0%	*2.10E+03*	0%	*1.60E+03*	0%	*1.60E+03*	0%
Sc46	*1.70E+03*	0%	*1.50E+03*	0%	*1.10E+03*	0%	*1.00E+03*	0%
Total	1.20E+08	99%	1.31E+08	99%	2.84E+07	99%	1.37E+07	99%
Total H3, Sr90, Cs137		95%		97%		94%		90%
Notes	total % relates to items in bold items in italics are < figures							

APPENDIX 2 SUMMARY OF QUARTERLY BULK EFFLUENT SAMPLES FOR 2006

Analysis type / Nuclide	1st Quarter		2nd Quarter		3rd Quarter		4th Quarter	
	Bq/m3	% cont	Bq/m3	% cont	Bq/m3	Bq/m3	% cont	Bq/m3
Alpha	*1.00E+04*		*1.00E+04*		*1.00E+04*		*1.00E+04*	
Beta	4.60E+06		7.00E+06		4.70E+06		1.40E+06	
H3	1.50E+06	**38%**	3.10E+06	**48%**	2.80E+07	**93%**	4.50E+05	**34%**
Sr89		0%		0%		0%		0%
Sr90	1.40E+06	**35%**	2.30E+06	**35%**	1.50E+06	**5%**	5.00E+05	**38%**
Y91		0%		0%		0%		0%
C14	*1.00E+04*	0%	*1.00E+04*	0%	*1.00E+04*	0%	*1.00E+04*	**1%**
S35	*2.00E+04*	**1%**	*2.00E+04*	**0%**	2.00E+04	**0%**	*2.00E+04*	**2%**
Ag110m	*3.10E+03*	0%	*3.10E+03*	0%	5.40E+03	0%	*3.90E+02*	0%
Am241	8.80E+03	0%	1.60E+04	0%	1.10E+04	**0%**	3.30E+03	0%
Ce141	*5.00E+02*	0%	*8.10E+02*	0%	*7.20E+02*	0%	*5.00E+02*	0%
Ce144	5.60E+03	0%	*2.20E+04*	0%	*3.60E+03*	0%	*2.40E+03*	0%
Co58	*4.00E+02*	0%	*5.40E+02*	0%	*3.80E+02*	0%	*3.40E+02*	0%
Co60	3.40E+04	1%	5.60E+04	1%	4.20E+04	**0%**	9.30E+03	**1%**
Cr51	*9.20E+03*	0%	*5.50E+03*	0%	*5.60E+03*	0%	*1.90E+04*	**1%**
Cs134	2.80E+04	1%	2.80E+04	**0%**	1.80E+04	**0%**	5.70E+03	0%
Cs137	9.00E+05	**23%**	9.10E+05	**14%**	5.30E+05	**2%**	2.80E+05	**21%**
Eu154	4.70E+03	0%	*5.30E+03*	0%	*1.00E+03*	0%	*8.60E+02*	0%
Eu155	5.10E+03	0%	*2.80E+03*	0%	*1.60E+03*	0%	*1.50E+03*	0%
Fe59	*5.90E+03*	0%	*4.80E+03*	0%	*5.10E+03*	0%	*5.00E+03*	0%
La140	*2.40E+03*	0%	*1.20E+03*	0%	*2.30E+02*	0%	*1.20E+02*	0%
Mn54	5.20E+03	0%	2.60E+03	0%	*2.40E+03*	0%	*5.10E+02*	0%
Nb95	1.70E+03	0%	*4.50E+02*	0%	*6.30E+02*	0%	*2.00E+03*	0%
Ru103	*1.20E+03*	0%	*1.00E+03*	0%	*7.90E+03*	0%	*7.80E+02*	0%
Ru106	*6.20E+03*	0%	*7.00E+03*	0%	*7.90E+03*	0%	*4.10E+03*	0%
Sb124	3.50E+03	0%	*3.30E+03*	0%	*4.50E+03*	0%	*2.00E+02*	0%
Sb125	1.10E+04	0%	*9.60E+03*	0%	*8.30E+03*	0%	*1.70E+03*	0%
Zn65	*6.60E+02*	0%	*3.00E+03*	0%	*5.20E+03*	0%	*1.80E+03*	0%
Zr95	*1.00E+03*	0%	3.20E+03	0%	*1.00E+03*	0%	*7.40E+02*	0%
Na22	*3.90E+02*	0%	4.10E+02	0%	*3.60E+02*	0%	*1.30E+03*	0%
Na24	*1.80E+02*	0%	*1.60E+03*	0%	*3.40E+02*	0%	*2.90E+03*	0%
Sc46	*4.60E+02*	0%	*1.50E+03*	0%	*5.10E+02*	0%	*3.30E+02*	0%
Total	3.97E+06	97%	6.52E+06	98%	3.02E+07	100%	1.32E+06	98%
Total H3, Sr90, Cs137		96%		97%		99%		93%

total % relates items in bold
items in italics are < figures

APPENDIX 3 ESTIMATE OF AERIAL DISCHARGES DUE TO NATURAL LEAKAGE RESULTING FROM EVAPORATION THE CHAPELCROSS COOLING PONDS

A3.1 Basis of Calculation

There is no general forced ventilation of the Pond building and any airborne discharge from the building will be due to adventitious leakage. The estimated annual discharge has been based on an estimate of the natural ventilation rate and airborne activity within the building, as measured by static air samplers.

A3.2 Estimated number of air changes within the facility.

The approximate volume of air in the building is based on general building drawing number G357, which indicates an approximate total volume of 8907 m^3.

Air flow into the building was measured in tow areas; the transit flash well opening and the fuel flask entry area (with doors open).

Airflow into the transit flask well area = Linear flow rate (ft/min) x cross-sectional area (ft^2)

$= 10 \times \pi \times 5^2$

$= 785\ ft^3.min^{-1}$

$= 22.3\ m^3.min^{-1}$

Airflow into fuel flask entry area = Linear flow rate (ft/min) x cross-sectional area (ft^2)

$= 2 \times [5 \times 11 \times 14]$

$= 1540\ ft^3.min^{-1}$

$= 43.6\ m^3.min^{-1}$

Total air in-leakage rate $\approx 22.3 + 43.6\ m^3.min^{-1}$

$= 65.9\ m^3.min^{-1}$

The time for a total air-change is given by: $\dfrac{\text{Building Air Volume}}{\text{Air in leakage rate}}$

$= \dfrac{8907}{65.9} \times \dfrac{1}{60}$

= 2.25 hours per air-change

Number of air-changes per hour = 1 / 2.25

= 0.44

A3.3 General Air Activity Concentrations

Historic data from assessments made between 1982 and 1984 were analysed and the following mean air activity levels were measured for the principal nuclides and groups of interest.

Nuclide	**Airborne activity ($Bq.m^{-3}$)**
Total α	< 0.0007
Total β	0.07
Sr-90	0.016
Co-60	0.002
Cs-137	0.02

A3.4 Airborne Annual Discharge

Annual Discharge = Mean Airborne Activity (Bq,m^{-3}) x volume Air discharged per year (m^3)

Air discharged By natural leakage = V x AC x H x D

Where:

V	=	Building vol (m^3)	=	8907 m^3
AC	=	Number of airchanges per hour	=	0.44 h^{-1}
H	=	Hours per day	=	24 h
D	=	Days per year	=	365.25

Annual volume of air discharged by natural leakage is therefore:

8907 x 0.44 x 24 x 365.25 = 3.44 E7 m^3

The maximum estimated Annual Discharge via natural leakage is therefore:

For total α = $0.0007\ 10^{-6}$ x $3.44\ 10^{7}$ = 0.024 $MBq.y^{-1}$

For Total β = $0.07\ 10^{-6}$ x $3.44\ 10^{7}$ = 2.4 $MBq.y^{-1}$

Accounting for deposition mechanisms within the building and the decontamination factor of the intact building, the estimated Annual Discharge via natural leakage can conservatively be reduced by an order of magnitude to :

For total α = 0.0024 $MBq.y^{-1}$

For Total β = 0.24 $MBq.y^{-1}$

Tritium and Sulphur-35 discharges were based on the typical activity concentrations in the pond water evaporation rate, based on pond water make-up. This pessimistically assumes that the isotopic composition in water vapour is the same as in the pond water.

The highest H3 concentration in pondwater in 2007 was around 55 $MBq.m^{-3}$ for Pond 2, as compared with 2.7 MBq. m^{-3} for Pond 1. The pond water make-up during 2004 – the most recent year for which information is available - was 180 m^3. The figure for pond water make-up is conservative for estimation of future evaporative discharges as, following removal of spent fuel, the ambient pond temperature has reduced significantly.

The estimated tritium discharge is therefore: 55 E6 ($Bq.m^{-3}$)_x 180 (m^3)

= 9.9 $GBq.y^{-1}$

For Sulphur-35, radioactive decay has reduced the average activity concentrations in quarterly bulk samples in 2006 to below the limit of detection of 0.02 $MBq.m^{-3}$. The estimated discharge via evaporative transfer from the ponds and natural leakage from the building is:

2 E4 ($Bq.m^{-3}$)_ x 180 (m^3)

= 3.60 $MBq.y^{-1}$

APPENDIX 4 RADIOLOGICAL RISK ASSESSMENT SUMMARY

Authorised discharges to atmosphere are currently made from several locations on the Chapelcross site. These included discharges from the Reactor, the Chapelcross processing plant, uranium store and Storage Ponds. The proposed atmospheric discharge limits are shown in Tables A1 (Reference A1). Authorised discharges of liquid effluent are also made by to the Solway Firth. The proposed marine discharge limits are shown in Table A2 (Reference A1).

Table A56 Annual Proposed Limit for Discharges to Atmosphere from the Chapelcross

Radionuclide/Group	Proposed Limits (TBq/y)
H-3	750
C-14	0.1
Beta part (Co-60)	0.00025

Table A57 Annual Proposed Limit for Liquid Discharges to the Solway Firth from Chapelcross

Radionuclide/Group	Proposed Limits (TBq/y)
H-3	2
Beta (Cs-134)*	2.5
Alpha (Pu-239)*	0.02

*These radionuclides were selected as they are the most radiotoxic of those identified so have been chosen to ensure that the assessment is conservative.

Assessments were made of doses to the public from discharges of gases to atmosphere and liquid discharges to the marine environment.

Assessment Methodology

The assessment of the radiological impact of discharges to atmosphere and of liquid discharges from the site to the Solway Firth was performed as detailed in Appendix B (atmospheric discharges from the reactors), Appendix C (discharges to the marine environment), using predicted environmental concentrations obtained with the PC CREAM model [Reference A2].

Exposure pathways

Members of the public can be exposed to radionuclides discharged to atmosphere and discharged to the Solway Firth by a range of exposure pathways. The exposure pathways considered in the assessment were based on a habits survey of groups around the site [Ref A3]. The exposure pathways for the discharges considered are as follows.

Discharges to atmosphere:

- ***Internal irradiation*** following inhalation of radionuclides discharged to atmosphere;
- ***Internal irradiation*** from the ingestion of radionuclides incorporated into locally produced foods following deposition of radionuclides discharged to atmosphere; and
- ***External irradiation*** from radionuclides in the atmosphere and deposited on the ground following discharge to atmosphere.

Discharges of liquids to the Irish Sea:

- ***External irradiation*** following incorporation of radionuclides into coastal sediment, including exposure to the skin from handling of fishing gear which has come into contact with the sediment.
- ***Internal irradiation*** following the ingestion of radionuclides in marine fish and shellfish caught along the coast and inhalation of sea spray incorporating radionuclides; and
- ***Internal irradiation*** following the inadvertent intake of coastal sediment incorporating radionuclides along the coast.

Candidate critical groups and habits

Details of the land use around the site were determined from site specific data and a review of Ordnance Survey Map data. The nearest domestic residences are about between 500 m and 1 km of the site. The site is surrounded by farmland at a comparable distance. For the purposes of this assessment it was assumed that the residence was located 750 m away from the discharge point. It was further assumed, conservatively, that all food was grown or collected at a similar distance.

There is current evidence of commercial fishing for a wide variety of fish and shellfish along the coast, where the liquid discharges from the site are made.

The mode of radioactive waste discharge, information from habits surveys, and radiological assessments made around the site in the past have been used to identify realistic candidate critical groups. The candidate critical groups were chosen to reflect the residential and other communities in the area closest to the site. Candidate critical groups' profiles have been based on both marine and aerial release pathways. To provide clarity to the assessment these groups have been designated based on the local produce they eat and where they tend to spend large amounts of time. It is important to note that each group may be exposure by both marine and terrestrial pathways, however one or the other pathway tends to dominate and has been used to categorise these site specific groups.

Candidate Critical Groups:

- ***CCG1 Local residents.*** For the purposes of this assessment it is assumed that a family (adults, children and infants) lives in the nearest habitation (approximately 750m from the site), are exposed to atmospheric discharges and to liquid discharges in the marine environment. It is assumed that members of this family spend most of their time at home, some of which is spent outside. They get their green vegetables, root vegetables and fruit from their garden or other local source (within 1 km from the site) and milk and meat from local farms close to the site and small amounts of local fish and shellfish. Local habit survey results were used to determine the occupancy and food intakes of the members of this group.
- ***CCG2 Fisherman and family.*** For the purposes of this assessment it is assumed that the fishermen and their families are exposed to liquid discharges from the site by spending some time on the intertidal sediments in the area and consuming high levels of locally caught fish and shellfish. They live within 1 km from the site and in some cases consume small amounts of locally produced foodstuffs (fruit and vegetables). They are exposed to atmospheric plumes arising from discharges. Local habit survey results were used to determine the occupancy and food intakes of the members of this group.

Results

Individual doses to candidate critical groups arising from discharges from Chapelcross site

The individual doses to the candidate critical groups are summarised in Table A3 for discharges at proposed limits. At these limits the dose from discharges to the terrestrial candidate critical group of local residents was 50 μSv/y (infants), 45 μSv/y (children) and 41 μSv/y (adults).

Table A3 Summary of Individual Doses to Candidate Critical Groups arising from Discharges at Chapelcross at Proposed Limits (μSv/y)

Candidate Critical Group	Age Group	Chapelcross site		
		Aerial	Marine	Total
CCG1 - local resident (high rate terrestrial food consumer	Adult	41	<1	41
	Child	43	2	45
	Infant	49	<1	50
CCG2 – local fisherman (high marine exposure)	Adult	35	6	41
	Child	38	2	40
	Infant	46	<1	46

Of the 50 μSv/y dose from discharges to terrestrial candidate critical group the contribution from liquid discharges was <1 μSv/y. The main pathway was to the terrestrial critical group was the inhalation of tritium. Table A4 provides a breakdown by pathway.

Table A4 Breakdown of Terrestrial Critical Group Dose by pathway arising from Discharges at Chapelcross at Proposed Limits (μSv/y)

Critical Group	Inhalation	Ground shine	Sub total non-food	Cow Meat	Sheep Meat	Sub total Terr food	Sub total terrestrial	Subtotal marine food	Sub total marine	Grand total
Infant	45.7	0.03	45.8	3.4	0.1	3.5	49.3	0.0	0.3	49.6

At the proposed limits the doses to members of the marine candidate critical group (local fisherman family) from discharges from the site was 40 μSv/y to adults, of which 35 μSv/y was attributed to atmospheric discharges. The main marine pathway was from beta activity in the fishing nets. The assessment has cautiously assumed that the predominant contributor to beta activity is Cs-134. It should be noted that Cs-134 levels will decline through radioactive decay. Dose based on the assumption that Cs-137 is the main beta activity contributor are about a factor of two lower. Table A5 provides a breakdown by pathway.

Table A5 **Breakdown of Marine Critical Group Dose by pathway arising from Discharges at Chapelcross at Proposed Limits (μSv/y)**

Critical Group	Inhalation	Ground shine	Sub total non-food	Sub total Terr food	Sub total terrestrial	Fish (sea)	Crustaceans	Molluscs	Subtotal marine food	External sediment	Other Marine Pathways	Sub total marine	Grand total
Adult	34.7	0.1	34.7	0.0	34.7	0.5	0.2	0.01	0.7	4.7	0.4	5.7	40.4

Critical group for Chapelcross site

The critical group for discharges at proposed limits Chapelcross are infant local residents, who received a dose of 50 μSv/y from discharges at the proposed limits.

At the proposed limits, the dose to the critical group from Chapelcross discharges is less than the dose constraint of 300 μSv/y and less than the site dose constraint of 500 μSv/y (Reference A4).

Collective Dose

Collective dose calculated for discharges at the proposed limits are given in Table A6.

Table A5 **Collective Dose associated with Liquid effluent Discharges to the Solway Firth**

Radionuclide	Collective Dose (man.Sv)		
	UK	Europe	World
Tritium	1.02E-06	4.36E-06	8.73E-05
Beta activity	0.015	0.035	0.04
Alpha activity	0.0016	0.003	0.003
Total	0.02	0.04	0.04

Table A6 **Collective Dose associated with Gaseous Discharges to Atmosphere**

Radionuclide	Collective Dose (man.Sv)		
	UK	Europe	World
Tritium	0.75	1.65	1.95
Carbon-14	0.028	0.24	1.8
Beta particulate	0.0011	0.0018	0.0018
Total	0.78	1.89	3.75

Conclusions

A prospective radiological assessment has been undertaken for future proposed discharge limits for Chapelcross as part of a review of this operator's authorised limits. Discharges are authorised to atmosphere and liquid discharges are authorised into the Solway Firth. The assessment has considered releases from aerial discharges and liquid discharges.

The critical group for discharges from the Station at proposed limits are infants in the high rate terrestrial consumers group of sheep meat and cattle meat who receive a dose of 50 μSv/y with the majority of the dose arising from aerial discharges from the inhalation of tritium.

All the doses associated with the proposed discharges from each source on the site are less than the source constraint of 300 μSv/y (Reference A4).

The maximum site dose taking account of discharges at proposed limits on aerial discharges from all sources and liquid discharges (but excluding direct radiation) is calculated as 50 μSv/y. Thus all the doses associated with the proposed discharges are less than the site constraint of 500 μSv/y (Reference A4).

References

A1. Pers. Comm, B Millard, Magnox, 2007 to Enviros.

A2. Mayall A, Cabianca T, Attwood C, Fayers C A, Smith J G, Penfold J, Steadman D, Martin G, Morris T P and Simmonds J R. PC CREAM-97 (PC CREAM-98 code update) NRPB Chilton NRPB-SR-296 (EUR 17791) (1997).

A3. CEFAS (2005) Radiological Habits Survey: Chapelcross, 2005. Commission by Food Standards Agency.

A4. Principles for the Assessment of Prospective Public Doses (Interim Guidance). Joint Environment Agencies' Document (December 2002).

APPENDIX 5 AERIAL ASSESSMENT METHODOLOGY

Model Information

Environmental concentrations (air concentration and ground deposition values were calculated using the computer model, PC CREAM. The methodology for the assessment of aerial and liquid discharges, including transfer through the food chain is described in (Reference B1).

Discharge Information

- The proposed limits, indicated in Table A1 are for tritium, carbon-14 and other beta. Other beta was conservatively assessed as Cobalt-60.
- The concept of effective stack heights was used in this assessment. Given there were a number of potential release points, a cautious approach was taken assuming that all of the discharge occurs at 15m above ground level. This is consistent with the effective stack height for the Ponds at Chapelcross. It is worth noting that that reactor building and production plant have effective release heights of 40 m and 35 m respectively, whilst the Uranium Store has an effective release height of 10 m.
- The duration of the release is assumed to be 1 year, i.e. 8760 hours.
- A dry deposition velocity of 10^{-3} m s^{-1} for all radionuclides considered except, tritium and carbon-14 (deposition of which is assumed to be zero).
- Generalised meteorological data are used in a continuous release assessment. It was assumed that Pasquill-Gifford Stability category D, indicating neutral weather conditions occurred 60% of the time. The meteorological data used in the Chapelcross assessment is derived from NRPB-R91 (Reference B2).
- A wind rose multiplier of 2.52[11] was applied to the meteorological data for the assessment based on the location of the local critical group and the prevailing wind direction.
- Surface roughness at Chapelcross is assumed to equal 0.3 m. This corresponds to data supplied in (Reference B2) for agricultural areas, similar to the environment around the Chapelcross site.
- Wet deposition is based on a washout coefficient of 10E-4 s^{-1} (Reference B3). This is based on an assumed precipitation rate of 1 mm h^{-1}.

Dosimetric Information

- The inhalation dose coefficients are taken from ICRP Publication 72 (Reference B4). The default lung class fractions are those recommended by the ICRP (Reference B4).
- Ingestion dose coefficients are also taken from the same source (Reference B4)
- The dose coefficients for external exposure to deposited material, taken from US EPA Federal Guidance Report 12 (Reference B5).
- The inhalation dose is multiplied by a resuspension factor to account for the remobilization of deposited particulates. The default value for this parameter is 1E-4.
- In the event of tritium being released to atmosphere it is assumed that the amount of tritium absorbed through the skin is equivalent to 50% of the amount inhaled, i.e. the inhalation dose from tritium is multiplied by a factor of 1.5 (Reference B6).
- Environmental concentrations in the food chain (integrated to 50 years) have been used (Reference B1).
- The overall dose is the sum of the doses from all the pathways over one year and integrated to emulate the dose over a lifetime. Inhalation and ingestion doses

[11] Assessment of recent years data indicates that the multiplier is 2.25, indicating that the estimates made in this report are suitably conservative.

are committed, subsequent irradiation is assumed to take place for a further 50 years for adults, 60 years for children and 70 years for infants (Reference B4).

Critical Group Data

- The Chapelcross critical group for atmospheric discharges is assumed to reside 750 m from the site centre.
- The methodology assesses the dose impact to 3 distinct age-groups; adults, 10 year old child and 1 year old infant.
- It is conservatively assumed that food production occurs at 750m.
- Where possible site specific habit data was used. In the absence of such data generic values from (Reference B7) were used. This includes a generic occupancy value of 0.9 for all age groups, breathing rates for the 3 age groups and the fraction of time spent indoors, assumed to be 0.9 for all age groups (Reference B7).
- The immersion dose is attenuated by a cloud-shielding factor based on the construction of the habitation. A value of 0.2 taken from (Reference B1) is a typical value for a house in the area surrounding Chapelcross. A ground-shielding factor must also be applied to attenuate the external dose from material deposited to ground. A value of 0.1 is used in these assessments (Reference B1).
- The current methodology assesses 10 foodstuffs, these are:

  - milk;
  - beef;
  - mutton;
  - offal;
  - green vegetables;
  - root vegetables (including potatoes);
  - fruit;
  - fish;
  - crustaceans; and
  - molluscs.

- Consumption rate data for the 3 age groups are derived from site survey data carried out by (Reference B8). The consumption rates were calculated using the "one-third cut-off method" as endorsed by the Environment Agency. The maximum recorded value is identified. This is divided by three to calculate a "critical sub group" for each food stuff. The arithmetic mean for those intakes above the cut-off value are used in the assessment. This process is repeated for each potential candidate critical group to build up a profile of the consumption habits of each candidate critical group.
- It is assumed that all of the food recorded in the local habit survey data by the candidate critical groups was produced locally, the local food multiplier is therefore 1.0.
- A specific activity model was used to determine the tritium and carbon-14 the ingestion doses.
- The food chain model assumes continuous deposition for a period of 1 year. The model integrates concentrations over a period of 50 years.

Collective Dose

Collective doses to the UK, Europe and the World, truncated to 500 years, were calculated using the computer code PC-CREAM (Reference B1) augmented as described in Reference A1. For present purposes for aerial discharges, "Europe" was taken to include all of Europe within about 3000km of London, including Western Russia, Iceland and Greenland.

References

B1. Simmonds J R, Lawson G and Mayall A (1995). Methodology for assessing the radiological consequences of routine releases to the environment, EUR 15760, Office for Official Publications of the European Communities.

B2. Clarke R H, (1979). 'The first report of a Working Group on Atmospheric Dispersion (WGAD): A model for short and medium range dispersion of radionuclides released to the atmosphere', NRPB-R91 (London, HMSO).

B3. Jones J A (1981). 'A procedure to include deposition in the model for short and medium range atmospheric dispersion of radionuclides', NRPB Report NRPB-R122.

B4. International Commission of Radiological Protection - ICRP (1996), 'Age-Dependent Doses to Members of the Public from Intake of Radionuclides. Part 5. Compilation of Ingestion and Inhalation Dose Coefficients', Annals of the ICRP. ICRP-72.

B5. EPA (1993). External Exposure to Radionuclides in Air, Water, and Soil. Federal Guidance Report No. 12, EPA-402-R-93-081(Oak Ridge National Laboratory, Oak Ridge, TN; U.S. Environmental Protection Agency, Washington, DC).

B6. Higgins N A, Shaw P V, Haywood S M and Jones J A (1996). A dynamic model for predicting the transfer of tritium through the terrestrial foodchain, NRPB-278.

B7. Smith K and Jones J A (2003) Generalised Habit Data for Radiological Assessments, NRPB W41.

B8. CEFAS (2005) Radiological Habits Survey: Chapelcross, 2005. Commission by Food Standards Agency

APPENDIX 6 MARINE ASSESSMENT METHODOLOGY

Model Information

Environmental concentrations (sea water concentrations (filtered and unfiltered), sediment concentrations and concentration in sea spray) were calculated using the computer model, PC CREAM. The methodology for the assessment of aerial and liquid discharges, including transfer through the food chain is described in (Reference C1).

Discharge Information

- The proposed limits, indicated in Table A2 are for tritium, alpha and other beta excluding tritium. Alpha was conservatively assessed as Plutonium-239, other beta was conservatively assessed as Caesium-134 as this is more radiotoxic then Sr-90 or Cs-137.
- The duration of the release is assumed to be 1 year, i.e. 8760 hours.

Dosimetric Information

- The inhalation dose coefficients are taken from (Reference C2). The default lung class fractions are those recommended by the ICRP (Reference C2).
- Ingestion dose coefficients are also taken from the same source, (Reference C2).
- The dose coefficients for external exposure to deposited material, taken from US EPA Federal Guidance Report 12 (Reference C3).
- Environmental concentrations in the marine environment (integrated to 50 years) are based on the methodology outlined in (Reference C1)
- The overall dose is the sum of the doses from all the pathways over one year and integrated to emulate the dose over a lifetime. Inhalation and ingestion doses are committed, subsequent irradiation is assumed to take place for a further 50 years for adults, 60 years for children and 70 years for infants (Reference C2).
- External doses from handling fishing gear were calculated using the methodology outlined in (Reference C4). It is widely acknowledged that this is a very cautious approach.
- Concentrations in marine foods were calculated using concentrations factors from (Reference C5).

Critical Group Data

- The Chapelcross critical group for marine discharges is conservatively assumed to reside 750 m from the site centre.
- The methodology assesses the dose impact to 3 distinct age-groups; adults, 10 year old child and 1 year old infant.
- It is conservatively assumed that food production occurs at 750 m.
- Where possible site specific habit data was used. In the absence of such data generic values from (Reference C6) were used. This includes a generic occupancy value of 0.9 for all age groups, breathing rates for the 3 age groups and the fraction of time spent indoors, assumed to be 0.9 for all age groups (Reference C6).
- A shoreline dose reduction factor was applied to external doses from sediments. This is based on guidance in (Reference C3) and the approach has been accepted by the Environment Agency in the assessment of marine discharges from Nuclear Power Stations.
- The current methodology assesses 10 foodstuffs, these are:

- milk;
- beef;
- mutton;
- offal;
- green vegetables;
- root vegetables (including potatoes);
- fruit;
- fish;
- crustaceans; and
- molluscs.

- Consumption rate data for the 3 age groups are derived from site survey data carried out by (Reference C7). The consumption rates were calculated using the "one-third cut-off method" as endorsed by the Environment Agency. The maximum recorded value is identified. This is divided by three to calculate a "critical sub group" for each food stuff. The arithmetic mean for those intakes above the cut-off value are used in the assessment. This process is repeated for using the same data defined by the initial cut off for each pathway within each potential candidate critical group to build up a profile of the consumption habits of each candidate critical group.
- It is assumed that all of the food recorded in the local habit survey data by the candidate critical groups was produced locally, the local food multiplier is therefore 1.0.
- Occupancy across the different environments was aggregated within the candidate critical groups to give a total exposure time in hours per year.
- A specific activity model was used to determine the tritium and carbon-14 the ingestion doses.

Collective Dose

Collective doses to the UK, Europe and the World, truncated to 500 years, were calculated using the collective dose factors given in Reference C6. For present purposes for aquatic discharges, "Europe" was taken to include all of European Union.

References

C1. Simmonds J R, Lawson G and Mayall A (1995). Methodology for assessing the radiological consequences of routine releases to the environment, EUR 15760, Office for Official Publications of the European Communities.

C2. International Commission of Radiological Protection - ICRP (1996), 'Age-Dependent Doses to Members of the Public from Intake of Radionuclides. Part 5. Compilation of Ingestion and Inhalation Dose Coefficients', Annals of the ICRP. ICRP-72.

C3. EPA (1993). External Exposure to Radionuclides in Air, Water, and Soil. Federal Guidance Report No. 12, EPA-402-R-93-081(Oak Ridge National Laboratory, Oak Ridge, TN; U.S. Environmental Protection Agency, Washington, DC).

C4. Hunt (1984), Simple models to calculate external dose. Jour, Rad Prot.

C7. CEFAS (2005) Radiological Habits Survey: Chapelcross, 2005. Commission by Food Standards Agency.

C6. Smith K and Jones J A (2003) Generalised Habit Data for Radiological Assessments, NRPB W41.

C5. International Atomic Energy Agency (2004) Sediment Distribution Coefficients and Concentration Factors for Biota in the Marine Environment, Technical Report Series 422.

C6. Monitoring our Environment, Discharges and Monitoring of the Environment in the UK, BNFL Annual Report.

APPENDIX 7 ACTIVITY FINGERPRINTS FOR LLW STREAMS

Six LLW streams have been identified for the Chapelcross site. These include:

- CXPP Tritiated LLW;
- Reactor and CXPP non-tritiated LLW;
- Ponds LLW;
- Reactor irregular LLW;
- Ponds irregular LLW; and,
- Uranium store LLW.

The activity fingerprints for the reactor and CXPP non-tritiated, pond and uranium store waste streams are detailed in Tables A6 to A8, respectively. The CXPP tritiated LLW stream is currently under review and therefore the waste fingerprint has not been detailed. For both the reactor and ponds irregular LLW streams, no specific activity fingerprint is available. Samples of waste from both streams are analysed for gamma, beta and alpha radionuclide content. However, where this is impracticable the standard fingerprints for the reactor or standard (non-tritiated) tritium plant waste stream (C211) is used for the reactor irregular stream and the pond waste stream fingerprint (2C12) is used for the pond irregular stream.

Table A60 Radionuclide composition of the waste streams 2C11 - Reactor and CXPP non-tritiated

Drigg D4 Form Notation	Radionuclide	% Activity	
		Reactor	CXPP (non-tritiated)
Specified beta emitting radionuclides	C-14	0.029	0.01
	C-60	6.2	7.1
	Tritium	0.71	59.8
Other beta emitting radionuclides with half-life >3 months	Cd-109	0.31	0.26
	Ce-144	0.13	N/D(1)
	Cs-137	0.099	N/D
	Fe-55	87.9	25.9
	Mn-54	0.43	0.37
	Ni-63	0.32	1.5
	Ru-106	0.20	N/D
	Zn-65	0.40	2.0
Other beta emitting radionuclides with half-life < 3 months	Cr-51	1.4	2.4
	Fe-59	1.3	0.6
	Nb-95	0.11	N/D
	Sc-46	0.23	N/D
	Zr-95	0.18	N/D
	Total	100	100

Table Notes: (1) N/D - below limit of detection by analysis or less than 1% of total activity

Table A61 - Radionuclide composition of the waste streams 2C12 - Pond

Drigg D4 Form Notation	Radionuclide	% Activity
Alpha emitting radionuclides with half-life >3 months	Pu-238	0.032
	Pu-239	0.052
	Pu-240	0.068
	Am-241	0.30
Specified beta emitting radionuclides	C-14	0.74
	C-60	8.6
	Tritium	30.7
Other beta emitting radionuclides with half-life >3 months	Cd-109	0.47
	Cs-134	0.089
	Cs-137	5.6
	Fe-55	33.8
	Mn-54	0.43
	Pu-241	2.9
	Sr-90	12.4
	Zn-65	0.57
Other beta emitting radionuclides with half-life < 3 months	Cr-51	0.93
	Fe-59	0.66
	S-35	1.3
	Sc-46	0.39
	Total	100

Table A62 - Radionuclide composition of the waste streams 2C16 – Uranium Store

Drigg D4 Form Notation	Radionuclide	% Activity
Uranium nuclides	U 234	42.6
	U 235	1.5
	U 236	4.1
	U 238	50.3
Other alpha emitting radionuclides with half-life >3 months	Pu 239	0.011
	Pu 240	0.013
	Am 241	0.020
Other beta emitting radionuclides with half-life >3 months	Tc 99	1.2
	Pu 241	0.24
Other beta emitting radionuclides with half-life < 3 months	Pa 233	0.04
	Total	100

APPENDIX 8 AGREEMENT IN PRINCIPLE FOR DISPOSAL OF ORGANIC WASTE FOR INCINERATION

VEOLIA
ENVIRONMENTAL SERVICES

Our Ref.: NG 242
Your Ref.:

Subject to Contract

Date: 28th March 2007

Walter Kennedy
British Nuclear Group
Chapelcross
Annan
Dumfriesshire
DG12 6RF

Dear Mr Kennedy,

Re: Radioactive Waste for Incineration at Veolia Environmental Services Fawley Incinerator – Authorisation No. AL5160/BZ6759

I can confirm that Veolia Environmental Services can accept 'in principal (up to our consent)' radioactive wastes that have been generated at the aforementioned address providing that the waste requires treatment by the principal activity of incineration and subsequent chemical treatment within the gas cleaning and effluent treatment plants.

Acceptance of the waste will be subject to:

1. Agreement by the Environment Agency or Scottish Environment Protection Agency.
2. The levels allocated under Veolia Environmental Services Authorisation No. AL5160/BZ6759 or authorisation issued to any future owner of the site.
3. Our Terms & Conditions.
4. Our Conditions of Acceptance.
5. The price of disposal.

The material must be packed to comply with our authorisation for processing such wastes as outlined in the schedule attached.

For details of the incinerator as required for RSA 3 please see attached.

Full technical details can be discussed with myself on 023 8088 3508 or Mr Mike Beedham – General Manager Organics on 07773 813808.

Yours sincerely,
For and on behalf of Veolia Environmental Services

N Green

Mrs Nicki Green
Customer Services Manager (Radioactives) /
Radiation Protection Supervisor

Tel: 023 8088 3508
Fax: 023 8088 3010
Email: nicki.green@veolia.co.uk

Page 1 of 3

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Registered office: Veolia House, 154A Pentonville Road, London, N1 9PE
Registered in England 2481991

VEOLIA
ENVIRONMENTAL SERVICES

Summary of the Authorisation to Accept Radioactive Waste at Veolia Environmental Services Fawley Incinerator

Veolia Environmental Services RSA93 authorised monthly limits and standard package and consignment limits appear in the following table. All values quoted are in MegaBecquerels (MBq).

Categories and individual radionuclides			Authorised monthly limit	Consignment limit	Package limit
1	Tritium		800,000	600,000	100,000
2	Carbon-14			300,000	
3	Iodine-125 and Iodine-131	^{125}I	1000	1000	200
		^{131}I		100	10
4	Beta and weak gamma emitters ^{32}P, ^{33}P, ^{35}S, ^{36}Cl, ^{45}Ca, ^{51}Cr, ^{55}Fe, ^{63}Ni, ^{90}Sr, ^{109}Cd, ^{129}I, ^{147}Pm		500	500	40
5	Medium gamma emitters ^{57}Co, ^{65}Zn, ^{75}Se, ^{85}Sr, ^{86}Rb, ^{95}Zr, ^{103}Ru, ^{106}Ru, ^{133}Ba, ^{137}Cs, ^{203}Hg			100	10
6	Strong gamma emitters ^{22}Na, ^{46}Sc, ^{54}Mn, ^{59}Fe, ^{56}Co, ^{58}Co, ^{60}Co, ^{110m}Ag, ^{124}Sb, ^{134}Cs, ^{152}Eu, ^{154}Eu			100	4
7	Other isotopes not listed (excluding alpha emitters)			100	4
8	Alpha emitters		5	5	0.5

The maximum volume that can be accepted per consignment is 30 cubic metres with an individual package size of 200 litres.
Each container shall be labelled with the activities of each radioactive isotope present.
The activities for all isotopes must be declared separately.
We would prefer liquid waste to be sent in vials or containers of less than 10 litres. If free liquids are sent they must be fully pumpable and shall be transported in closed head or bung top drums.
These package limits are based on Veolia Environmental Services processing constraints, including RSA93 authorised daily limits and limits on concentrations in solid waste arisings from the incinerator. They do NOT necessarily imply that these activities can be transported in individual packages declared as "excepted packages" or "industrial packages" under the current Transport Regulations or other applicable regulations. Consignors must ensure that they address this issue themselves. Note that the limits for Tritium, Carbon-14 and some alpha emitters in excepted packages are lower than stated above, especially in the case of liquid wastes.

VEOLIA
ENVIRONMENTAL SERVICES

Information Required For RSA3 Application to the Environment Agency or SEPA

1. Incinerator Operator:	Veolia Environmental Services Charleston Road Hardley Hythe Southampton Hants SO45 3ZA
2. Map Reference:	SU432058
3. Mr Mike Beedham	Tel: 07773 813808 Fax: 023 8088 3010 Email: mike.beedham@veolia.co.uk
Mrs Nicki Green	Tel: 023 8088 3508 Fax: 023 8088 3010 Email: nicki.green@veolia.co.uk

4. New Forest District Council
5. Incinerator was designed and built by Rechem with MAN as the main contractor. There is no model type.
6. The incinerator is a rotary kiln fitted with an afterburner, a wet quenching system, a wet packed absorber (gas cleaning) and wet electrostatic precipitators.
7. Solid and liquid industrial and chemical waste with an average throughput of 35,000 to 40,000 tonnes per year. The incinerator runs on a 24 hour a day, 340 days a year basis. Ash is collected, quenched and removed from the kiln via a deslagger. After satisfactory analysis the slag is sent to landfill.
8. Average daily volume of ash is 11 tonnes.
9. The stack discharge point is 37m above ground level.
10. The estimated rate of aerial discharge is 25 cubic metres per second.
11. The public has access to a point 60 metres away from the stack.
12. The nearest person lives 500 metres away.
13. Disposal information is recorded as part of Veolia Environmental Services authorisation to discharge issued by the Environment Agency under Authorisation Number AL5160/BZ6759.

APPENDIX 9 INTERSITE AGREEMENT FOR TRANSFER OF BETA / GAMMA WASTES TO SELLAFIELD

Agreement for 2007/2008

SERVICE SPECIFICATION 2007/2008

Specification No			**Total Cost (£):**	£1,087,380
Customer	**Site**	Chapelcross		
	Company	British Nuclear Group		
Customer Contact(s)		Mr C Archibald	**Tel:**	01461 208778
Supplier	**OU No**	35060		
	Service provided	Handling and storage of miscellaneous beta gamma waste.		
Supplier Contact(s)		Mr G Freeman	**Tel:**	019467 76063
Basis of charging **Tick required option**		☐ **Fixed Amount**	☐ **Timebooking**	☒ **Direct Activity Allocation**
Charging Frequency		Invoices will be raised/costs flowed at the end of each period, unless otherwise agreed between BNGSL Commercial and receiving Customers.		
Total Budget Cost		**Labour (timebooking)**	0	
		Materials	0	
		T&E	0	
		Fixed Amount	0	
		Direct Activity Allocation	£1,087,380	
		Total	**£**	
Service Supplier CWBS no.		35.14.43.35060.39900.35/05708		
CWBS Description		MBGWS Storage Operations		
Service Demander CWBS no.		Chapelcross – 33.52.99.33/20091.46.95		
Scope of Service		As part of the integrated service to Site, accept consignments into MBGWS and put to store.		
Service Level		Receive and store 84 consignments from Chapelcross to MBGWS for 2007/08. It has been agreed with Chapelcross that they will be charged on a pro-rata basis based on the total number of consignments into MBGWS in 2007/08.		
Limitations		N/A		

SERVICE SPECIFICATION AGREED BY:

Role	Name	Signature	Date
Technical Customer – Affiliate/SLC/3rd Party Customer	G. FREEMAN		9/2/07
Technical Supplier - BNGSL	P. JOWLES		20/2/07
Commercial – Affiliate/SLC/3rd Party	COLIN ARCHIBALD		15/2/07
Commercial - BNGSL			

Draft agreement for 2008/2009

SERVICE SPECIFICATION 2008/2009

Specification No			**Total Cost (£):**	**£394,592**
Customer	**Site**	Chaplecross		
	Company	Magnox North		
Customer Contact(s)		Mr C Archibald	**Tel:**	01461 208778
Supplier	**OU No**	35060		
	Service provided	Handling and storage of miscellaneous beta gamma waste.		
Supplier Contact(s)		Mr G Freeman	**Tel:**	019467 76063
Basis of charging **Tick required option**		☐ **Fixed Amount**	☐ **Timebooking**	☒ **Direct Activity Allocation eg Utility/Laundry** **Please Note: Any tariff rates quoted for DAA's are indicative and for planning purposes only, the actual rates will be communicated as soon as they are known.**
Charging Frequency		**Invoices will be raised/costs flowed at the end of each period, unless otherwise agreed between Sellafield Ltd Commercial and receiving Customers.**		
Total Budget Cost		**Labour (timebooking)**		**£**
		Materials		**£**
		T&E		**£**
		Fixed Amount		**£**
		Direct Activity Allocation		**£**
		Total		**£394,592**
Service Supplier CWBS no. (SAP 4.7 only)		35.14.43.35060.3990.35/05708		
CWBS Description		MBGWS Storage Operations		
Service Demander CWBS no.				
Scope of Service		As part of the integrated service to Site, accept consignments into MBGWS and put to store.		
Service Level		Receive and store 12 reactor consignments (1.727m3) and 60 process plant consignments (0.3 m3) from Chapelcross to MBGWS for 2008/09. It has been agreed with Chapelcross that they will be charged on a tariff rate per m3.		

Limitations	N/A

SERVICE SPECIFICATION AGREED BY:

Role	Name	Signature	Date
Technical Customer – Affiliate/SLC/3rd Party Customer	P. JONES	[illegible]	25-10-07
Technical Supplier - Sellafield Ltd			
Commercial – Affiliate/SLC/3rd Party	COLIN ARCHIBALD	Archibald	25.10.07
Commercial – Sellafield Ltd	Iain Copeland		