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BWRX-300 UK Generic Design Assessment (GDA) Chapter E5 - Radioactive Waste Management Arrangements

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EXECUTIVE SUMMARY

The purpose of this Preliminary Environmental Report (PER) chapter is to present the arrangements for management of the radioactive wastes (including Spent Fuel (SF)) arising from commissioning, operation, and subsequent decommissioning of the BWRX-300 SMR in compliance with United Kingdom (UK) requirements.

The arrangements presented include considerations for the management of SF as radioactive waste, since it is presently assumed, in line with UK government policy, that SF will not be reprocessed and will therefore be redefined as radioactive waste at a point in the future.

The chapter presents a level of detail commensurate with a two-step Generic Design Assessment (GDA).

The scope of this chapter covers the Radioactive Waste Management (RWM) systems integral to the BWRX-300 design as presented for GDA and includes discussions of the upstream systems that generate radioactive wastes. The document provides indicative information on the additional 'on-site' RWM capabilities that will be required to provide a holistic set of arrangements that are fully compliant with UK requirements, noting that related strategic decision making, and demonstration of Best Available Technique (BAT) are beyond the scope of GDA Step 2.

System interfaces/dependencies are identified, and suitable cross references used to direct the reader to the relevant interfacing chapters of the PER.

This chapter supports the overall claim that "the BWRX-300 is capable of being constructed, operated and decommissioned in accordance with the standards of environmental, safety, security and safeguard protection required in the United Kingdom", and provides information to support the environmental Level 1 claim that "the design of the BWRX-300 SMR has been optimised to reduce environmental impacts to As Low as Reasonably Achievable (ALARA) throughout the whole lifecycle (construction, commissioning, operation and decommissioning)".

Appendix A provides an overview of the Low-Level Waste Repository Ltd waste services contract structure, which provides a range of treatment and disposal services for low level radioactive waste in the UK.

Appendix B provides a Forward Action Plan (FAP), which includes future work commitments and recommendations for future work where 'gaps' to GDA expectations have been identified.

An overview of the management arrangements for the main waste categories is presented in Appendices C, D and E.

ACRONYMS AND ABBREVIATIONS

Acronym	Explanation
ABWR	Advanced Boiling Water Reactor
AHU	Air Handling Unit
ALARA	As Low As Reasonably Achievable
ALARP	As Low As Reasonably Practicable
BAT	Best Available Technique
BWR	Boiling Water Reactor
CFD	Condensate Filters and Demineralizers System
CRB	Control Rod Blade
CST	Condensate Storage Tank
CUW	Reactor Water Cleanup System
DSILW	Dry Solid Intermediate Level Waste
EFS	Equipment and Floor Drain System
ESBWR	Economic Simplified Boiling Water Reactor
EUST	End User Source Term
FAP	Forward Action Plan
FPC	Fuel Pool Cooling and Cleanup System
GAC	Granular Activated Carbon
GDA	Generic Design Assessment
GDF	Geological Disposal Facility
GEH	GE Hitachi Nuclear Energy Americas, LLC
GT	Gamma Thermometer
HAW	Higher Activity Waste
HHGW	High Heat Generating Waste
HLW	High Level Waste
HVS	Heating, Ventilation and Cooling System
ICC	Isolation Condenser Pools Cooling and Cleanup System
IICC	Irradiated In-Core Components
ILW	Intermediate Level Waste
IWS	Integrated Waste Strategy
LAW	Lower Activity Waste
LHGW	Low Heat Generating Waste
LLW	Low Level Waste
LLWR	Low Level Waste Repository
LoC	Letter of Compliance
LPRM	Local Power Range Monitor
LWM	Liquid Waste Management

Acronym	Explanation
NDA	Nuclear Decommissioning Authority
NPP	Nuclear Power Plant
NSD	Near Surface Disposal
NWS	Nuclear Waste Services
ONR	Office for Nuclear Regulation
PCF	Pre/Post Conditioning Filter
PER	Preliminary Environmental Report
POCO	Post Operational Clean Out
PSR	Preliminary Safety Report
RO	Reverse Osmosis
RPV	Reactor Pressure Vessel
RWM	Radioactive Waste Management
RWST	Refueling Water Storage Tank
SF	Spent Fuel
SMR	Small Modular Reactor
SWM	Solid Waste Management
UK	United Kingdom of Great Britain and Northern Ireland
U.S.	United States of America
VLLW	Very Low Level Waste
WAC	Waste Acceptance Criteria
WRNM	Wide Range Neutron Monitor
WSILW	Wet Solid Intermediate Level Waste

SYMBOLS AND DEFINITIONS

Term	Definition
Becquerel	The unit of radioactivity used in the International System of Units (SI). A measure of the amount of ionizing radiation released when a radioactive element spontaneously emits energy as a result of the radioactive decay (or disintegration) of an unstable atom. 1 Becquerel (Bq) represents a rate of radioactive decay equal to 1 disintegration per second.

Symbol	Definition
Bq	Becquerel
GBq	Gigabecquerel
GBq/t	Gigabecquerels per Tonne
MBq	Megabecquerel

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REVISION SUMMARY

Revision #	Section Modified	Revision Summary
A	All	Initial Issuance

5. RADIOACTIVE WASTE MANAGEMENT ARRANGEMENTS

Introduction

The purpose of this Preliminary Environment Report (PER) chapter is to set out the arrangements for management of the radioactive wastes generated by the commissioning, operation, and subsequent decommissioning of a generic UK installation of the GEH BWRX-300 Small Modular Reactor (SMR). The BWRX-300 is the tenth evolution of the Boiling Water Reactor (BWR) design and an evolution of both the Economic Simplified Boiling Water Reactor (ESBWR) and the Advanced Boiling Water Reactor (ABWR).

The arrangements presented for the management of radioactive wastes arising from the commissioning, operation and subsequent decommissioning of a BWRX-300 SMR include considerations for the management of Spent Fuel (SF) as radioactive waste, since it is presently assumed, in line with United Kingdom (UK) government policy CP 1009, "Civil Nuclear: Roadmap to 2050," (Reference 5-1), that SF will not be reprocessed and will therefore be redefined as radioactive waste at a point in the future.

The overall objective of the Generic Design Assessment (GDA) submissions for BWRX-300 is to demonstrate that the BWRX-300 is capable of being constructed, operated, and decommissioned in accordance with the standards of environmental, safety, security and safeguard protection required in the UK.

With specific regards to the management of radioactive wastes (including SF) arising from the commissioning, operation, and subsequent decommissioning of a BWRX-300 the chapter provides further and more detailed information in support of the claims presented in NEDC-34223P, "BWRX-300 UK GDA Ch. E6: Demonstration of Best Available Techniques Approach," (Reference 5-2).

A UK variant of the ABWR (the UK ABWR) was previously submitted for GDA by GEH, supported by its UK subsidiary Horizon Nuclear Power Ltd.

The UK ABWR was granted Design Acceptance Confirmation by the Office for Nuclear Regulation (ONR), and a Statement of Design Acceptability by the Environment Agency, supported by Natural Resources Wales (hereafter referred to as 'the environmental regulators') in December 2017.

Predictably, the radioactive wastes generated through the commissioning, operation, and decommissioning of the BWRX-300 are similar in nature to those generated by predecessor BWR designs.

The BWRX-300 is a GEH design, and as such it is more aligned to the ESBWR design and reflects a significant design effort to simplify the design, reduce the amount of plant and systems and simplify its operation. These simplifications also contribute to a reduction in manufacturing and construction costs, thereby increasing the commercial viability of the BWRX-300 and enabling it to support UK Government aspirations with respect to decarbonising the UK economy to meet the declared "Net Zero target by 2050, outlined in Net Zero Strategy: Build Back Greener," (Reference 5-3).

The generation of radioactive waste is a direct and inevitable consequence of the use of nuclear energy for power generation. The generation of radioactive waste is justified by balancing the benefits of generation of large quantities of low carbon electricity, and wider beneficial societal impacts, with the detriments associated with managing, storing, and ultimately disposing of the radioactive wastes generated.

Section 5 of the document NEDC-34228P, "Integrated Waste Strategy," (IWS) (Reference 5-4) for the BWRX-300 provides a broad justification against the principle of sustainability, and, specifically, show how new nuclear build supports achievement of the relevant United Nations Sustainable Development Goals from "The 17 Goals: Sustainable Development," (Reference 5-5).

NEDC-34221P, “BWRX-300 UK GDA Ch. E4: Information About the Design,” (Reference 5-6) provides more detailed information relating to the relevant systems within the BWRX-300 design which have a bearing on the generation and subsequent management of radioactive wastes and SF arising from commissioning and operation of a BWRX-300.

Consideration of the wastes arising from subsequent decommissioning of BWRX-300 are presented in this chapter.

At this early stage of development, the BWRX-300 design does not fully reflect alignment with UK expectations and requirements for the compliant management of radioactive wastes arising from its commissioning and operation. In order to present an indicative alignment of BWRX-300 wastes with ‘typical’ UK practices a large number of assumptions have been defined in this document. A summary of the assumptions is presented in Table 5-8.

Indicative baselines for the management of the main waste streams, based on the stated assumptions, are presented in Appendices C, D and E.

Scope

The scope of this chapter covers the management of all anticipated solid radioactive wastes arising from the commissioning, operation, and eventual decommissioning of a BWRX-300 reactor, including the arrangements for management of SF, on the assumption that SF will not be reprocessed and will ultimately be disposed of to a national Geological Disposal Facility (GDF) (CP 1009 (Reference 5-1)) as High Heat Generating Waste (HHGW) as defined in WPS/240/02, “Waste Package Specification and Guidance Documentation: Specification for High Heat Generating Waste Precursor Product,” (Reference 5-7).

Additional detail in support of this chapter is presented in the following supporting documents:

- NEDC-34221P, “BWRX-300 UK GDA Ch. E4: Information About the Design,” (Reference 5-6)
- NEDC-34223P, “BWRX-300 UK GDA Ch. E6: Demonstration of Best Available Techniques Approach,” (Reference 5-2)
- NEDC-34224P, “BWRX-300 UK GDA Ch. E7: Radioactive Discharges,” (Reference 5-8)
- NEDC-34228P, “Integrated Waste Strategy,” (IWS) (Reference 5-4)
- NEDC-34229P, “Demonstration of Disposability for Higher Activity Radioactive Wastes (Including Spent Fuel),” (Reference 5-9)
- NEDC-34174P, “BWRX-300 UK GDA Ch. 11: Management of Radioactive Waste,” (Reference 5-10)
- NEDC-34193P, “BWRX-300 UK GDA Ch. 21: Decommissioning and End of Life Aspects,” (Reference 5-11)
- NEDC-34198P, “BWRX-300 UK GDA Ch. 26: Interim Storage of Spent Fuel,” (Reference 5-12)

The wastes associated with the commissioning, operation, and decommissioning of the BWRX-300 are similar to those produced by the ABWR, but with a few notable differences that will be fully detailed in this report. The wastes will arise through four primary means:

- Treatment and purification of aqueous fluids (reactor coolant, condensate, feedwater, pools, and plant drainage systems) giving rise to secondary (wastes arising as a result of materials coming into contact with radioactive substances) wet solid wastes
- Generation of SF

- Operational, maintenance and repair/refurbishment activities giving rise to several waste types
- Decommissioning, giving rise to a final batch of SF and a range of decommissioning wastes

At this early stage, the BWRX-300 design comprises the power block which houses the reactor, turbine, radwaste, control and service buildings and this is presented as a generic design capable of being deployed anywhere in the world. In order for the design to integrate in a UK context, and to align with UK regulatory expectations, additional capabilities will be required outside of the power block to provide additional support functions, such as radioactive waste processing and storage and SF storage. Since these capabilities are not included within the power block design and require ‘tailoring’ to fit appropriate UK strategy and context, they are presented as ‘indicative scope’ which will be subject to more detailed consideration, design development, and associated justification and substantiation at the site-specific development stage. It is recognised that considerations, such as siting multiple units on a site, are likely to significantly impact decision making relating to these aspects and it is therefore appropriate to present them as ‘indicative only’ at this stage.

This chapter includes a number of waste process diagrams as appendices. The diagrams indicate the full lifecycle ‘cradle to grave’ strategy for the management of each waste stream from generation to eventual disposal, and clearly state the provision of waste management capabilities within and outside of the power block (defined as definite scope and indicative scope respectively). Detail of certain aspects that cannot be confirmed at this stage (for example repackaging of SF into a final disposable form) are excluded from scope and clearly identified on the waste process diagrams – see Appendices to this document. As outlined above, indicative scope will be subject to future development and decision making, including the establishment of relevant BAT and As Low As Reasonably Practicable (ALARP) justifications.

The environmental regulators have stated an expectation in the “New Nuclear Power Plants: Generic Design Assessment guidance for Requesting Parties,” (Reference 5-13) that AOOs (analogous to “frequent design basis faults” as defined by the Office for Nuclear Regulation in their document NS-TAST-GD-006, “Nuclear Safety Technical Assessment Guide – Design Basis Analysis,” (Reference 5-14)) that result in an environmental radiological impact, should be identified as an inclusive consideration of environmental radiological discharges and radioactive wastes arising from normal operation of the BWRX-300.

A preliminary review of 005N3558, “BWRX-300 Fault Evaluation,” (Reference 5-15), has not resulted in the identification of any relevant AOOs. The current safety analysis relates primarily to reactor faults and, as such, faults that could primarily result in fuel damage. All of the faults listed present adequate mitigation through design and therefore do not give rise to environmental impact consequences within AOO frequency.

The environmental regulators have also stated an expectation that the arrangements for management of failed fuel are discussed. Fuel clad failure is not currently defined as an AOO (since it is the consequence of faults and not a fault in itself) but as the predicted frequency for fuel clad defects falls within the AOO frequency range it is discussed further in Section 5.2.1.1.

It is recognised that further work is required to assess the wider BWRX-300 design for faults that could give rise to environmental consequences, resulting in the generation of radioactive wastes, at frequencies that would define them as AOOs. This is identified as a forward action.

FAP.PER5-110 – Undertake a systematic review of initiating events across the entirety of the BWRX-300 design to identify a comprehensive list of faults, that may result in an environmental radiological impact, through an increase in radioactive discharges, waste volumes or activities, and at frequencies that would define them as AOOs.

This chapter presents relevant information in the following sections:

- Section 5.1: Overview of the UK regulatory context with respect to radioactive waste and SF management, including explanation of UK RWM classifications and categories
- Section 5.2: Description of the sources and characteristics of radioactive wastes arising from BWRX-300 commissioning and operation, and how these wastes are anticipated to be managed to comply with UK regulatory requirements
- Section 5.3: Description of the sources and characteristics of radioactive wastes arising from BWRX-300 decommissioning, and how these wastes are anticipated to be managed to comply with UK regulatory requirements
- Section 5.4: Table presenting estimates of the anticipated quantities of radioactive wastes and SF arising from commission, operation and decommissioning of the BWRX-300
- Section 5.5: Table of assumptions made within this document

Purpose

The overall objective of the PER is to demonstrate that the design of the BWRX-300 SMR has been optimised to reduce environmental impacts to ALARA throughout the whole lifecycle (construction, commissioning, operation, and decommissioning).

The objective of this chapter of the PER is to set out the arrangements for managing the radioactive wastes generated through the commissioning, operation, and eventual decommissioning of a BWRX-300 reactor, and to demonstrate their compliance with applicable UK regulatory requirements and expectations. There is an emphasis on demonstrating how those arrangements serve to minimise the environmental impact associated with commissioning, operating, and decommissioning the BWRX-300 SMR to levels that are ALARA.

In support of this broad demonstration of ALARA this chapter will support the following environmental Level 2 claims and related arguments presented in NEDC-34223P (Reference 5-2):

- Prevention or, where this is not practicable, minimisation of the creation of radioactive waste and SF
- Minimisation of the activity of aqueous radioactive waste disposed of by discharge to the environment
- Minimisation of the volume of solid radioactive waste disposed of by transfer to other premises.
- Selection of the optimal disposal routes for wastes and SF

5.1 Regulatory Context

This chapter of the PER presents information on how the radioactive waste generated by the BWRX-300 will be generated, characterized, and managed in compliance with relevant UK regulatory requirements and expectations.

A summary of the applicable UK policies, strategies, legislation, and guidance that apply to the management of radioactive wastes in the UK is provided in a first iteration of NEDC-34228P (Reference 5-4) for the UK BWRX-300. These policies are set out in the document "UK Policy Framework for Managing Radioactive Substances and Nuclear Decommissioning," (Reference 5-16). This document has been developed by the UK Government and devolved administrations. Its purpose is to provide a coherent UK-wide policy framework for managing radioactive substances and nuclear decommissioning.

This chapter provides an overview of the UK requirements derived from the policy framework that will need to be satisfied under the RWM topic. The IWS goes into greater detail on specific UK requirements arising from national policy, strategy, legislation, regulations, good practice guidance etc. It will be necessary to incorporate these UK specific requirements into the requirements management system for the onward development of a UK BWRX-300.

FAP.PER5-111 – Identify and incorporate relevant UK RWM compliance requirements into the BWRX-300 requirements management system.

5.1.1 United Kingdom Radioactive Waste Categories and Disposition Requirements

This section outlines the UK arrangements for management of radioactive wastes, providing an overview of the classification scheme and the related disposition requirements for each disposal category.

5.1.1.1 United Kingdom Radioactive Waste Categories

In the UK, radioactive waste is defined as "any substance or object that has no further use, and is contaminated by, or incorporates, radioactivity above certain levels defined in UK legislation" within the Nuclear Decommissioning Authority (NDA) UK Radioactive Waste Inventory source, "What is Radioactive Waste?" (Reference 5-17).

Radioactive waste is then classified according to how much radioactivity it contains and the heat that this radioactivity produces. The broad definitions are provided in the corporate report "UK Radioactive Waste Inventory 2022," (Reference 5-18). These relate to the disposal requirements and designate radioactive wastes as 'Higher Activity Waste' (HAW) or 'Lower Activity Waste' (LAW).

HAW comprises High Level Waste (HLW), Intermediate Level Waste (ILW) and a small fraction of Low Level Waste (LLW).

LAW comprises both LLW and Very Low Level Waste (VLLW).

The waste categories are then further defined in relation to the specific disposal requirements associated with UK RWM policy. Figure 5-1 provides an overview of the classification structure defined in "NDA Integrated Waste Management Radioactive Waste Strategy," (Reference 5-19).

The outline specification for each UK radioactive waste category is provided in Table 5-1.

In addition to the above categories, where wastes that have the potential to be exposed to radioactive contamination or neutron irradiation can be shown to contain radioactivity at levels below the requirement for them to be managed as radioactive waste, these wastes can be classified as 'out of scope of regulatory control' (i.e., the wastes are not considered radioactive for purposes of UK legislation) and are termed 'Out of Scope' wastes.

5.1.1.2 United Kingdom Radioactive Waste Disposition Requirements

Provision of services and facilities for the disposition of radioactive waste in the UK are primarily provided by the NDA through its subsidiary organisations, Low Level Waste Repository (LLWR) Limited and RWM Limited.

LLWR Ltd operates the LLWR for disposal of LLW, and also provide a waste services contract which can be used to access additional packaging, characterisation, transport, LLW pre-treatment and VLLW disposal services. Some of these services are provided by third party commercial organisations and can also be accessed directly via the respective service provider. LLWR Ltd provides an overview of these services in their brochure, "Logistic Services," (Reference 5-22)[1].

An overview of the LLWR Ltd Waste Services Contract is provided in Appendix A.

A suite of Waste Acceptance Criteria (WAC) detailing the specific compliance criteria for these services are available from LLWR. The individual WAC are summarised in WSC-WAC-OVR, "Waste Services Contract: Waste Acceptance Criteria – Overview," (Reference 5-23). Table 5-2 lists the individual WAC documents for each service.

RWM Ltd are responsible for the provision and operation of HAW disposal facilities including the GDF and, potentially, alternate Near-Surface Disposal (NSD) facilities (see Section 5.1.1.2).

The services of LLWR Ltd and RWM Ltd have now been combined under an umbrella organisation, titled Nuclear Waste Services (NWS). NWS is a trading name of LLW Repository Limited and RWM Limited, and a wholly owned subsidiary of the NDA.

RWM Ltd have previously published guidance for "Creating Standardised Waste Packages," (Reference 5-24), an extensive suite of waste packaging specification and guidance documents that advise waste producers on the requirements for compliance with anticipated GDF disposal criteria. Newer releases of documents in this suite are published under the NWS name.

High Activity Waste Disposition

At present, there is no UK capability for the receipt and ultimate disposal of HAW, and nuclear site licensees are required to retain HAW on site pending the provision of such capabilities. As indicated in Section 5.1.1.2 this could include both GDF and NSD facilities. Programmes of work are underway to provide these capabilities, and these are led by NWS on behalf of the NDA.

The latest planning assumption presented in the UK Government website "Geological Disposal – a programme like no other," (Reference 5-25) is that a GDF could be ready to receive ILW between 2050-2060, with HLW and SF from 2075.

It should be noted that this facility will be a single capability, servicing the needs of the whole UK nuclear industry (with the exception of Scotland, which has an alternate policy). There are already several thousand 'final waste packages' in storage across UK nuclear licensed sites (both civil and defense) that are destined for disposal in the GDF, with many more to be produced from ongoing operational and decommissioning activities. These existing packages are assumed to take precedence in terms of the 'queue' for access to the GDF.

It is therefore reasonable to assume that a new nuclear facility will be required to retain HAW on site for at least 100 years. The regulators have stated clear expectations that HAW is required to be processed into a passively safe and disposable form at the earliest practicable opportunity – see Table 5-3.

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[1] It is noted that the brochure was withdrawn on 9 August 2022 for updating, however the resource remains indicative of the LLWR Ltd Services available.

In the absence of a GDF, NWS have put in place arrangements to ensure that HAW packaged now and in the immediate future will be acceptable for disposal to a future GDF. These arrangements include the provision of a suite of 'Waste Packaging Specifications and Guidance' material, (see (Reference 5-24)) that specify how wastes should be packaged to comply with the requirements of a future GDF. A 'Letter of Compliance' (LoC) process is presented in "Our work with Radioactive Waste Producers," (Reference 5-29) and is applied to enable waste producers to submit packaging proposals to NWS for assessment prior to packaging the wastes. The provision of a Final Stage LoC from NWS provides assurance to the waste producer that their waste packaging proposals have undergone a satisfactory disposability assessment, and provided the waste is packaged in line with the detail provided in the packaging proposal, the wastes should be suitable for acceptance into the future GDF.

Waste producers are therefore required to apply the NWS waste packaging specifications in developing their arrangements for processing HAW into a passively safe and disposable form.

It should also be noted that the UK is currently considering the possibility of an intermediate 'Near Surface Disposal' solution that is positioned between a GDF and a LLW surface repository, on the basis of relative radiological hazard. At present this remains an early-stage consideration, and no precise specification is available on the requirements for NSD within the NDA document "Near-Surface Disposal Strategic Position Paper," (Reference 5-30). Nonetheless, it is appropriate for waste producers, in assessing their disposal options, to consider areas where non-foreclosure of packaging options is justifiable to facilitate optimisation of waste disposal, taking due account of all relevant options and related criteria.

Lower Activity Waste Disposition

UK radioactive waste capabilities exist for the disposition of LAW. These capabilities include: the LLWR disposal facility in West Cumbria, operated by LLWR Ltd on behalf of NWS, for receipt and disposal of LLW; a number of landfill sites that are permitted to receive VLLW for disposal; and options for processing of LAW to minimise disposals in accordance with application of the waste hierarchy. Figure 5-2 provides an illustration of the waste hierarchy as provided by the NDA within "NDA Strategic Position on Radioactive Waste Treatment," (Reference 5-31).

Compliance criteria for disposal to LLWR are presented in a series of WAC documents, which are summarised in a WAC overview document, WSC-WAC-OVR (Reference 5-23). Waste producers are required to demonstrate compliance with the WAC in generating, packaging, characterising and consigning their LLW.

The LLWR WAC provide a number of options for waste disposition that align with the requirements of the waste hierarchy and promote practices to minimise the amount of waste consigned for disposal. The arrangements for management of LAW arising from the operation of a UK BWRX-300 will be developed to conform to UK relevant good practice through compliance with the LLWR WAC documents.

VLLW landfill sites are operated by a number of companies and each provide their own acceptance criteria, based on the specific conditions present in their environmental permits. Waste producers are required to demonstrate compliance with these criteria in generating, packaging, characterising, and consigning their VLLW. Access to VLLW disposal sites can either be procured through the LLWR Ltd waste services contract or directly with the operators of the sites.

5.2 BWRX-300 Operational Wastes

The generation of radioactive waste is a direct and inevitable consequence of the use of nuclear energy for power generation. The BWRX-300 SMR will generate quantities of radioactive waste throughout its operational lifetime. Additional radioactive wastes will be generated at the end of its operating life when the plant is decommissioned and dismantled.

It is assumed that no radioactive wastes will be generated until the point at which nuclear fuel is first brought onto site at an appropriate stage during the commissioning phase. For the purposes of this document radioactive wastes (including SF) arising during the commissioning phase are considered part of the overall inventory generated during the operational life of the plant.

It is recognised that there is a risk of generating radioactive waste from remediation of pre-existing radiologically contaminated land identified during the construction phase, but this is entirely dependent on the site selected for construction and its prior history. No further consideration is given to this risk in this document since it is a site-specific consideration for a future licensee to address.

At the point that new nuclear fuel and radioactive sources are brought onto site, numerous operating practices will come into force to provide appropriate radiological protection for operators working in the proximity of these materials, and to protect people and the environment from the risks of incidents involving their receipt, handling, storage, and use. These practices will begin to generate radioactive wastes in the form of protective clothing and ‘barrier wastes’ (wastes generated due to access to the radiologically controlled area). Once new fuel is introduced to the fuel pool, and subsequently the reactor, the various cleanup systems will begin to generate secondary radioactive wastes in the form of filter backwash sludges and spent resins. Once the reactor is taken critical for the first time, neutron irradiation of the coolant and plant and components in the vicinity of the core will commence. This is the point at which routine generation of operational radioactive wastes will commence.

This section describes the range of radioactive wastes that will be generated through operation of the BWRX-300. The wastes will be described in relation to their anticipated category and classification as outlined in Section 5.1.1.

5.2.1 Higher Activity Wastes

HAW comprises HLW, ILW and a small fraction of LLW that is not suitable for disposal to the LLWR. Normal operation of BWRX-300 is anticipated to generate the following HAW streams:

- SF (assumed HLW if designated as radioactive waste)
- Irradiated In-Core Components (IICC) (assumed HLW when generated)
- Wet solid wastes (assumed ILW when generated)

5.2.1.1 Spent Fuel

In the UK, SF is no longer processed (Table 5-4), and the UK government has advised that new build vendors (i.e,. those organisations considering constructing new nuclear power plants in the UK) should proceed on the assumption that plans for disposal of SF as a radioactive waste should be progressed.

SF will emit radiogenic heat at levels that require heat to be taken into account in the design of storage or disposal facilities. SF is therefore considered HLW for the purposes of on-site management as radioactive waste and is required to be managed as HHGW (WPS/240/02 (Reference 5-7)) for the purpose of disposal to GDF.

It is assumed that SF arising from operation of a UK BWRX-300 will be stored on-site pending eventual disposal to a national GDF, as described in “National Policy Statement for Geological Disposal Infrastructure,” (Reference 5-32). This is consistent with advice provided by the UK regulators within ONR-GDA-GD-007 “New Nuclear Power Plants (NPPs): Generic Design Assessment Technical Guidance,” (Reference 5-33) and presented in Table 5-5.

Since the specific disposal requirements are not available at this time, the SF will be stored in an interim state and will require repackaging into a disposable form once a disposal specification has been provided. In so doing, future options for alternate treatment (e.g., reprocessing) will not be foreclosed.

SF will initially be stored in the fuel pool to undergo cooling prior to packaging in a SF cask. The fuel pool can be accessed on level 13.0 m of the Reactor Building (RB) from the operating deck. The fuel pool provides storage for new and used fuel, along with equipment used during refueling.

The BWRX-300 core comprises 240 fuel bundles, as per document 005N9751, “BWRX-300 General Description,” (Reference 5-34). The functional requirements for the BWRX-300 fuel pool are presented in system design description 006N5377, “BWRX-300 Refueling and Servicing Equipment,” (Reference 5-35). This states a wet storage capacity of at least 8 years of operation plus one core load of new fuel and one full core offload (removal of all fuel bundles from the core).

For GDA purposes it is assumed that the BWRX-300 will operate on a 12-month fuel cycle with 32 fuel bundles replaced during each refueling outage. For a 60-year operating life this equates to an initial core load of 240 bundles, plus 59 reloads of 32 bundles, giving rise to 2,128 SF bundles.

For the purpose of conservatism, a similar calculation has been performed for a 24-month operating cycle on the basis that this generates 72 SF bundles every other year within DBR-0057741, “BWRX-300 Plant Performance Envelope,” (Reference 5-36). This would give rise to 2,368 SF bundles for a 60-year operating life.

Dry cask storage of SF from light water reactors (described in “Dry Cask Storage,” (Reference 5-37)) is a well-established storage method with significant worldwide precedent, extensive operational experience, and a range of commercially available solutions. It is assumed that a UK BWRX-300 will employ dry cask storage as the technical basis for SF storage in alignment with 006N5339, “BWRX-300 Irradiated Fuel Management Plan,” (Reference 5-38). Dry cask storage involves emplacing SF bundles in a sealed and inerted high integrity canister and placing this canister inside a shielded cask for long term storage. This method of SF storage has UK precedent at Sizewell B power station and is also planned at Hinkley Point C power station, as evidenced by EPR/ZP3690SY/V005, “RSR Permit Variation,” (Reference 5-39).

The timing of construction for a SF storage capability is not yet determined, but it is noted that the regulators accept that storage in the fuel pool is acceptable for an initial period provided there is a demonstration of adequate capacity (ONR-GDA-GD-007 (Reference 5-33)).

The design of the fuel pool incorporates a position for receipt, handling, loading, and export of SF casks as shown in Figure 5-3 and derived from 005N1730, “General Arrangement Drawing – Reactor Building,” (Reference 5-40).

At this early stage no decision has been made on a specific design or vendor for SF casks.

Once packaged, SF casks will be exported from the RB for on-site storage. Again, at this early stage no decision has been made on a specific design or vendor for SF cask storage. It is assumed that SF cask storage will be required for multiple decades until such time as a GDF is made available and a disposal specification for SF provided. As with HAW storage, it is assumed this could be for at least 100 years.

Fuel failures are not quantified as AOOs as they are the consequence of faults, rather than faults in themselves (for example fuel clad fretting as a result of particle ingress into the fuel bundle). Operating experience derived from NEDC-33415P, “Nordic GNF2 Operational

Experience Update," (Reference 5-41) identifies a failure rate of 2.1 failures per 1000 fuel bundles in service. Based on an anticipated 2,128 fuel bundles arising from operation of BWRX-300 over a 60-year operating life this would indicate 5 failed fuel bundles over the life of the plant (or one every 12 cycles). This gives a failure frequency greater than the threshold for AOOs and therefore it is appropriate to discuss the planned approach for management of failed fuel.

Arrangements for the management of failed fuel will be developed in line with the selection of a cask storage system, as any additional containers used for either whole bundles or single fuel pins will need to be compatible with the chosen cask system. The requirement for use of additional containment is itself dependent on the extent of the failure, and in some instances may not be necessary. The fuel pool provides the capability to either manage a failed bundle as a whole or to extract and manage a single failed pin if this is deemed necessary. Failed fuel is therefore assumed to be stored in a similar manner to the main population of SF (but with potential for additional containment on a case-by-case basis) and would be repackaged to meet GDF disposal requirements once the fuel had cooled sufficiently and a disposal specification is made available.

GNF2 fuel bundles are loaded into the core inside a fuel channel. The fuel channels contain each fuel bundle within the reactor core to direct the coolant flow and contain the boiling regions. The dimensions of the fuel channels for BWRX-300 are not yet confirmed but are anticipated to be similar to the UK ABWR design submitted as GA91-9901-0022-00001, "UK ABWR Generic Design Assessment: Radioactive Waste Management Arrangements," (Reference 5-42).

Under normal operations the fuel channel will remain with the SF bundle for placement into a SF cask. At the point of SF repackaging, it is assumed that the fuel channel would be removed, segregated, and sentenced for management as HLW/ILW dependent on prevailing radioactivity level at that point.

Since there is a possibility that a fuel bundle may be disassembled in the fuel pool to recover a failed fuel pin, it is assumed that a fuel channel removed for this purpose would be disposed of as an irradiated item along with other IICC.

5.2.1.2 Irradiated Incore Components

IICC will include spent Control Rod Blades (CRBs) and instrumentation used to measure neutron flux and gamma radiation levels in the reactor core as part of the control system.

Control Rods

CRBs are neutron absorbing components which provide negative reactivity into the core to allow for the control of reactor power. BWRX-300 uses GE Ultra™ control rods (see Figure 5-4). The control rods are cruciform shaped elements that occupy alternate spaces between fuel assemblies throughout the core. The neutron absorber material is typically boron carbide or hafnium, as described in 005N9751 (Reference 5-34).

GE Ultra™ control rods are an evolutionary design based on learning from prior operational experience and feature a simplified design using less stainless steel and reduced cobalt. These enhancements will result in a reduction in irradiation induced radioactivity for spent control rods.

There are 57 control rods in the core, as stated in 005N9751 (Reference 5-34). During normal operation of the BWRX-300 a 'control group' of four (4) control rods are inserted into the reactor core to control neutron flux when the reactor is critical, the other 53 are fully withdrawn.

The four (4) 'control group' rods are exchanged at each operating cycle to balance control rod depletion over time across all of the control rods.

As part of this overall process for management of the control rods it is conservatively assumed that four (4) control rods will be replaced every 3rd cycle. This would equate to 19 cycles x 4 = 76 rods replaced during the operational life of the plant. At end of life (cycle 60) all rods would be removed from the core once the fuel core had been removed, giving rise to a further 57 rods. The total inventory of spent control rods over a 60-year operating life is therefore calculated to be 133.

Nuclear Instrumentation

The nuclear (core) instrumentation consists of the thirteen Local Power Range Monitor (LPRM) and Gamma Thermometer (GT) assemblies (termed 'strings'), each with four LPRMs and eight GTs in a wet tube, and ten Wide Range Neutron Monitors (WRNMs), as per the technical specification 006N5114, "BWRX-300 Plant I&C Systems Architecture Requirements and Design," (Reference 5-43). Each of the WRNMs has a single detector contained in a dry tube.

Each 'string' is a small-diameter vertical instrument tube located at the intersection of four fuel bundles in the reactor core and has an array of detectors spaced vertically along the approximate 3.7 m (12 feet) height of the core. The string extends vertically to the top of the core and below the core to the vessel bottom, where the electrical leads of the monitoring instruments are brought through penetrations to the under-vessel connectors. The instrument tubes are therefore in the region of 8.0 m long and will require some form of size reduction to facilitate waste handling and packaging. It is anticipated that, once size-reduced, there will be an opportunity to segregate sections of the instrument tube for sentencing in accordance with the waste hierarchy.

The instrument tubes are not anticipated to be replaced on a fixed periodicity so will arise on an ad hoc basis. Instrument tubes will be removed and replaced during refueling outages as it is necessary to remove the four (4) surrounding fuel assemblies prior to removing the instrument tube. Size reduction of the instrument tubes is assumed to take place in the fuel pool.

Irradiated Incore Components Management

IICC are anticipated to meet the HLW criteria on production due to elevated levels of radiogenic heat emission (>2 kW/m^3) (as per the basic principles of RWM (Reference 5-20)). These components are managed via the fuel pool where they will undergo initial cooling.

IICC will initially be packaged and stored in a very similar manner to SF. IICC are assumed to undergo decay storage and cooling in SF casks in the same storage location as the SF until they decay to the point where radiogenic heat has reduced to satisfy the Intermediate Level Waste criteria (<2 kW/m^3), according to the basic principles of RWM, "Basic Principles of Radioactive Waste Management – An Introduction to the Management of HAW on Nuclear Licensed Site," (Reference 5-20). They will then be recovered, processed, and repackaged in compliance with NWS criteria in "Low Heat Generating Waste (LHGW) Specifications," (Reference 5-44).

Appendix C presents an overview of the anticipated through life management arrangements for SF and IICC arising from operation of a UK BWRX-300.

5.2.1.3 Wet Solid Radioactive Wastes

Generation of Wet Solid Radioactive Wastes

BWRs utilise a single reactor coolant, steam, condensate, and feedwater circuit design whereby water is boiled in the Reactor Pressure Vessel (RPV) to generate steam and this steam passes directly to the turbine to generate electrical power. Exhausted steam is drawn into the condenser and cooled to produce condensate. The condensate is returned to the reactor via the feedwater circuit in a continuous process. The single circuit design places a great emphasis on water purity and the BWRX-300, in-keeping with previous BWR designs, incorporates 'on-line' (i.e. integral to the reactor coolant circuits) aqueous liquid treatment processes to remove soluble and insoluble impurities, and maintain water quality to meet the requirements of technical requirements specification 006N6766, “BWRX-300 Water Quality,” (Reference 5-45). Operation of these systems results in the generation of wet solid radioactive waste in the form of spent ion exchange resins and filter backwash sludges.

1. 006N7941, “BWRX-300 Fuel Pool Cooling and Cleanup System,” (FPC) (Reference 5-46). The FPC is based on separate backwashable fine filtration and deep bed demineraliser technologies and generates wet solid wastes in the form of filter backwash sludge and spent bead resin.
2. 006N7741, “BWRX-300 Condensate Filters and Demineralizers (CFD),” (Reference 5-47). The CFD is based on separate backwashable fine filtration and deep bed demineraliser technologies and generates wet solid wastes in the form of filter backwash sludge and spent bead resin.
3. 006N7609, “BWRX-300 Reactor Water Cleanup System,” (CUW) (Reference 5-48). In the BWRX-300 design CUW effluent is routed upstream of the CFD system and utilises the CFD system filters and demineralisers for effluent treatment. CUW flow into CFD represents 1% of total feedwater flow.
4. 006N7345, “Isolation Condenser Pools Cooling and Cleanup System,” (ICC) (Reference 5-49). ICC is based on deep bed demineraliser technology and generates wet solid waste in the form of spent bead resin.

Reactor water quality and related circuit cleanliness is further enhanced by an integrated water chemistry regime comprising Hydrogen Water Chemistry, On-Line NobleChem™ and GE Zinc Injection Passivation. The water chemistry regime is anticipated to result in further reduction of corrosion and erosion particulate, leading to reduced volumes of filter backwash sludge, and minimisation of cobalt deposition on coolant facing surfaces which will have a beneficial impact on decommissioning waste volumes.

Further information on the water treatment systems described above is presented in NEDC-34221P (Reference 5-6).

In addition to these four ‘on-line’ systems the Liquid Waste Management System (LWM) provides further filtration and demineralisation in the form of a skid mounted abatement system. This system replaces the separate high and low conductivity wastes systems found in earlier BWR designs and provides a common set of effluent treatment functions for aqueous effluents collected by the system 006N7789, “BWRX-300 Equipment and Floor Drain System (EFS),” (Reference 5-50). The function of the LWM is to clean drained effluents to meet the reactor water quality specification, 006N6766 (Reference 5-45), such that plant water can be reused, thereby reducing the requirement to discharge aqueous effluents to the environment. It is therefore important to note that, whilst termed a ‘waste management system’, the LWM system actually performs the function of aqueous effluent treatment to facilitate recycling, and thereby avoids the generation of waste in line with the principle of waste hierarchy application.

Figure 5-5 provides an overview of the arrangements for Process Water and Effluent Management for the BWRX-300 and is a composite image derived from:

- 006N7941, “BWRX-300 Fuel Pool Cooling and Cleanup System,” (FPC) (Reference 5-46)
- 006N7741, “BWRX-300 Condensate Filters and Demineralizers (CFD),” (Reference 5-47)
- 006N7345, “Isolation Condenser Pools Cooling and Cleanup System,” (ICC) (Reference 5-49)
- 006N7729, “BWRX-300 Liquid Waste Management System (LWM),” (Reference 5-51)
- 006N7733, “BWRX-300 Solid Waste Management System (SWM),” (Reference 5-52)

- 008N0988, “BWRX-300 Power Block General Arrangement,” (Reference 5-53)
- 006N7828, “BWRX-300 Nuclear Boiler System,” (Reference 5-54)
- 006N7757, “BWRX-300 Main Condenser and Auxiliaries System,” (Reference 5-55)

The diagram presents a simplified line diagram of the reactor coolant circuit and shows where all of the cleanup systems interact with the circuit, as well as effluent drainage routes from the plant leading to the LWM system. The wet solid waste routes from the various abatement systems are shown linking to the SWM storage tanks. The connection to the aqueous liquid effluent discharge route is also shown.

Sources of plant effluent directed to the LWM system collection tanks include:

- Drain effluents from the EFS system
- Excess water from the CUW system
- Excess water from the Shutdown Cooling System, described in 006N7708, “BWRX-300 Shutdown Cooling System,” (Reference 5-56)
- Excess water from the Refueling Water Storage Tank (RWST), 006N7729 (Reference 5-51)
- Return line from the LWM sample tanks and skid
- Decant water from the SWM system, 006N7733 (Reference 5-52) storage tanks

Application of appropriate abatement technologies in the LWM system enables liquid radioactive effluents generated during normal operation to be cleaned and purified to achieve water quality that meets the requirements of the reactor water quality specification, 006N6766 (Reference 5-45). It is therefore feasible to integrate both drainage streams into a single combined treatment system.

The LWM system, as defined in 006N7729 (Reference 5-51), utilises the latest effluent purification technologies to provide a comprehensive capability that can treat all aqueous effluents to meet to meet the reactor water quality specification, 006N6766 (Reference 5-45). This enables the BWRX-300 to recycle all treated effluents and allows the plant to be operated on a zero aqueous radioactive effluent discharge basis during normal operations (including routine refueling outages). Evidence that a BWR can be operated on a zero effluent discharge basis is presented in NEDC-34279P, “Analysis of Environmental Discharge Data for US Nuclear Power Plants,” (Reference 5-57), thereby demonstrating effective application of the waste hierarchy (water re-use), minimisation of waste, and elimination of the requirement to discharge water from the plant under normal operating conditions.

BWRX-300 utilises a ‘skid mounted’ approach to provide a series of effluent treatment sub-systems that can be configured to cope with an array of effluent scenarios arising from upstream plant events. This provides significant mitigation against upstream faults and errors that could result in the generation of effluents that are beyond the normal plant parameters (e.g., increased fission products due to a fuel clad failure, ingress of foreign materials such as organics, oils, greases from a foreign materials intrusion, or chloride ingress from a main condenser tube leak).

This approach is consistent with that applied at the Tokyo Electric Power Company Fukushima-Daiichi site as part of the Advanced Liquid Processing System, as presented in “Overview of the Multi-nuclide Removal Equipment (ALPS) at Fukushima Daiichi Nuclear Power Station,” (Reference 5-8) and this provides a substantial amount of operating experience to support further design development of the LWM system.

Sampling of effluents in the collection tank, aided by upstream sampling of individual effluent feeds, will inform the series of treatments required for an individual batch of effluent. Further information on sampling arrangements is presented in NEDC-34224P (Reference 5-8).

It should be noted that LWM system design is presently at a conceptual stage and may be subject to future revisions. A more detailed description of the LWM system is presented in NEDC-34221P (Reference 5-6).

The LWM system is anticipated to comprise the following abatement stages:

- Sludge Consolidation Filter
- Pre-Conditioning Filter (PCF)
- Ozone System
- Ion Exchanger
- Reverse Osmosis (RO) System
- Polishing Ion Exchanger

Note: If sampling of the collection tank indicates contaminant levels in excess of filter skid influent requirements the tank contents can also be routed through the spent resin tank in the SWM system for pre-treatment prior to processing through the LWM system.

Effluents are processed to meet the water quality parameters as specified in the reactor water quality specification, 006N6766 (Reference 5-45) and returned to the Condensate Storage Tank (CST) for reuse. In the event of a requirement to discharge aqueous effluent from the plant, a discharge route to the outfall side of the Circulating Water System is provided.

The LWM system also incorporates a separate backwashable fine filtration system for cleanup of aqueous effluents drained from the reactor cavity at the start and end of refueling outages. Drained filtered effluent is routed to the RWST, a component of the LWM system, and reused for refilling the reactor cavity.

Management of Wet Solid Radioactive Wastes

Operation of the aqueous liquid cleanup systems described in Section 5.2.1.3 is anticipated to result in the generation of wet solid wastes in the form of filter backwash sludges, spent bead resins, and Granular Activated Carbon (GAC). The wet solid wastes arising from these abatement systems are routed to the SWM system for onward management.

It is assumed that spent GAC, sludge consolidation filters and RO modules will arise as LAW. Further consideration of these streams is presented in Section 5.2.2.

It should be noted that filter backwash sludges and spent bead resins have been classified as ILW based on source term data within 008N0133, “BWRX-300 Solid Waste Management System – Contained Source Activity,” (Reference 5-59). This source term has been derived to provide bounding and conservative values for the purposes of dose and shielding calculations. A related conservative assumption on classification of the wastes provides a bounding consideration for their management. Should subsequent refinement of the source term result in the wastes being classified as LLW this would simplify the requirements for their management.

A realistic model (best estimate) radioactive waste End User Source Term (EUST) is therefore required in order to determine a more realistic classification for these wastes. This should be provided before any further consideration is made of the discrete processing and storage requirements for these wastes. The FAP should therefore include activity to develop a Realistic Model radwaste EUST for wet solid wastes.

FAP.PER5-113 – Derive Realistic Model EUST Values for BWRX-300 wet solid waste streams.

Mixed anion and cation bead resins are used in the demineralisers in the CFD, FPC, LWM, and ICC systems. The resin beds are non-regenerative and will therefore be depleted over time. The spent bead resin is discharged by backwashing the demineralisers and transferred to storage tanks in the Radwaste Building (RWB) for decay storage prior to processing.

BWRX-300 bead resins are assumed to be either a styrene divinylbenzene copolymer or cross-linked polystyrene matrix in a fine bead form, similar to those used in the ABWR and described in WN0908-HZCON-PAC-REP-00003, "Radioactive Substances Regulation – Environmental Permit Application," (Reference 5-60). Wet bead resin is assumed to arise as an aqueous slurry with a wet density of 1.165 t/m^3 (WN0908-HZCON-PAC-REP-00003 (Reference 5-60)). The resin is used in reactor coolant cleanup systems and the effluent treatment system to remove dissolved impurities (both radioactive and non-radioactive). The density value stated is derived from ABWR information and will require confirmation as the design progresses. A forward action has been raised for this and documented in NEDC-34229P (Reference 5-9).

Filter backwash sludges will arise from backwashing of high flow fine filters in the reactor coolant cleaning circuits and LWM system. The sludge is made up of predominantly ferrous Corrosion Products (CPs) that will arise during reactor operations. The CPs will form as particulates entrained in the coolant circuit filtrations systems. The sludge is assumed to arise as an aqueous slurry with a wet density of 1.1 t/m^3, as in WN0908-HZCON-PAC-REP-00003 (Reference 5-60). This density value stated is derived from ABWR information and will require confirmation as the design progresses. A forward action has been raised for this and documented in NEDC-34229P (Reference 5-9).

The Wet Solid Intermediate Level Waste (WSILW) streams are assumed to be transferred to an on-site WSILW processing capability, where they will be packaged and conditioned to form passively safe, disposable Final Waste Packages (FWPs). The wastes are assumed to be solidified in a cementitious matrix within 3 m^3 unshielded stainless steel drums. Note that the final choice of waste container and related immobilisation method will be subject to appropriate consideration and demonstration of BAT during site-specific design development, as detailed in NEDC-34223P (Reference 5-2). Packaging will comply with NWS waste packaging specifications and will be substantiated through their disposability assessment and LoC process.

For GDA Step 2 a 'Demonstration of Disposability' document, NEDC-34229P (Reference 5-9) has been produced in accordance with published guidance from NWS, RWPR63-WI11, "Preparation of Expert Views to Support Step 2 of the Generic Design Assessment Process," (Reference 5-61). NWS will review the demonstration of disposability document and provide their expert view, in the form of a formal letter, on the suitability of the BWRX-300 HAW (including SF) streams for disposal in the GDF.

The resultant FWPs will be transferred to an appropriately designed on-site storage facility for storage pending eventual disposal to a national GDF. A final decision on WSILW management strategy will be made at a future site-specific stage and will need to take account of a wider range of factors reflecting the site-specific design, to include consideration of a solution for a multiple unit site, and related considerations of shared facilities etc.

An overview of the anticipated WSILW management process is presented in Appendix D.

In 006N7938, "BWRX-300 Process Radiation and Environmental Monitoring System," (PREMS) (Reference 5-62) capabilities for both automated online sampling and grab sampling of the various systems related to the production of radioactive effluents and wet solid wastes are described. An onsite laboratory is located on the first floor of the RWB, as presented in 008N0988 (Reference 5-53) for analysis of samples recovered from the PREMS. The laboratory will provide radioactive waste characterisation data in support of waste assessment, waste inventory derivation and sentencing activities. NEDC-34225P, "BWRX-300 UK GDA Ch. 8: Approach to Sampling and Monitoring," (Reference 5-63) provides additional information on the sampling and monitoring arrangements for the BWRX-300.

The LWM system incorporates an aqueous effluent discharge route to provide a means of displacing water from the system to the environment in infrequent cases of excessive water volume. In general, it will be possible to maintain plant water balance using designed storage capacity in the numerous effluent and water storage tanks (LWM collection and sample tanks, CST, and RWST) without recourse to use of the discharge route.

In 006N7673, “BWRX-300 Water Balance,” (Reference 5-64) it is demonstrated that the system water storage capacities are designed to cope with the maximum effluent transfer volumes that occur during refueling outages and include adequate capacity to support the zero aqueous effluent discharge philosophy for the plant.

As with the on-line abatement processes, operation of the LWM system will result in the generation of wet solid wastes in the form of filter backwash sludges and spent bead resins. These are also routed to the SWM system for onward management.

It is recognised that a small amount of radiologically contaminated water will be lost from the plant through evaporation from the RB pools. This evaporate is swept from the pool surface by the RB pool ventilation system and discharged via the plant Heating, Ventilation, and Cooling System (HVS), as per 006N7781, “BWRX-300 Heating Ventilation and Cooling System,” (Reference 5-65). A small amount of high purity water make-up is therefore required to compensate for evaporative losses, and this is provided by the Water, Gas, and Chemical Pads System, 006N7797, “BWRX-300 Water, Gas, and Chemical Pads System (WGC),” (Reference 5-66).

In the event of off-specification water due to an abnormal event or, in exceptional circumstances, when water balance requires water to be discharged from the plant, an aqueous effluent discharge line is provided downstream of the LWM abatement, sampling and monitoring systems to demonstrate that radioactivity content in discharges is within permitted limits prior to discharge. The aqueous effluent discharge is routed into the circulating water system at the outgoing side of the main condenser, captured in 006N7761, “BWRX-300 Circulating Water System,” (Reference 5-67).

5.2.2 Lower Activity Wastes

LAW comprises both LLW and VLLW. Normal operation of BWRX-300 is anticipated to generate the following LAW streams:

- Ventilation filters
- Aqueous effluent filter modules
- Heterogeneous dry solid wastes
- Non-aqueous wet solid and liquid wastes

5.2.2.1 Ventilation Filters

The BWRX-300 design incorporates a number of Air Handling Units (AHUs) serving various parts of the plant, as per 006N7781 (Reference 5-65). Those extracting air from active (and therefore potentially contaminated areas) of the plant will give rise to used ventilation filters that have the potential to be contaminated and will therefore be managed as dry solid radioactive waste. Since it will initially be difficult to quantify levels of radioactivity on spent ventilation filters, it will be important that arrangements are in place to segregate and characterise filters to apply the correct disposition route in line with application of the waste hierarchy. It is anticipated that ventilation filters will be a LLW stream, but where characterisation indicates spent filters meet VLLW or out of scope criteria they will be managed accordingly in line with the waste hierarchy.

Spent filters will arise in the form of pre-filters and high efficiency particulate air filters from extract AHUs serving radioactive areas of the plant. Precise details on the type, size and number of filters is not yet available but it is assumed that spent filters will undergo safe change (i.e. radiological containment of the spent filter will be maintained throughout the filter change process) and will be presented as waste already contained in protective packaging (in the form of bagged filters). It is further assumed that, as with other dry solid wastes, the bagged filters will be placed into appropriate waste containers to afford appropriate mechanical protection of the filters as close as practicable to the point of arising, and prior to on-site movement. Since the wastes are assumed to be LLW, it is considered good practice to ensure that the containers conform to LLWR Ltd packaging specifications, found in the brochure, (see (Reference 5-22)). This will enable efficient and compliant disposition via the relevant waste route.

Ventilation filters are assumed to have an operational life of up to 10 years. Those that operate in areas that have the potential to be exposed to moisture (steam or pool evaporate) are assumed to require replacement more frequently.

5.2.2.2 Aqueous Effluent Filter Modules

The backwashable fine filters utilised in the CFD, FPC and LWM (including RWST) systems comprise a vessel housing the filter modules. The vessels are backwashed to remove adherent sludge, and this is flushed to the SWM sludge storage tank. Over time, the filter media itself will degrade, and underlying differential pressure across the filter will rise, ultimately resulting in a requirement for the filter modules to be replaced. Backwashable filters are anticipated to last for more than ten years if operated under an appropriate regime. Due to the highly efficient backwash process, the filter modules themselves are anticipated to contain very little radioactive waste and are assumed to arise as LLW.

The PCF, sludge consolidation and RO sections of the LWM system are also anticipated to generate spent activated carbon, filter cartridges and RO membrane modules that will require periodic replacement.

Spent PCF media will arise in the form of GAC and is anticipated to be classified as a LAW stream and will be removed from the plant separately for onward management. At present no inventory data is available for this stream.

The sludge consolidation filter is anticipated to generate spent filtration cartridges. These are anticipated to be classified as a LAW stream and will be removed from the plant separately for onward management via the SWM system. At present no inventory data is available for this stream.

The RO system is anticipated to generate spent RO modules. These are anticipated to be classified as a LAW stream and will be removed from the plant separately for onward management via the SWM system. At present no inventory data is available for this stream.

FAP.PER5-112 – Provide further design detail and Realistic Model EUST Values for wastes arising from BWRX-300 LWM system operation including GAC, sludge consolidation filters and RO modules**.**

On removal, the filters, cartridges, and RO modules may require size reduction in order to be packaged to an appropriate waste container. Once packaged, the filter modules will be consigned for off-site disposition and may undergo further volume reduction (incineration or super-compaction) prior to disposal, in line with application of the waste hierarchy.

5.2.2.3 Heterogeneous Dry Solid Wastes

A range of dry solid wastes will be generated through operational, maintenance and repair/refurbishment on an ad hoc basis associated with activities undertaken in the radioactive areas of the plant throughout the operating life of the BWRX-300 (006N7733 (Reference 5-52)). A range of similar wastes are anticipated to be generated during the decommissioning phase, and these are considered separately in 5.3.

Dry solid radioactive wastes will arise in the form of contaminated articles and substances, such as air filters, and miscellaneous wastes including cartridge filters, activated carbon cartridges, RO membranes, rags, plastic bags and packaging, paper, disposable clothing, personal protective equipment, tools, laboratory wastes, and equipment utilised in radioactive areas of the plant.

The substances are expected to include metals, hard wastes, soft wastes, inert wastes, and organic wastes, plastics, paper, card, wood, glass, building materials, insulation etc. Waste items are expected to include motors, cables and pipes, valves, actuators, instruments, miscellaneous filters, strainers etc.

Heterogeneous LLW may be generated anywhere within the active facilities throughout the power block. Dry solid wastes will be collected, segregated, collated, and initially characterised in nominal 205 l drums. These drums will be located in appropriate areas throughout the plant, as dictated by volume of wastes generated during operation and maintenance, and the segregation criteria defined by downstream disposition routes, as specified in LLWR WSC-WAC-OVR (Reference 5-23). Filled waste containers will be sealed and moved to controlled access enclosed areas for temporary storage and final characterisation, pending disposition.

The waste characteristics will be diverse and will include a range of sizes, shapes, masses, and densities. It is assumed that, wherever practicable, wastes will be generated in quantities/sizes that are manageable using the ‘standard’ range of LLW containers used in the UK, as per the brochure, (see (Reference 5-22)). Where any requirement for size reduction of wastes to facilitate packaging is identified, it will be necessary to demonstrate that this can be done in a safe and contained manner that minimises operator risks to ALARP.

It is assumed that increased volumes of waste are generated during outages due to an increase in intrusive work on the plant and the greatly increased footfall of personnel necessary during an outage.

5.2.2.4 Non-Aqueous Wet Solid and Liquid Wastes

Non-aqueous wastes in the form of lab samples, chemical wastes, and oily waste from the EFS non-aqueous sumps (006N7789 (Reference 5-50)) will be collected in nominal 205 l drums conforming to UK LLW WAC, and loaded in the drum evaporator which forms part of the SWM system (CP 1009 (Reference 5-1)). The drum evaporator removes excess moisture, through evaporation, which is routed to the RWB ventilation system for elimination. The remaining waste in the drum will be sent offsite via the appropriate waste route in accordance with the waste hierarchy and relevant LLWR WAC.

An overview of the anticipated arrangements for management of LAW is presented in Appendix E.

It will be necessary for a future developer/operator of a UK BWRX-300 to engage with NWS to establish off-site waste disposition routes for LAW via the LLWR Ltd waste services contract, noting that the developer/operator also has recourse to engage directly with LAW pretreatment service providers and VLLW disposal sites.

FAP.PER5-115 – Future developer/operator of a UK BWRX-300 installation to engage with NWS and/or other LAW service providers to establish off-site routes for LAW disposition.

5.3 BWRX-300 Decommissioning Wastes

Decommissioning of the BWRX-300 SMR is addressed in 006N8745, “BWRX-300 Incorporation of Decommissioning in Design Considerations,” (Reference 5-68). Decommissioning is assumed to be conducted in a similar manner to that applied to existing LWRs:

- Post Operational Clean Out (POCO)
- Reactor coolant circuit decontamination
- RPV dismantling

- POCO of fuel pool, equipment pool and reactor cavity
- Balance of plant dismantling and demolition

POCO wastes will comprise further wastes analogous to those produced during operation:

- Final core offload of SF
- All control rods
- All reactor instrumentation assemblies
- Final batches of filter backwash sludges and spent resins, HVS filters
- Offload of spent charcoal from offgas system delay beds
- Contaminated and irradiated plant and equipment from pools, including fuel storage racks

Actual sequence of waste arisings will be dependent on the decommissioning strategy and sequence applied.

Following POCO, it is assumed that the coolant circuit will undergo appropriate in-situ decontamination using an intrusive chemical/mechanical process that generates a concentrated sludge/particulate waste stream. If a liquid transport medium is used as a component of the applied in-situ decontamination technique this will also need to undergo appropriate abatement, resulting in further sludges and potentially further spent resins/filtrates/filters etc.

It is anticipated that RPV dismantling will focus on the establishment of a cutting plan that enables resultant metal sections to be segregated according to waste category. This may also entail decay storage strategies dependent on levels of activation of the cut sections. Since the BWRX-300 utilizes a taller ‘chimney’ design, it is assumed that some RPV components (moisture separator, steam dryer etc.), located a greater distance from the neutron flux, will be less irradiated than similar components in previous designs, such as ABWR. This may reduce the volume of decommissioning HAW.

Fuel storage racks in the fuel pool will undergo a degree of neutron irradiation from storage of irradiated SF. It is anticipated that these may be irradiated to ILW levels and would be managed as a decommissioning ILW stream.

All other wastes arising from decommissioning are assumed to meet UK LAW disposal criteria and will be managed in line with prevailing disposal requirements at the time.

5.4 Anticipated Waste Quantities

Table 5-7 presents a summary of estimated SF and radioactive waste quantities for the anticipated 60-year operating life of a BWRX-300 SMR, including commissioning and decommissioning.

5.5 Assumptions

At this early stage of development for a UK installation of BWRX-300 a large number of assumptions have been made within this chapter. These assumptions are summarised in Table 5-8. Where assumptions have been derived from external publications the reference is stated. Where assumptions have been made in the compilation of this chapter the relevant section is referenced as the source.

5.6 Conclusion

The RWM arrangements for the BWRX-300 presented in this chapter provide a demonstration of how the BWRX-300 can be developed to integrate with UK RWM and wider environmental protection requirements. Since GDA step 2 represents a single unit design in a non-specified location it does not demonstrate that the design has been fully optimised for UK deployment.

The BWRX-300 SMR design has evolved from the previous ESBWR and ABWR designs but is primarily influenced by the design simplifications introduced for the ESBWR. This has resulted in corresponding simplifications in systems that produce radioactive wastes and on the resultant radioactive wastes themselves.

5.6.1 Higher Activity Wastes

The use of high efficiency backwashable filters and deep bed demineralisers throughout the design has reduced the number of wet solid radioactive waste streams to two, namely:

- Filter backwash sludges
- Spent bead resins

At present, based on the SWM source term in 008N0133 (Reference 5-59), these wet solid wastes align to the UK radioactive waste classification of ILW, which necessitates on site management and eventual disposal to GDF, inferring a requirement for on-site processing and storage capabilities. It should be noted that the current source term is highly conservative and has been derived to present a bounding case for the purposes of radiation protection and shielding design. A FAP action has been defined to provide a realistic model (best estimate) radwaste EUST – see Section 5.2.1.3.

It should also be noted that the BWRX-300 design incorporates enhanced design aspects that have the potential to further reduce radioactivity in these waste streams. These include:

- Use of improved GNF2 fuel described in NEDC-334159P, “BWRX-300 Fuel Summary Report,” (Reference 5-69) – this is anticipated to result in a lower incidence of fuel cladding failures that will positively impact on all downstream source term values.
- Increased use of stainless steel throughout the design – this is anticipated to result in reduced corrosion and erosion particulate generation throughout the plant. This will both reduce wet solid waste volumes and result in fewer particles undergoing irradiation in the core, reducing the overall radioactivity of the filter backwash sludges produced. Reduced presence of particles in the RPV is also complementary to reduced fuel clad failures.
- Reduced cobalt inventory – the BWRX-300 material selection strategy presented in 006N5956, “BWRX-300 Materials and Process Controls,” (Reference 5-70) focusses on reducing cobalt inventory wherever practicable throughout the plant design.
- Enhanced water chemistry regime – this is anticipated to result in further reduction of corrosion and erosion particulate as above, and minimisation of cobalt deposition on coolant facing surfaces.

These design enhancements are presently difficult to quantify in terms of their contribution to an improved radwaste EUST. As with considerations for the UK ABWR, it is therefore prudent to consider that the designs for on-site wet solid wastes processing and storage should not be finalised until the full effectiveness of these design improvements have been established (i.e. after the first wastes have been generated by operation of a BWRX-300). Due to the potential construction of BWRX-300 SMRs in a number of countries, it is considered that the FAP should include an activity to utilise wet solid waste characterisation data from the first operating BWRX-300 SMR(s). This will inform decision making on the design for on-site wet solid waste processing and storage capabilities for a UK version of the BWRX-300 SMR.

FAP.PER5-114 – Utilise wet solid waste streams characterisation data from the first operating BWRX-300 SMR(s) to finalise design decisions for on-site processing and storage capabilities for a UK version of the BWRX-300 SMR.

BWRX-300 design is predicated on United States (U.S.) requirements, and the RWM arrangements provide the interface to the U.S. radioactive waste classification scheme and related disposition criteria. It is recognised that there are differences between U.S. and UK RWM policy and the design of a UK BWRX-300 SMR will require alignment with UK requirements. Assessment of the source term for wet solid radioactive wastes (see 008N0133 (Reference 5-59)) indicates that they would meet the UK criteria of ILW, resulting in a requirement for on-site processing and storage pending availability of a national GDF (and noting that the present source term is design basis and considered conservative and bounding – see FAP.PER5-110).

Other HAW streams arising from operation of the BWRX-300 SMR are very similar to those previously considered for the UK ABWR:

- SF bundles
- Irradiated control rod
- Irradiated instrumentation assemblies

These are considered to present no significant issues for management and disposal to GDF. SF disposal requirements are awaited from NWS before firm decisions can be reached on the precise arrangements for packaging for disposal. Irradiated wastes will initially be managed as HLW in a similar manner to SF and will subsequently be recovered and repackaged as Dry Solid Intermediate level Waste (DSILW) after an appropriate decay storage period.

5.6.2 Lower Activity Wastes

LAW streams arising from operation of the BWRX-300 SMR are very similar to those previously considered for the UK ABWR:

- Spent HVS filters
- Effluent Filter Modules
- Heterogeneous dry solid wastes

These are considered to present no significant issues for management and disposition as LAW. Waste management arrangements will be implemented to ensure compliance with the relevant LLWR WAC, WSC-WAC-OVR (Reference 5-23), and to ensure appropriate application of the waste hierarchy to optimise disposal. Wastes will be appropriately segregated, packaged, characterised, sentenced, and consigned in accordance with the requirements of the relevant LLWR WAC document.

5.6.3 Future Responsibilities

During a future site-specific development phase decisions will be required on some of the areas that are highlighted as incomplete in this document, and this is likely to include exploration of the economic viability of a plant and considerations of important aspects such as multiplication of units to form a nuclear licensed site. Specifically in relation to SF and RWM arrangements, this may include determination of appropriate strategies for the on-site management of waste from multiple units, taking into account economies of scale, demonstration of an optimised approach, construction timings, and required design integration activities.

The following key aspects are therefore considered the future responsibilities of an organisation undertaking a UK site-specific development of the BWRX-300 SMR:

- Considerations of the implications of a multiple unit site with respect to BAT, optimisation, facility integration and sizing, construction timings etc.
- Technical decision making and related demonstration of BAT and optimisation relating to:
  - SF management, including siting, sizing, and form of dry cask storage
  - HLW management, including integrated storage with SF casks, decay storage period, and provision of future DSILW processing capability
  - WSILW Management, including decision making on choice of final waste container, immobilisation method and form of ILW storage facility (i.e. shielded or unshielded), and store sizing taking account of potential additional requirement for storage of packages arising from processing of decay stored DSILW – control rods
  - Arrangements to align DSILW management with the UK LLW waste services framework, including on-site segregation, packaging, and characterisation requirements to enable application of the waste hierarchy and compliance with relevant LLW WAC, WSC-WAC-OVR (Reference 5-23)

Table 5-1: UK Radioactive Waste Categories and Definitions

Category	Definition
HLW	Wastes in which the temperature may rise significantly as a result of their radioactivity. The heat therefore has to be taken into account in the design of storage or disposal facilities. Typical characteristics of HLW are thermal power above about 2 kW/m^3, as described in "Basic principles of RWM – an introduction to the management of HAW on nuclear licensed sites" (Reference 5-20). This classification would include SF that has been determined to be radioactive waste – see Section 5.2.1.1.
ILW	Wastes exceeding the upper boundaries for LLW, as defined in "What are the Main Waste Categories?" (Reference 5-21), but do not generate sufficient heat to be considered in the design of storage or disposal facilities. Includes LLW that is not compliant for disposal as LLW.
LLW	Wastes having relatively low levels of radioactive content, not exceeding 4 Giga-becquerels (GBq) per tonne (t) of alpha activity or 12 GBq/t of beta/gamma activity (see (Reference 5-21)).
VLLW	A sub-category of LLW. It comprises waste that can be safely disposed of with municipal, commercial, or industrial waste, or can be disposed of at specified landfill sites. VLLW is further sub-divided into two categories according to "What is Radioactive Waste?" (Reference 5-17). High Volume VLLW – wastes with maximum concentrations of 4 MBq (megabecquerels) per tonne (MBq/t) of total activity that can be disposed to specified landfill sites. There is an additional limit for tritium in wastes containing this radionuclide. Low Volume VLLW – wastes that can be safely disposed of to an unspecified destination with municipal, commercial, or industrial waste. Each 0.1 m^3 of material must contain less than 400 kBq (kilobecquerels) of total activity, or single items must contain less than 40 kBq of total activity. There are additional limits for C-14 and tritium in wastes containing these radionuclides.

Table 5-2: Low Level Waste Repository Waste Services Framework Waste Acceptance Criteria

Service	WAC Reference	Issue & Date
LLW Disposal	WSC-WAC-LOW	Version 5, Issue 1, July 2016
Supercompaction	WSC-WAC-SUP	Version 3, April 2012
Incineration	WSC-WAC-COM	Version 3, April 2012
VLLW Disposal	WSC-WAC-VER	Version 3, April 2012
Metal Melting	WSC-WAC-MET	Version 3, April 2012

Note: Individual service providers may also provide their own specific WAC requirements if being engaged directly.

Table 5-3: References to Regulatory Guidance Related to Passive Safety and Disposability

Joint Regulatory Guidance, "The management of higher activity radioactive waste on nuclear licensed sites," (Reference 5-26).
"Wastes should be conditioned to a safe, passive, transportable and disposable form as soon as is reasonably practicable."
ONR Safety Assessment Principle: RW.5 Storage of Radioactive Waste and Passive Safety from CM9 Ref 2019/367414 "Safety Assessment Principles for Nuclear Facilities," (Reference 5-27).
"Radioactive waste should be stored in accordance with good engineering practice and in a passively safe condition."
ONR Safety Assessment Principle: RW.6 Passive Safety Timescales, from CM9 Ref 2019/367414 (Reference 5-27).
"Radiological hazards should be reduced systematically and progressively. The waste should be processed into a passive safe state as soon as is reasonably practicable."
Environment Agency Radioactive Substances Regulation – Developed Principle 11 – Storage in a Passively Safe State, from "Radioactive substances management: generic developed principles," (Reference 5-28).
"Where radioactive substances are currently not stored in a passively safe state and there are worthwhile environmental or safety benefits in doing so then the substances should be processed into a passively safe state."

Table 5-4: United Kingdom Position on Spent Fuel Management

UK Department for Energy Security and Net Zero: CP 1009, "Civil Nuclear: Roadmap to 2050" (Reference 5-1)

Managing spent fuel

"Spent fuel can either be managed through interim storage prior to final disposal or through reprocessing. Interim storage involves safely and securely storing the spent fuel, potentially for several decades, until it is conditioned and permanently disposed of as waste in a GDF or reprocessed. Decisions on the management of spent fuel are a matter for the owner of the spent fuel.

The UK reprocessed spent fuel on an industrial scale from the 1950s to 2022. Commercial industrial scale reprocessing came to an end in the UK with the closure of the Thermal Oxide Reprocessing Plant in 2018. There is currently no industrial scale reprocessing in the UK. The government has not received any credible proposals from industry to restart reprocessing and has no plans to pursue, or provide financial support for, industrial scale reprocessing of spent nuclear fuel."

In the absence of reprocessing proposals from industry, owners of spent fuel, including from new or advanced reactors, should proceed on the basis that spent fuel will not be reprocessed and waste management plans, including financing, should reflect this.

Table 5-5: Requirement for Interim Storage of Spent Fuel

ONR-GDA-GD-007, NPPs: GDA Technical Guidance (Reference 5-33)
"The UK government's Base Case strategic assumption is the spent fuel from a new nuclear power station will be kept in interim storage on the site of the power station until the point at which it is disposed of in a GDF, and that the packaging of spent fuel will also be carried out on-site."

Table 5-6: Timing of Construction of Spent Fuel Storage

ONR-GDA-GD-007, NPPs: GDA Technical Guidance (Reference 5-33)
It may not be necessary for Spent Fuel Interim Storage to be available at the start of reactor operations if the RP can demonstrate there is sufficient storage capacity in the spent fuel pool for a number of fuel cycles (and provide adequate storage for removal of all fuel from the reactor core as a result of an emergency).

Table 5-7: Estimate of Spent Fuel and Radioactive Waste for a 60-Year Operating Life

Quantity	Frequency	Totals	Basis
Spent Fuel			
240	Initial Core Load	240	005N9751 (Reference 5-34)
32	59 x 12-month Cycles	1888	Section 5.2.1.1
Overall Total		**2128**	
Irradiated In-Core Components			
Control Rods			
57	Initial Load	57	005N9751 (Reference 5-34)
4	19 x 36-month cycles	76	Section 5.2.1.2
Overall Total		**133**	
Nuclear Instrumentation			
LPRM			
13	Initial Load	13	005N9751 (Reference 5-34)
Ad hoc arisings		Not quantified	
Overall Total		**Not Quantified**	
WRNM			
10	Initial Load	10	005N9751 (Reference 5-34)
Ad hoc arisings		Not quantified	
Overall Total		**Not Quantified**	
Wet Solid Wastes			
Filter Backwash Sludges			
Condensate Filter			
0.3 m^3	Annually	18.0 m^3	008N0133 (Reference 5-59)
Fuel Pool Cooling and Cleanup Filter			
0.03 m^3	Annually	1.8 m^3	008N0133 (Reference 5-59)
Refueling Water Storage Tank Filter			
0.37 m^3	Annually	22.2 m^3	008N0133 (Reference 5-59)
Spent Bead Resins			
Condensate Demineraliser			

Quantity	Frequency	Totals	Basis
18.18 m^3	Annually	1090.8 m^3	008N0133 (Reference 5-59)
Fuel Pool Cooling and Cleanup Demineraliser			
3.35 m^3	Annually	201.0 m^3	008N0133 (Reference 5-59)
Isolation Condenser Pools Cooling and Cleanup Demineraliser			
0.7 m^3	Annually	42.0 m^3	008N0133 (Reference 5-59)
LWM Filter Skid Demineraliser			
5.4 m^3	Annually	324.0 m^3	008N0133 (Reference 5-59)
Lower Activity Wastes			
Ventilation Filters			
To be determined		Not Quantified	Section 5.2.2.1
Aqueous Effluent Filter Cartridges and RO Modules			
To be determined		Not Quantified	Section 5.2.2.2
Heterogeneous Dry Solid Wastes			
To be determined		Not Quantified	Section 5.2.2.3
Non-Aqueous Wet Solid and Liquid Wastes			
To be determined		Not Quantified	Section 5.2.2.4
Total Dry Active Waste Arisings			
148.0 m^3	Annually	8,880.0 m^3	006N8745 (Reference 5-68)
Decommissioning Wastes			
High Level Waste			
115.4 m^3	Decommissioning Phase	115.4 m^3	NEDC-34229P (Reference E5-9)
Intermediate Level Waste			
557.9 m^3	Decommissioning Phase	557.9 m^3	NEDC-34229P (Reference E5-9)
Low Level Waste			
8,200 m^3	Decommissioning Phase	8,200 m^3	NEDC-34229P (Reference E5-9)

Table 5-8: List of Assumptions

No	Assumption	Source
1	It is assumed that SF will not be reprocessed and will ultimately be disposed of to a national GDF as HHGW.	CP 1009 (Reference 5-1)
2	It is assumed that a GDF could be ready to receive intermediate level waste between 2050-2060, with high level waste and SF from 2075.	"Geological Disposal – a programme like no other" (Reference 5-25)
3	It is assumed that currently existing final waste packages on UK nuclear sites will take priority over new wastes in timing of disposal to the GDF.	Section 5.2.1.1
4	It is assumed that a new nuclear facility will be required to retain HAW (including SF) on site for at least 100 years.	
5	It is assumed that no radioactive wastes will be generated until the point at which nuclear fuel is first brought onto site at an appropriate stage during the commissioning phase.	Section 5.2
6	It is assumed that SF arising from operation of a UK BWRX-300 will be stored and repackaged on-site pending eventual disposal to a national GDF.	CM9 Ref 2019/367414 (Reference 5-27)
7	It is assumed that BWRX-300 will operate on a 12-month fuel cycle with 32 fuel channels replaced during each refueling outage.	Section 5.2.1.1
8	It is assumed that UK BWRX-300 will employ dry cask storage as the technical basis for SF storage.	
9	It is assumed that failed fuel will be packaged for on-site dry cask storage in a similar manner to SF	
10	It is assumed that when SF is repackaged for disposal, the fuel channels will be segregated and managed separately as IICC.	
11	It is assumed that IICC will be classified as HLW on generation and will decay to meet ILW classification criteria during the storage period.	Section 5.2.1.2
12	It is assumed that four (4) control rods will be replaced every 3rd fuel cycle.	
13	It is assumed that size reduction of the instrument tubes by folding or cutting takes place in the fuel pool.	
14	It is assumed that IICC will undergo decay storage and cooling in SF casks in the same storage location as SF.	
15	It is assumed that once IICC has decayed to meet the ILW classification it will be recovered from cask storage and repackaged to produce FWPs that conform to GDF disposal criteria for LHGW.	
16	It is assumed that wet solid wastes (filter backwash sludges and spent resins) will be classified as ILW on generation.	Section 5.2.1.3

No	Assumption	Source
17	It is assumed that BWRX-300 resins will be either a styrene divinylbenzene copolymer or cross-linked polystyrene matrix in a fine bead form, similar to those used in the ABWR.	WN0908-HZCON- PAC-REP-00003 (Reference 5-60)
18	It is assumed that wet bead resin will arise as an aqueous slurry with a wet density of 1.165 t/m^3.	
19	It is assumed that filter backwash sludges will arise as an aqueous slurry with a wet density of 1.1 t/m^3.	
20	It is assumed that WSILW will be processed on-site by cement immobilisation in RWM approved 3 m^3 drums.	Section 5.2.1.3
21	It is assumed that spent GAC, sludge consolidation filters and RO modules arising from LWM system operation will be classified as LAW on generation.	
22	It is assumed that spent ventilation filters will undergo safe change (I.e. no breach of radiological containment during filter changing) and will be presented as waste already contained in protective packaging (in the form of bagged filters).	Section 5.2.2
23	It is assumed that bagged ventilation filters will be placed into appropriate waste containers to afford appropriate mechanical protection of the filters as close as practicable to the point of arising.	
24	It is assumed that spent ventilation filters will be classified as LLW.	
25	It is assumed that ventilation filters will have an operational life of up to 10 years.	
26	It is assumed that ventilation filters serving areas that have the potential to be exposed to moisture (steam or pool evaporate) will require replacement more frequently.	
27	It is assumed that, wherever practicable, wastes will be generated in quantities/sizes that are manageable using the ‘standard’ range of LLW containers used in the UK.	
28	It is assumed that increased volumes of waste will be generated during outages due to an increase in intrusive work on the plant and the greatly increased footfall of personnel necessary during an outage.	
29	It is assumed that decommissioning of the BWRX-300 SMR will be conducted in a similar manner to that applied to existing LWRs.	Section 5.3
30	It is assumed that the BWRX-300 fluid circuit will undergo in-situ chemical descaling as part of decommissioning POCO activities.	
31	It is assumed that some RPV components (moisture separator, steam dryer etc.), situated at a greater distance from the neutron flux will be less irradiated than similar components in previous designs, such as ABWR.	

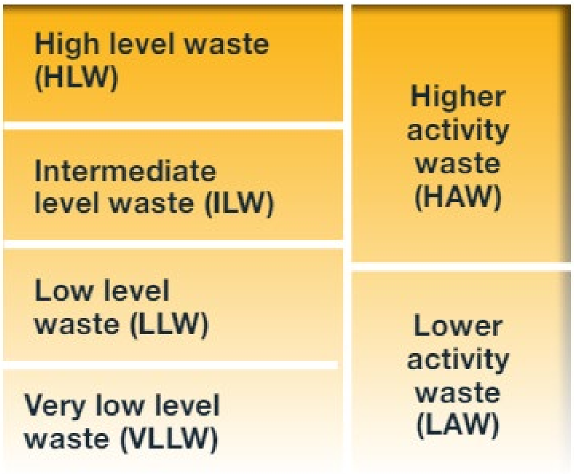


Figure 5-1: UK Radioactive Waste Categories

Figure 5-2: Waste Hierarchy

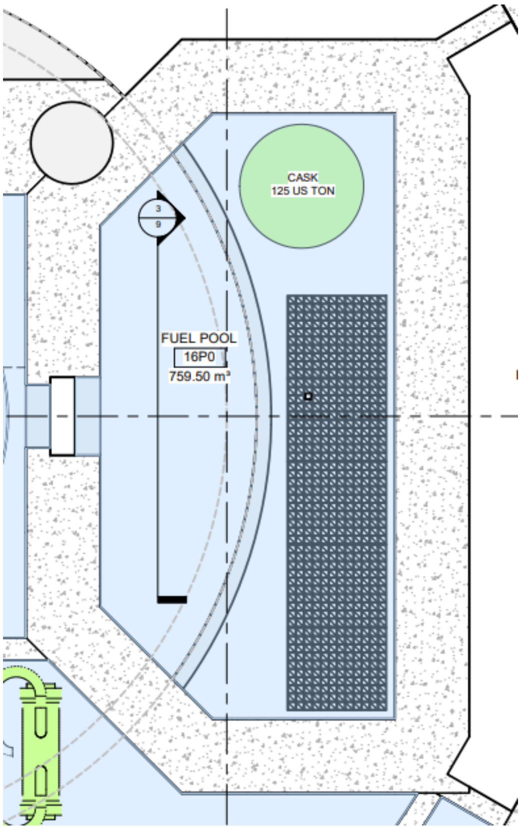


Figure 5-3: BWRX-300 Fuel Pool showing Fuel Cask Position

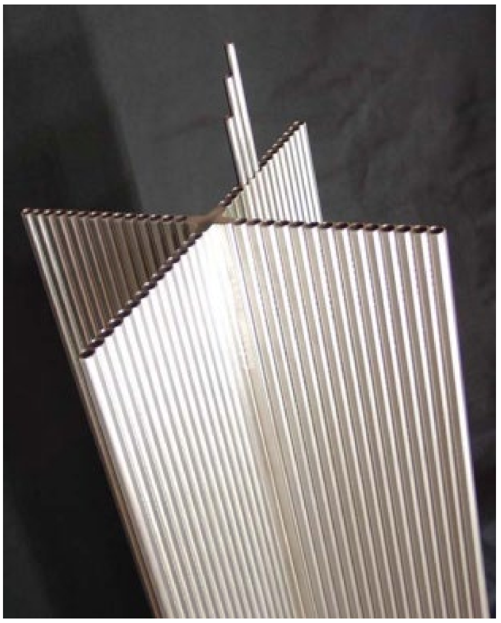


Figure 5-4: GE Ultra™ Control Rod

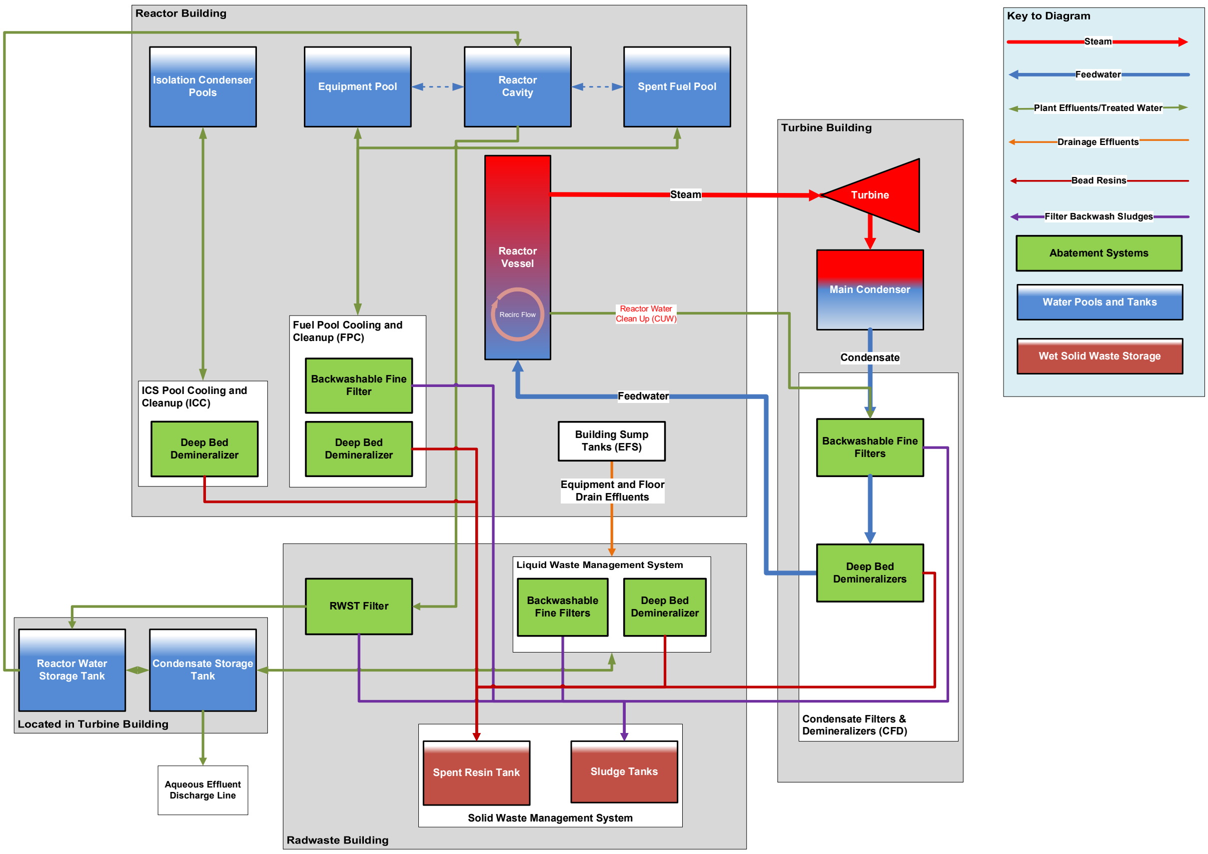


Figure 5-5: Overview of BWRX-300 Process Water and Effluent Management

5.7 References

5-1 CP 1009, "Civil Nuclear: Roadmap to 2050," UK Government, ISBN 978-1-5286-4560-7, January 2024.

5-2 NEDC-34223P, "BWRX-300 UK GDA Ch. E6: Demonstration of Best Available Techniques Approach," Rev A, GE-Hitachi Nuclear Energy, Americas, LLC.

5-3 "Net Zero Strategy: Build Back Greener," UK Government. ISBN 978-1-5286-2938-6, October 2021

5-4 NEDC-34228P, "BWRX-300 UK GDA "Integrated Waste Strategy," GE-Hitachi Nuclear Energy, Americas, LLC.

5-5 "The 17 Goals: Sustainable Development," United Nations, Available at https://sdgs.un.org/goals, Accessed September 2024.

5-6 NEDC-34221P, "BWRX-300 UK GDA Ch. E4: Information about the Design," Rev A, GE-Hitachi Nuclear Energy, Americas, LLC.

5-7 WPS/240/02, "Waste Package Specification and Guidance Documentation: Specification for High Heat Generating Waste Precursor Product", Nuclear Waste Services, Version 2, October 2024.

5-8 NEDC-34224P, "BWRX-300 UK GDA Ch. E7: Radioactive Discharges," Rev A, GE-Hitachi Nuclear Energy, Americas, LLC.

5-9 NEDC-34229P, "BWRX-300 UK GDA Demonstration of Disposability for Higher Activity Radioactive Wastes (Including Spent Fuel)," Rev A, GE-Hitachi Nuclear Energy, Americas, LLC.

5-10 NEDC-34174P, "BWRX-300 UK GDA Ch. 11: Management of Radioactive Waste," Rev A, GE-Hitachi Nuclear Energy, Americas, LLC.

5-11 NEDC-34193P, BWRX-300 UK GDA Ch. 21: Decommissioning and End of Life Aspects," Rev A, GE-Hitachi Nuclear Energy, Americas, LLC.

5-12 NEDC-34198P, BWRX-300 UK GDA Ch. 26: Interim Storage of Spent Fuel," Rev A, GE-Hitachi Nuclear Energy, Americas, LLC.

5-13 "New Nuclear Power Plants: Generic Design Assessment Guidance for Requesting Parties," Environment Agency, Office for Nuclear Regulation, and Natural Resource Wales, October 2023

5-14 NS-TAST-GD-006, "Nuclear Safety Technical Assessment Guide – Design Basis Analysis," Office for Nuclear Regulation, Issue 5.1, December 20225-15.

5-15 005N3558, "BWRX-300 Fault Evaluation," GE-Hitachi Nuclear Energy, Rev 3, June 2024.

5-16 "UK Policy Framework for Managing Radioactive Substances and Nuclear Decommissioning," Department for Energy Security and Net Zero, Version 3.0, May 2024.

5-17 "What is Radioactive Waste?," NDA UK Radioactive Waste Inventory, Available at https://ukinventory.nda.gov.uk/about-radioactive-waste/what-is-radioactive-waste/, Accessed August 2024.

5-18 "UK Radioactive Waste Inventory 2022," UK Government, Rev 1, Available at https://www.gov.uk/government/publications/uk-radioactive-waste-and-material-inventory-2022, February 2023

5-19 "NDA Integrated Waste Management Radioactive Waste Strategy", Nuclear Decommissioning Authority, September 2019.

5-20 "Basic Principles of Radioactive Waste Management – An Introduction to the Management of HAW on Nuclear Licensed Sites," Joint Guidance from the Office of Nuclear Regulation, the Environment Agency, the Scottish Environment Protection Agency and Natural Resources Wales to nuclear licensees, Rev 2, February 2015.

5-21 "What Are the Main Waste Categories?," NDA UK Radioactive Waste Inventory, Available at https://ukinventory.nda.gov.uk/information-hub/factsheets/what-are-the-main-waste-categories/, Accessed August 2024.

5-22 "Logistic Services," Low Level Waste Repository Ltd, Available at https://assets.publishing.service.gov.uk/media/65e08bfa2f2b3b00117cd788/Logistics_Services_Brochure.pdf, Accessed August 2024.

5-23 WSC-WAC-OVR, "Waste Services Contract: Waste Acceptance Criteria – Overview," Low Level Waste Repository Ltd, Version 3, April 2012.

5-24 "Creating Standardised Waste Packages," Nuclear Waste Services, November 2020.

5-25 "Geological Disposal – A Programme Like No Other," Nuclear Waste Services, Available at https://www.gov.uk/guidance/geological-disposal, Accessed August 2024.

5-26 "The Management of Higher Activity Radioactive Waste on Nuclear Licensed Sites," Joint Guidance from the Office for Nuclear Regulation, the Environment Agency, the Scottish Environment Protection Agency and Natural Resources Wales to nuclear licensees, Rev 2.1, July 2021.

5-27 CM9 Ref 2019/367414, "Safety Assessment Principles for Nuclear Facilities," Office for Nuclear Regulation, Rev 1, January 2020.

5-28 "Radioactive Substances Management: Generic Developed Principles," Environment Agency, Available at https://www.gov.uk/government/publications/rsr-generic-developed-principles-regulatory-assessment/radioactive-substances-management-generic-developed-principles, May 2024.

5-29 "Our Work with Radioactive Waste Producers," Nuclear Waste Services, Available at https://www.gov.uk/guidance/our-work-with-radioactive-waste-producers, Updated August 2018.

5-30 "Near-Surface Disposal Strategic Position Paper," Nuclear Decommissioning Authority, August 2020.

5-31 "NDA Strategic Position on Radioactive Waste Treatment," Nuclear Decommissioning Authority, August 2023.

5-32 "National Policy Statement for Geological Disposal Infrastructure," UK Government, ISBN 978-1-5286-1088-9, July 2019.

5-33 ONR-GDA-GD-007, "New Nuclear Power Plants: Generic Design Assessment Technical Guidance," Office for Nuclear Regulation, Rev 0, May 2019.

5-34 005N9751, "BWRX-300 General Description," GE-Hitachi Nuclear Energy, Rev F, December 2023.

5-35 006N5377, "BWRX-300 Refueling and Servicing Equipment," GE-Hitachi Nuclear Energy, Rev 2, October 2023.

5-36 DBR-0057741, "BWRX-300 Plant Performance Envelope," GE-Hitachi Nuclear Energy, Rev 0, April 2022.

5-37 "Dry Cask Storage," United States Nuclear Regulatory Commission, Available at https://www.nrc.gov/waste/spent-fuel-storage/dry-cask-storage.html, June 2023.

5-38 006N5339, "BWRX-300 Irradiated Fuel Management Plan," GE-Hitachi Nuclear Energy, Rev C, December 2021.

5-39 EPR/ZP3690SY/V005, "RSR Permit Variation," NNB Generation Company (HPC) Limited, October 2022.

5-40 005N1730, "General Arrangement Drawing – Reactor Building," Plan View, Level 4.9, GE Hitachi Nuclear Energy, Rev G, November 2019.

5-41 NEDC-33415P, "Nordic GNF2 Operational Experience Update," GNF/ENUSA, Supplement 1, Rev 4, November 2023.

5-42 GA91-9901-0022-00001, "UK ABWR Generic Design Assessment: Radioactive Waste Management Arrangements," GE-Hitachi Nuclear Energy, December 2017.

5-43 006N5114, "BWRX-300 Plant I&C Systems Architecture Requirements and Design," GE-Hitachi Nuclear Energy, Rev 0, July 2022.

5-44 "Low Heat Generating Waste Specifications," Nuclear Waste Services, Available at https://www.gov.uk/guidance/low-heat-generating-waste-lhgw-specifications#:~:text=WPS/220/01%20-%20Specification%20for%20Waste, November 2020.

5-45 006N6766, "BWRX-300 Water Quality," GE-Hitachi Nuclear Energy, Rev 4, March 2024.

5-46 006N7941, "BWRX-300 Fuel Pool Cooling and Cleanup System," GE-Hitachi Nuclear Energy, Rev 1, September 2023.

5-47 006N7741, "BWRX-300 Condensate Filters and Demineralizers," GE-Hitachi Nuclear Energy, Rev 1, March 2023.

5-48 006N7609, "BWRX-300 Reactor Water Cleanup System," GE-Hitachi Nuclear Energy, Rev 2, September 2023.

5-49 006N7345, "BWRX-300 Isolation Condenser Pools Cooling and Cleanup System," GE-Hitachi Nuclear Energy, Rev 1, September 2023.

5-50 006N7789, "BWRX-300 Equipment and Floor Drain System (EFS)," GE-Hitachi Nuclear Energy, Rev 2, April 2023.

5-51 006N7729, "BWRX-300 Liquid Waste Management System (LWM)," GE-Hitachi Nuclear Energy, Rev 1, March 2023.

5-52 006N7733, "BWRX-300 Solid Waste Management System (SWM)," GE-Hitachi Nuclear Energy, Rev 1, April 2023.

5-53 008N0988, "BWRX-300 Power Block General Arrangement," GE-Hitachi Nuclear Energy, Rev 2, December 2023.

5-54 006N7828, "BWRX-300 Nuclear Boiler System," GE-Hitachi Nuclear Energy, Rev 2, September 2023.

5-55 006N7757, "BWRX-300 Main Condenser and Auxiliaries System," GE-Hitachi Nuclear Energy, Rev 2, February 2024.

5-56 006N7708, "BWRX-300 Shutdown Cooling System," GE-Hitachi Nuclear Energy, Rev 2, August 2023.

5-57 NEDC-34279P, "BWRX-300 UK GDA Analysis of Environmental Discharge Data for US Nuclear Power Plants," Rev A, GE-Hitachi Nuclear Energy, Americas, LLC.

5-58 "Overview of the Multi-nuclide Removal Equipment (ALPS) at Fukushima Daiichi Nuclear Power Station," Tokyo Electric Power Company, Available at https://www.tepco.co.jp/en/nu/fukushima-np/handouts/2013/images/handouts_130329_01-e.pdf, March 2013.

5-59 008N0133, "BWRX-300 Solid Waste Management System – Contained Source Activity," GE-Hitachi Nuclear Energy, Rev 0, January 2024.

5-60 WN0908-HZCON-PAC-REP-00003, "Radioactive Substances Regulation – Environmental Permit Application," Horizon Nuclear Power, Wylfa Newydd Project. September 2015.

5-61 RWPR63-WI11, "Preparation of Expert Views to support Step 2 of the Generic Design Assessment Process," Radioactive Waste Management Ltd, Rev 0, March 2024.

5-62 006N7938, "BWRX-300 Process Radiation and Environmental Monitoring System," GE-Hitachi Nuclear Energy, Rev 1, August 2023.

5-63 NEDC-34225P, "BWRX-300 UK GDA Ch. E8: Approach to Sampling and Monitoring," Rev A, GE-Hitachi Nuclear Energy, Americas, LLC.

5-64 006N7673, "BWRX-300 Water Balance," Rev B, GE-Hitachi Nuclear Energy, October 2022.

5-65 006N7781, "BWRX-300 Heating Ventilation and Cooling System," Rev 3, GE-Hitachi Nuclear Energy.

5-66 006N7797, "BWRX-300 Water, Gas, and Chemical Pads System," Rev 1, GE-Hitachi Nuclear Energy, March 2023.

5-67 006N7761, "BWRX-300 Circulating Water System," Rev 1, GE-Hitachi Nuclear Energy, March 2023.

5-68 006N8745, "BWRX-300 Incorporation of Decommissioning in Design Considerations", Rev B, GE-Hitachi Nuclear Energy, May 2022.

5-69 NEDC-334159P, "BWRX-300 Fuel Summary Report," Rev A, GE-Hitachi Nuclear Energy, July 2024.

5-70 006N5956, "BWRX-300 Materials and Process Controls," Rev 1, GE-Hitachi Nuclear Energy, February 2023.

APPENDIX A OVERVIEW OF LOW-LEVEL WASTE REPOSITORY LIMITED WASTE SERVICES CONTRACT

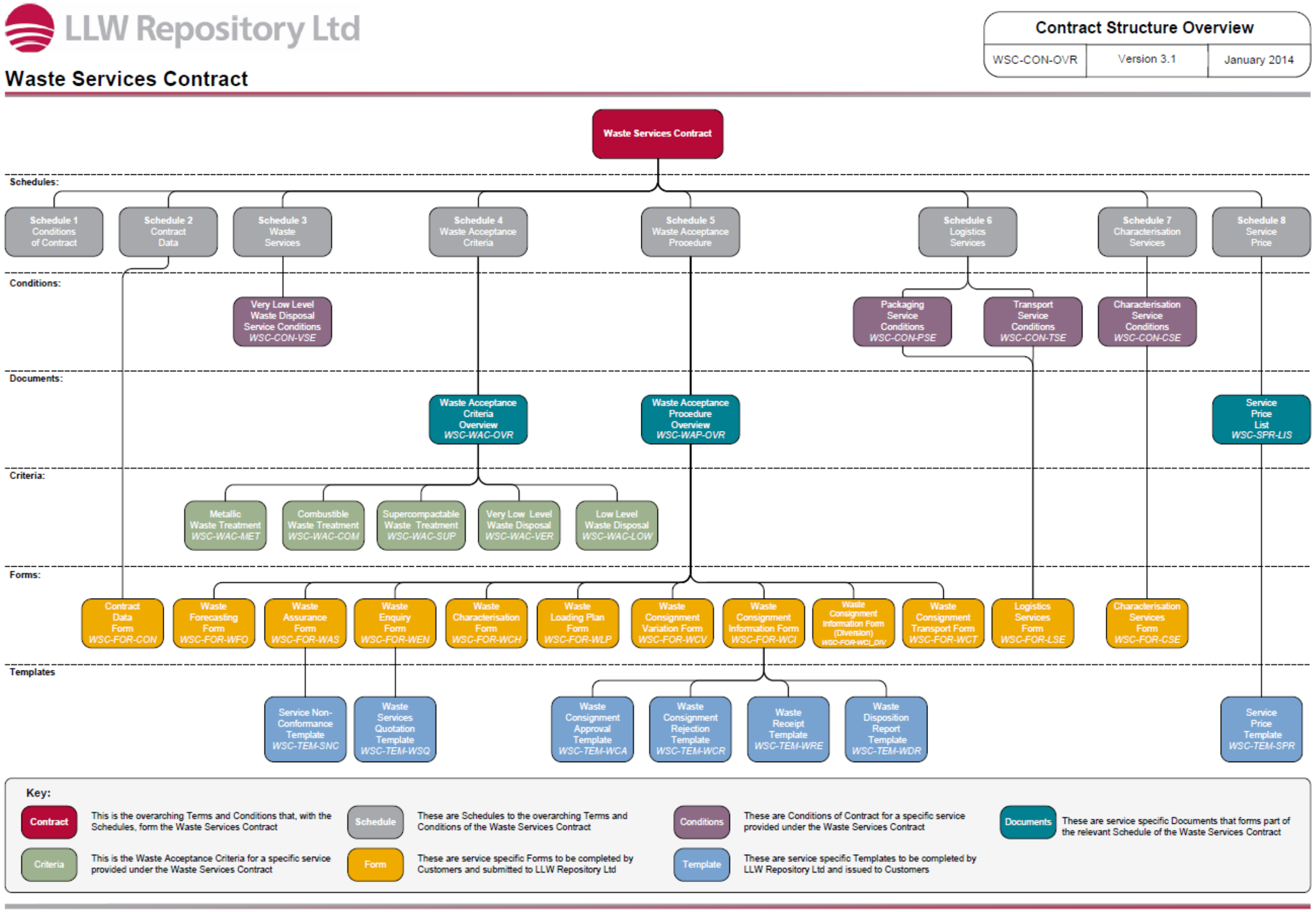


Figure A-1: Overview of Low Level Waste Repository Limited Waste Services Contract

APPENDIX B FORWARD ACTION PLAN

The following actions have been identified for incorporation into the Forward Action Plan for development of a UK version of the BWRX-300 SMR.

Table B-1: Forward Actions – Radioactive Waste Management Arrangements

Action ID	Source	Finding	Forward Action	Lead Discipline	Delivery Phase
PER5-110	PER Ch.E5 Section 5	The current BWRX-300 fault list does not identify any AOOs that appear to have consequences in relation to the generation of additional radioactive wastes. Further work is required to assess the wider BWRX-300 design for faults that could give rise to environmental consequences at frequencies that would define them as AOOs.	Undertake a systematic review of initiating events across the entirety of the BWRX-300 design to identify a comprehensive list of faults, that may result in an environmental radiological impact, through an increase in radioactive discharges, waste volumes or activities, and at frequencies that would define them as AOOs.	Fault Studies	For PCSR/PCER
PER5-111	PER Ch.E5 Section 5.1	Current System Design Descriptions (SDD) do not incorporate relevant UK RWM compliance requirements.	Identify and incorporate relevant UK RWM compliance requirements into the BWRX-300 requirements management system and update SDDs.	Requirements Management	For Site License Application
PER5-112	PER Ch.E5 Section 5.2.2	Design documentation does not currently detail or quantify the production of GAC, spent aqueous filters and RO modules from the LWM system.	Provide further design detail and Realistic Model EUST Values for wastes arising from BWRX-300 LWM system operation including GAC, sludge consolidation filters and RO modules.	Process Engineering	For Site License Application
PER5-113	PER Ch.E5 Section 5.2.1.3	Current SWM inventory estimate is based on conservative Design Basis Source Term (DBST) and indicates that wet solid wastes from CFD, FPC and LWM conform to UK Intermediate Level Waste (ILW) definition. This infers requirements for on-site ILW processing and storage capabilities that may not be necessary if the generated wastes are classified as UK LLW.	Derive Realistic Model EUST Values for BWRX-300 wet solid waste streams.	Chemistry	For Site License Application

Action ID	Source	Finding	Forward Action	Lead Discipline	Delivery Phase
PER5-114	PER Ch.E5 Section 5.6.1	A best estimate EUST will be derived from operational experience relating to older BWR designs and may not fully reflect numerous design enhancements on BWRX-300 that further reduce source term (GNF2 fuel, enhanced water chemistry, reduced cobalt inventory, greater use of stainless steel pipework). 'Actual' BWRX-300 data should be used to provide the most accurate quantification of wet solid wastes before committing to final design of UK waste processing and storage solutions	Utilise wet solid waste streams characterisation data from the first operating BWRX-300 SMR(s) to finalise design decisions for on-site processing and storage capabilities for a UK version of the BWRX-300 SMR.	Radwaste	For Site License Application
PER5-115	PER Ch.E5 Section 5.2.2	It will be necessary for a future developer/operator of a UK BWRX-300 to engage with NWS to establish off-site waste disposition routes for LAW via the LLWR Ltd waste services contract, noting that the developer/operator also has recourse to engage directly with LAW pretreatment service providers and VLLW disposal sites.	Future developer/operator of a UK BWRX-300 installation to engage with NWS and/or other LAW service providers to establish off-site routes for LAW disposition.	RWM	For Site License Application

APPENDIX C MANAGEMENT OF SPENT FUEL AND IRRADIATED INCORE COMPONENTS

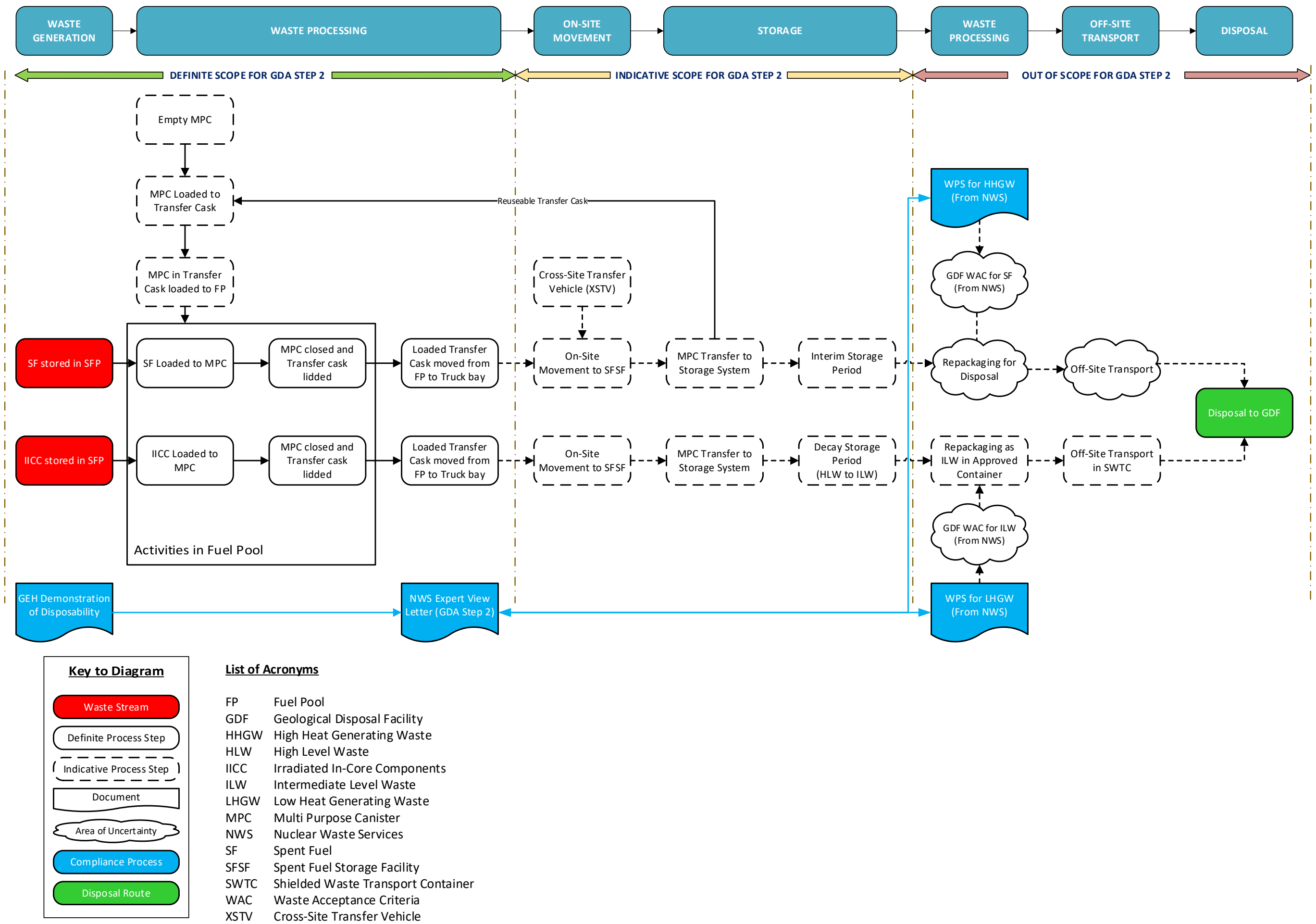
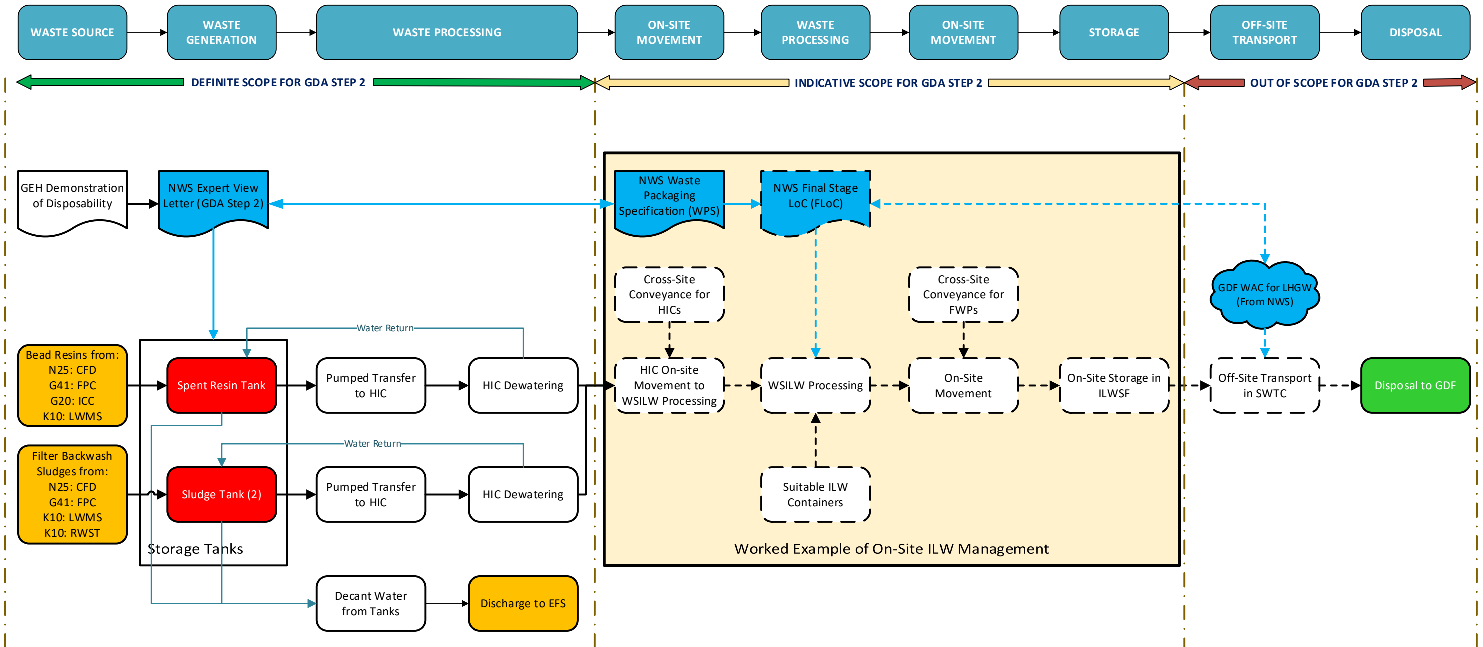
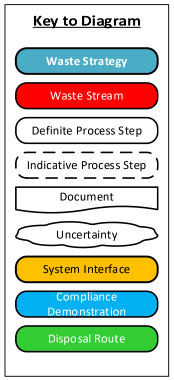


Figure C-1: Process Flow Diagram for Spent Fuel and Irradiated Incore Components Management

APPENDIX D MANAGEMENT OF WET SOLID INTERMEDIATE LEVEL WASTE





List of Acronyms

CFD	Condensate Filters and Demineralizers System
EFS	Equipment & Floor Drain System
FLoC	Final Stage Letter of Compliance
FPC	Fuel Pool Cooling and Cleanup System
FWP	Final Waste Package
GDA	Generic Design Assessment
GDF	Geological Disposal Facility
HIC	High Integrity Container
ICC	ICS Pool Cooling and Cleanup System
ILW	Intermediate Level Waste
ILWSF	ILW Storage Facility
LHGW	Low Heat Generating Waste
LWMS	Liquid Waste Management System
NWS	Nuclear Waste Services
RWST	Refueling Water Storage Tank
SWTC	Shielded Waste Transport Container
WAC	Waste Acceptance Criteria
WPS	Waste Packaging Specification
WSILW	Wet Solid Intermediate Level Waste

Figure D-1: Process Flow Diagram for Wet Solid Intermediate Level Waste Management

APPENDIX E MANAGEMENT OF LOWER ACTIVITY RADIOACTIVE WASTES

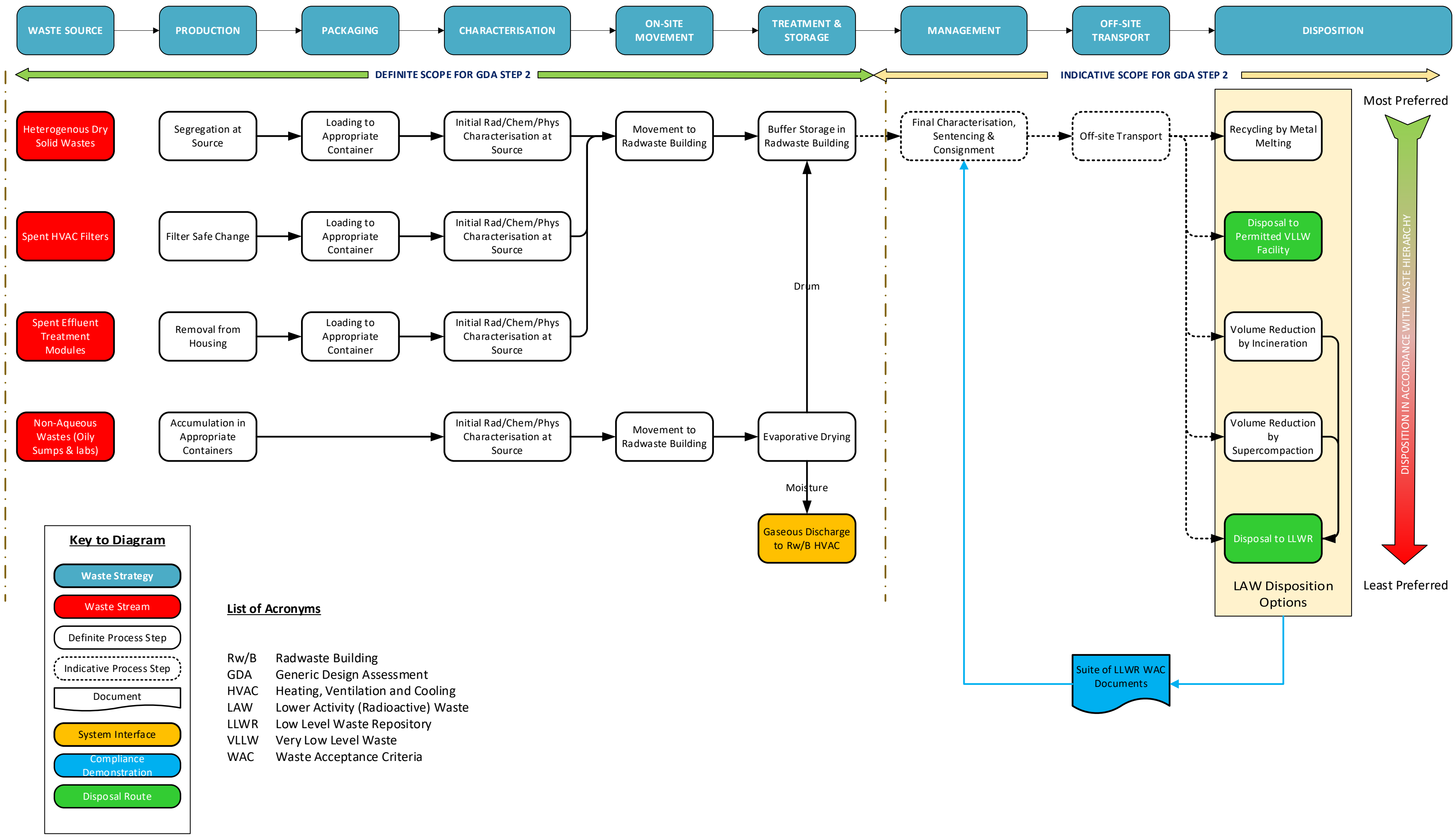


Figure E-1: Process Flow Diagram for Lower Activity Waste Management