GE Hitachi Nuclear Energy

NEDO-34224

Revision A

January 2025

US Protective Marking: Non-Proprietary Information
UK Protective Marking: Not Protectively Marked

BWRX-300 UK Generic Design Assessment (GDA) Chapter E7 – Radioactive Discharges

INFORMATION NOTICE

This document does not contain proprietary information and carries the notations "US Protective Marking: Non-Proprietary Information" and "UK Protective Marking: Not Protectively Marked."

IMPORTANT NOTICE REGARDING CONTENTS OF THIS REPORT

Please Read Carefully

The design, engineering, and other information contained in this document is furnished for the purpose of obtaining the applicable Nuclear Regulatory Authority review and determination of acceptability for use for the BWRX-300 design and licensing basis information contained herein. The only undertakings of GEH with respect to information in this document are contained in the contracts between GEH and its customers or participating utilities, and nothing contained in this document shall be construed as changing those contracts. The use of this information by anyone for any purpose other than that for which it is intended is not authorized; and with respect to any unauthorized use, no representation or warranty is provided, nor any assumption of liability is to be inferred as to the completeness, accuracy, or usefulness of the information contained in this document. Furnishing this document does not convey any license, express or implied, to use any patented invention or any proprietary information of GEH, its customers or other third parties disclosed herein or any right to publish the document without prior written permission of GEH, its customers or other third parties.

UK SENSITIVE NUCLEAR INFORMATION AND US EXPORT CONTROL INFORMATION

This document does not contain any UK Sensitive Nuclear Information (SNI) subject to protection from public disclosure as described in the Nuclear Industries Security Regulations (NISR) 2003, does not contain UK Export Controlled Information (ECI), and does not contain US Export Controlled Information (ECI) subject to the export control laws and regulations of the United States, including 10 CFR Part 810.

EXECUTIVE SUMMARY

The GEH BWRX-300 is a Boiling Water Reactor that is designed as a Small Modular Reactor. The tenth generation BWRX-300 design incorporates the lessons learned from worldwide programmes and the operational experience/programmes of several BWRs, most notably the Economic Simplified Boiling Water Reactor and the Advanced Boiling Water Reactor.

The BWRX-300 design has focused on:

- Preventing/eliminating the generation of radioactive waste;
- Where the generation of radioactive waste cannot be avoided then minimising the generation of that waste (activity and volume); and
- Treating/abating any radioactive waste generated so that it is concentrated/contained or minimised before release to the environment.

GEH is, as the Requesting Party, presenting an Environment Case submission to the United Kingdom regulators for a Generic Design Assessment (GDA) at the Step 2 level for the BWRX-300.

This document is a chapter within the Preliminary Environmental Report and is one of the documents that makes up the Environment Case.

This chapter provides conservative and bounding assessments of activities for radioactive discharges (gaseous and aqueous liquids) to the environment that will be generated from the normal operation of the BWRX-300. These assessments therefore provide maximum values for the activities of gaseous and aqueous liquid discharges. It should be noted that the aqueous liquid discharge volumes from the BWRX-300 are yet to be confirmed, and that a maximum discharge volume is assumed throughout this report unless stated otherwise.

The BWRX-300 conservative bounding discharges have also been compared to international plants and are comparable, when normalised for power output and operating hours.

This chapter presents a level of detail commensurate with a two-step GDA. A Forward Action Plan is presented in Appendix A, which defines the scope and timing of additional work beyond GDA Step 2.

GEH considers that the radioactive discharge assessment presented in this report satisfies Step 2 of the GDA.

ACRONYMS AND ABBREVIATIONS

Acronym	Explanation
ABWR	Advanced Boiling Water Reactor
ActP	Actinides Products
AHU	Air Handling Unit
ALARA	As Low As Reasonably Achievable
ANS	American Nuclear Society
ANSI	American National Standards Institute
AOO	Anticipated Operational Occurrence
AP	Activation Product
ASD	Adjustable Speed Drive
BAT	Best Available Techniques
BWR	Boiling Water Reactor
CEAP	Continuous Exhaust Air Plenum
CFD	Condensate Filters and Demineralisers System
CIS	Containment Inerting System
CP	Corrosion Product
CST	Condensate Storage Tank
CWS	Circulating Water System
D&ID	Ducting and Instrumentation Diagram
DP	Developed Principle
EA	Environment Agency
EFS	Equipment and Floor Drain System
EPR16	The Environmental Permitting (England and Wales) Regulations 2016 (as amended)
ESBWR	Economic Simplified Boiling Water Reactor
EUST	End User Source Term
FAP	Forward Action Plan
FOAK	First of a Kind
FP	Fission Product
GDA	Generic Design Assessment
GEH	GE Hitachi Nuclear Energy
GSC	Gland Steam Condenser
HEPA	High Efficiency Particulate Air
HVS	Heating, Ventilation and Cooling System
LWM	Liquid Waste Management System
MCA	Main Condenser and Auxiliaries
MTE	Main Turbine Equipment

Acronym	Explanation
NC	Non-Condensable
NPP	Nuclear Power Plant
NRC	Nuclear Regulatory Commission
OGS	Offgas System
OPEX	Operational Experience
OPG	Ontario Power Generation
PCER	Pre-Construction Environmental Report
PCSR	Pre-Construction Safety Report
PER	Preliminary Environmental Report
P&ID	Piping and Instrumentation Diagram
PLSA	Plant Services Area
PREMS	Process Radiation and Environmental Monitoring System
PrST	Process Source Term
PSR	Preliminary Safety Report
PST	Primary Source Term
PVS	Plant Vent Stack
PWR	Pressurised Water Reactor
RB	Reactor Building
RG	Regulatory Guide
RM	Realistic Model
RP	Requesting Party
RPV	Reactor Pressure Vessel
RSR	Radioactive Substances Regulation
RWB	Radwaste Building
SCCV	Steel-Plate Composite Containment Vessel
SDD	System Design Description
SJAE	Steam Jet Air Ejectors
SMR	Small Modular Reactor
TB	Turbine Building
TGSS	Turbine Gland Seal Subsystem
U.S.	United States
UK	United Kingdom

DEFINITIONS

Term	Definition
U41	Heating, Ventilation, and Cooling System (HVS)

SYMBOLS

Symbol	Definition
α	Alpha particle
ɣ	Gamma ray
Bq/GWh	Becquerel per Gigawatt hour
Bq/y	Becquerel per year
GWe	Gigawatt electric
GWh	Gigawatt hour
H-2	Deuterium
H-3	Tritium
inHg	Inch of mercury
m	Metres
m^3	Cubic metres
MBq/y	Megabecquerel per year
mSv	Millisievert
MWe	Megawatt electrical
m^3/y	Cubic metres per year
n	Neutron

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

REVISION SUMMARY

Revision #	Section Modified	Revision Summary
A	All	Initial Issuance

7. RADIOACTIVE DISCHARGES

The GEH BWRX-300 is a Boiling Water Reactor (BWR) that is designed as a Small Modular Reactor (SMR).

The tenth generation BWRX-300 design incorporates the lessons learned from worldwide programmes and the Operational Experience (OPEX)/programmes of several GEH BWRs, most notably the Economic Simplified Boiling Water Reactor (ESBWR) and the Advanced Boiling Water Reactor (ABWR). The BWRX-300 design process incorporates applicable OPEX and lessons learned to mitigate nuclear design and construction risk. OPEX sources for the BWRX-300 project include the Institute of Nuclear Power Operations, Electrical Power Research Institute's Material Reliability Program documents and Utility Requirements Document, and other regulatory guidance issued by the United States (U.S.) Nuclear Regulatory Commission (NRC) and U.S. Department of Energy. Construction experience and improved construction methods from previous large projects are used to improve the quality and efficiency of the construction effort (see GEH's System Design Description (SDD) document 006N7781, "BWRX-300 Heating, Ventilation and Cooling System (HVS)," (Reference 7-1)).

The BWRX-300 design has focused on:

- Preventing/eliminating the generation of radioactive waste.
- Where the generation of radioactive waste cannot be avoided, then minimising the generation of that waste (activity and volume).
- Treating/abating any radioactive waste generated so that it is concentrated/contained or minimised before release to the environment.

GEH is, as the Requesting Party (RP) presenting an Environment Case submission to the United Kingdom (UK) regulators for a Generic Design Assessment (GDA) at the Step 2 level for the BWRX-300. It should be noted that after completion of Step 2, GEH intend to proceed directly to site licensing rather than completing Step 3 as an intermediate stage.

This document is a chapter within the Preliminary Environmental Report (PER), which forms the main part of the Environment Case.

Scope

This chapter describes the radioactive gaseous and aqueous liquid discharges arising from normal operation of the BWRX-300. It addresses the following key questions:

- How is the radioactivity created?
- How does the radioactivity become gaseous and aqueous liquid waste?
- Where in the plant/process does the gaseous and aqueous liquid radioactive waste arise?
- How is the gaseous and aqueous liquid radioactive waste conveyed through the plant/process?
- How is the gaseous and aqueous liquid radioactive waste collected/segregated from the process water and steam?
- How is the gaseous and aqueous liquid waste treated to reduce the amount of radioactivity in it?
- How is the gaseous and aqueous liquid waste monitored to determine whether it can be discharged to the environment?
- How is the gaseous and aqueous liquid waste discharged to the environment?

- What is the anticipated radioactivity of gaseous and aqueous liquid discharges?
- How do the gaseous and aqueous liquid discharges from BWRX-300 compare with the discharges from other Nuclear Power Plants (NPPs) around the world?

Table 7-1 shows how these questions have been considered within the scope of this report at GDA Step 2. The level of detail presented in this chapter is commensurate with this early stage of the GDA. A Forward Action Plan (FAP) is presented in Appendix A, which defines the scope and timing of additional work beyond GDA Step 2. Discussions on Best Available Techniques (BAT), optimisation, and radioactive waste management arrangements are not included in this chapter as they are addressed in NEDC-34223P, "BWRX-300 UK GDA Preliminary Environmental Report Ch. E6: Demonstration of Best Available Techniques Approach," (Reference 7-2) and NEDC-34222P, "BWRX-300 UK GDA Preliminary Environmental Report Ch. E5: Radioactive Waste Management Arrangements," (Reference 7-3).

The following key assumptions about the BWRX-300 have been made:

- The BWRX-300 is a single unit of 300 Megawatt electric (MWe) capacity.
- The generic site is on the coast.
- There is no on-site incinerator.
- There is no on-site laundry.
- Sanitary waste from welfare facilities within the power block are handled by the Water, Gas, and Chemical Pads System and not treated as radioactive wastes, as described in SDD document 006N7789, "BWRX-300 Equipment and Floor Drain System (EFS)," (Reference 7-5).
- The operating cycle is 12 months.
- The outage period is 10 to 20 days.
- The top of the Plant Vent Stack (PVS) is 35 metres (m) above ground level.

Document Structure

Following this introductory section, the document is structured in the following manner:

Section 7.1	Regulatory Context
Section 7.2	Source Terms
Section 7.3	Discharge Routes – Gaseous
Section 7.4	Discharge Routes – Aqueous Liquid
Section 7.5	Radioactive Discharge Assessments
Section 7.6	Comparison with International Plants
Section 7.7	Conclusion
Section 7.8	References
Appendix A	Forward Action Plan
Appendix B	Annual Gaseous Activity Contribution by Route

Chapter Interfaces

This document interfaces with the following chapters in the PER:

NEDC-34219P, "BWRX-300 UK GDA Preliminary Environmental Report Ch. E2: Generic Site Description," (Reference 7-6)

NEDC-34221P, "BWRX-300 UK GDA Preliminary Environmental Report Ch. E4: Information about the Design," (Reference 7-7)

NEDC-34222P, "PER Ch. E5: Radioactive Waste Management Arrangements," (Reference 7-3)

NEDC-34223P, "PER Ch. E6: Demonstration of Best Available Techniques Approach," (Reference 7-2)

NEDC-34225P, "BWRX-300 UK GDA Preliminary Environmental Report Ch. E8: Approach to Sampling and Monitoring," (Reference 7-4)

NEDC-34226P, "BWRX-300 UK GDA Preliminary Environmental Report Ch. E9: Prospective Radiological Assessment," (Reference 7-8)

It also interfaces with the following chapters in the Preliminary Safety Report (PSR):

NEDC-34195P, "BWRX-300 UK GDA Preliminary Safety Report Ch. 23: Reactor Chemistry," (Reference 7-9)

7.1 Regulatory Context

GEH has entered the GDA process up to Step 2 with the BWRX-300 design, before progressing directly to site licensing. This approach has been informed by regulatory guidance and decision documents, supplemented by regulatory engagement. Regulator feedback has been taken into account in the GDA Step 2 PER submission.

This section provides a brief overview of the regulatory framework relating to radioactive discharges of gaseous and aqueous liquid wastes. Additional details of relevant national and international legislation, as well as regulatory guidance and good practice can be found in the references provided.

7.1.1 The Environmental Permitting (England and Wales) Regulations 2016

Through Schedule 23, Section 11(2)(b) of "The Environmental Permitting (England and Wales) Regulations 2016" (as amended) (EPR16) (Reference 7-10):

"A radioactive substances activity is carried on where a person uses premises for the purposes of an undertaking and that person disposes of radioactive waste on or from those premises."

Based on EPR16 Schedule 23, the future operator of the BWRX-300 will be undertaking a radioactive substances activity by virtue of gaseous and aqueous liquid radioactive discharges to the environment. These discharges will necessarily result in exposure of members of the public to radioactivity.

EPR16 (Reference 7-10) applies specified dose limits on the annual radiation exposure of members of the public. The principal aims of the legislation are that the environmental regulators, in exercising their duties and functions under the regulations, ensure that:

- *"All exposures to ionising radiation of any member of the public and of the population as a whole resulting from the disposal of radioactive waste are kept as low as reasonably achievable, taking into account economic and social factors";*
- The sum of the doses arising from such exposures does not exceed the individual public dose limit of 1 millisievert (mSv) per year;
- The individual dose received from any new discharge source since 13th May 2000 does not exceed 0.3 mSv per year; and
- The individual dose received from any single site does not exceed 0.5 mSv per year.

The Environmental Permitting Regulations (England and Wales) 2010 "Criteria for setting limits on the discharge of radioactive waste from nuclear sites" (Reference 7-11) provides a lower bound of exposure for the most exposed group of members of the public of 10 microsieverts per year, below which the Environment Agency (EA) should not seek to further reduce the discharge limits that are in place, provided that the holder of the permit continues to apply BAT.

Information on anticipated radiological doses to members of the public arising from gaseous and aqueous liquid discharges from the operation of BWRX-300 are presented in NEDC-34226P, PER Ch. E9 (Reference 7-8).

7.1.2 Permits for Radioactive Substances Activities

The EA's guidance document, "Nuclear sites Radioactive Substances Regulation (RSR): environmental permits" (Reference 7-12) states that:

"If you are going to carry out a radioactive substances activity you may need to apply to the Environment Agency for a permit. You must do this before you start the activity."

Note that although the guidance specifically refers to the EA, if the permit application were to be in Wales, then Natural Resources Wales would be the relevant regulatory authority.

The guidance also states that:

"If you are nuclear site licensee, you should apply for an unsealed sources and waste permit if you plan to:

- *dispose of radioactive waste"*

Applications for radioactive substances activity permits for unsealed sources and radioactive waste for nuclear sites under EPR16 must be made using EP-RSR-B3, "Application for an environmental permit Form RSR-B3 – New bespoke radioactive substances activity permit (nuclear site – unsealed sources and radioactive waste)," (Reference 7-13). Under Section 4 (Disposal of radioactive wastes), the applicant must submit the following details:

"4a Provide quantitative estimates for normal operation of

- *discharges of gaseous and aqueous radioactive wastes*
- *arisings of combustible waste and disposals by on-site or off-site incineration*
- *arisings of other radioactive wastes, by category and disposal route (if any)*

4b Provide your proposed limits for

- *gaseous discharges*
- *aqueous discharges*
- *disposal of combustible waste by on-site incineration"*

7.1.3 Standard Permit Conditions and Application of Best Available Techniques

The guidance document, "RSR permits for nuclear licensed sites: how to comply," (Reference 7-14), sets out some standard permit conditions that the holder of the license is required to comply with. Although also concerned with BAT, Permit Operating Conditions 2.3.1, 2.3.2, and 2.3.3 address gaseous and aqueous liquid discharges:

"2.3.1 The operator shall use the best available techniques to minimise the activity of radioactive waste produced on the premises that will require to be disposed of on or from the premises."

"2.3.2 The operator shall use the best available techniques in respect of the disposal of radioactive waste pursuant to this permit to:

(a) minimise the activity of gaseous and aqueous radioactive waste disposed of by discharge to the environment;

(b) minimise the volume of radioactive waste disposed of by transfer to other premises;

(c) dispose of radioactive waste at times, in a form, and in a manner so as to minimise the radiological effects on the environment and members of the public."

"2.3.3 The operator shall use the best available techniques to:

(a) exclude all entrained solids, gases and non-aqueous liquids from radioactive aqueous waste prior to discharge to the environment;

(b) characterise, sort and segregate solid and non-aqueous liquid radioactive wastes, to facilitate their disposal by optimised disposal routes;

(c) remove suspended solids from radioactive waste oil prior to incineration."

The generation, treatment, management, and disposal of all radioactive waste that will arise as result of the operation of the GEH BWRX-300 have been assessed against the requirements to apply BAT. The approach to assessing BAT is described in NEDC-34223P, PER Ch. E6 (Reference 7-2) and NEDC-34225P, PER Ch. E8 (Reference 7-4). Claims and arguments for application of BAT are provided at GDA Step 2 to demonstrate that optimisation to the As Low As Reasonably Achievable (ALARA) requirements of EPR16 will be fulfilled by the BWRX-300 design.

7.1.4 Requirements

The environmental regulators' expectations for radioactive discharges and limits are set out in the joint guidance document "New nuclear power plants: Generic Design Assessment guidance for Requesting Parties," (Reference 7-15) and the environmental regulator presentation to the RP, "Environment: Introductions and Expectations," (Reference 7-16), for a three-step GDA. It should be noted that the scope of this document requires the guidance to be interpreted to GDA Step 2 only at this stage. Table 7-2 sets out the regulator expectations for a three-step GDA and the GEH interpretation of these expectations to Step 2.

7.1.5 Alignment with the RSR Objective, Principles and Generic Developed Principles

The methodologies presented in this report are consistent with industry Relevant Good Practice and consider the relevant RSR objective and principles, "Radioactive Substances Regulation (RSR): objective and principles," (Reference 7-18), and the supporting RSR generic Developed Principles (DPs), "RSR generic developed principles: regulatory assessment," (Reference 7-19). These guidance documents set out the EA's expectations on permit holders carrying out radioactive substance's activities.

NEDC-34231P, "Alignment with Sustainability, the Radioactive Substances Regulation Objective and Principles & Generic Developed Principles," (Reference 7-20) details the approach undertaken by GEH to reviewing and taking account of the relevant objective, principles, and DPs within this GDA Step 2 submission.

7.2 Source Terms

This section describes the main sources of gaseous and aqueous liquid radioactive waste, including the radiological source term used in calculating the activities of these effluent streams.

Sources of solid radioactive wastes, and non-aqueous liquid wastes, are described in NEDC-34222P, PER Ch. E5 (Reference 7-3).

7.2.1 Sources of Radioactive Waste

Gaseous radioactive waste is generated as a result of activation of the reactor coolant during normal operation, trace amounts of uranium that may adhere to the outside of the fuel cladding during fabrication, and leakage of gaseous Fission Products (FP) through miniscule defects in the fuel cladding.

Liquid radioactive waste is generated by cleanup of the reactor coolant, cleanup of the fuel pool, leakage from process streams, and decontamination activities. These liquids are collected through floor drains and process drains in the Reactor Building (RB), Turbine Building (TB), Radwaste Building (RWB), Plant Services Area (PLSA), and Steel-Plate Composite Containment Vessel (SCCV), and are pumped to the Liquid Waste Management System (LWM) for processing, (006N7789, EFS SDD (Reference 7-5)). Information on the treatment of drained effluents by the LWM is presented in Section 7.4.3.

7.2.2 Production Mechanisms

The radionuclides present in the reactor water and steam within the Reactor Pressure Vessel (RPV) of the GEH BWRX-300 fall into three distinct categories based on their production mechanism within the reactor core (see NAS-NS-3119, “Radiochemistry in Nuclear Power Reactors,” (Reference 7-21)):

- FP and Actinides Products (ActP)
- Corrosion Products (CPs)
- Activation Products (APs)

The principal means of generation of these radionuclides in the reactor is described in the sections below.

7.2.2.1 Fission Products and Actinide Products

The presence of FP and ActP in the reactor water and steam are mainly due to two mechanisms:

- Trace amounts of uranium that may be present on the external surfaces of the fuel assemblies, so called “tramp uranium”; and
- Leakage of volatile FP though small pinhole defects in the cladding surrounding the fuel during irradiation in the core.

Typical FP include radioisotopes of krypton, xenon, iodine, caesium-137 and strontium-90. Typical ActP include americium-241 and plutonium-239.

7.2.2.2 Corrosion Products

CP are formed as a result of corrosion that occurs during the normal wear and tear of reactor operations and may arise in soluble or particulate form. CP become radioactive waste as a result of:

- Corrosion of irradiated system materials (i.e., structural materials within the reactor that are activated by their proximity to nuclear fuel and the associated neutron flux); and
- Corrosion of metals in the steam circuit, that are carried by the process water and steam to the RPV, where they become activated as they pass through the neutron flux in the reactor core.

Examples of radioactive CP are cobalt-60, iron-55 and iron-59.

Particulates, such as activated CP, are produced in the core and are retained within the water circuit, i.e., they are not carried over into the steam circuit.

7.2.2.3 Activation Products

In addition to the formation of activated CP by activation of metallic species generated by corrosion of metals in the steam circuit (see Section 7.2.2.2), neutron activation of the reactor water itself will also produce radioactive species. Of particular interest for radioactive gaseous and aqueous liquid discharges are carbon-14, argon-41, and tritium (H-3). The main production mechanisms for these nuclides are described in the following paragraphs.

7.2.2.4 Carbon-14

Carbon-14 is mainly produced by the O-17 (n,α) C-14 reaction in the reactor water. The carbon-14 produced because of activation of the reactor water is likely to be present as carbon dioxide, as conditions in the upper part of the reactor core are oxidising and is transferred to the reactor steam.

7.2.2.5 Argon-41

Argon-41 is produced by the Ar-40 (n,ɣ) Ar-41 reaction in reactor water (see NS-TAST-GD-088, “Chemistry of Operating Civil Nuclear Reactors,” (Reference 7-22)). The reactor water contains a very small amount of residual entrained air, which itself contains trace amounts of naturally occurring stable argon. The argon becomes activated as the reactor water passes through the reactor core. The argon-41 produced is transferred to the reactor steam.

7.2.2.6 Tritium

Tritium is mainly produced by activation of naturally occurring deuterium (H-2) in the reactor water, H-2 (n,ɣ) H-3. Tritium is assumed to partition equally between steam and plant process water (see NUREG-0016, “Calculation of Release of Radioactive Materials in Gaseous and Liquid Effluents from Boiling-Water Reactors,” (Reference 7-23)). The concentration of tritium reached is controlled by the rate of loss of water from the system by evaporation (especially from the Fuel Pool) or leakage.

7.2.3 Coolant Radiation Concentrations

The concentration of each radionuclide in the reactor water and reactor steam within the primary system (i.e., the reactor core and coolant) is known as the Primary Source Term (PST). The radioactive concentrations in the ancillary systems are known as the Process Source Term (PrST). The PST and PrST are used to derive and assess the radiological doses and radionuclide activity associated with all aspects of plant operation and lifecycle, including radiation protection, radioactive waste, decommissioning, and discharge assessments. These are termed “technical areas” and each has its own associated End User Source Term (EUST). In this document the EUST of interest is that for “discharge assessment”.

7.2.4 The Basis of the End User Source Term

The PST for the BWRX-300 reactor coolant is calculated using American National Standards Institute (ANSI) and American Nuclear Society (ANS) ANSI/ANS-18.1-2020, "Radioactive Source Term for Normal Operation of Light Water Reactors," (Reference 7-24). This standard is based on available measured nuclide concentrations during normal operation at operating BWRs. The PST generated is referred to as the Realistic Model (RM) source term.

The validation of the current BWRX-300 PST is discussed in NEDC-34195P, PSR Ch. 23 (Reference 7-9). As a result of the validation work undertaken in PSR Ch. 23, it was considered that GEH's derivation of PST values is sufficient for completion of GDA Step 2 for BWRX-300.

The PST is used to produce the EUST for gaseous and aqueous liquid discharges using the methodologies described below.

7.2.4.1 End User Source Term for Gaseous Discharge

The BWRX-300 gaseous discharge assessment, 007N1078, "Annual Average Gaseous Effluent Releases for the BWRX-300 Standard Plant," (Reference 7-25), is performed with the GALE--BWR methodology, which implements the assumptions outlined in NRC Regulatory Guide (RG) 1.112, "Calculation of Releases of Radioactive Materials in Gaseous and Liquid Effluents from Light-Water-Cooled Nuclear Power Reactors," (Reference 7-26). The GALE-BWR methodology is described in NUREG-0016 (Reference 7-23), and calculates releases based on:

- Standardised coolant activities derived from ANS Standards 18.1 Working Group recommendations.
- Release and transport mechanisms that result in the appearance of radioactive material in aqueous liquid and gaseous waste streams.
- Plant-specific design features used to reduce the quantities of radioactive waste ultimately released to the environment.
- Information received on the operation of NPPs.

7.2.4.2 End User Source Term for Aqueous Liquid Discharge

The BWRX-300 aqueous liquid discharge assessment, 007N1460, "BWRX-300 Annual Average Liquid Effluent Activity Releases," (Reference 7-27), is performed with the GALE-BWR 3.2 code described in NUREG-0016 (Reference 7-23), which implements the analysis methods and assumptions for liquid effluent releases in RG 1.112 (Reference 7-26).

Releases are calculated based on the parameters described in End User Source Term for Gaseous Discharge, including consideration of the BWRX-300 LWM design features which reduce the quantities of radioactive waste released to the environment. The following design features are considered in the analysis:

- The BWRX-300 LWM does not use regenerant solutions.
- The BWRX-300 will not utilise any copper tubing in the condenser or anywhere in the reactor coolant pressure boundary.
- The BWRX-300 Condensate Filters and Demineralisers System (CFD) will not employ an ultrasonic resin cleaner.
- Because the BWRX-300 LWM implements a zero liquid release strategy (see Section 7.4.2), no tritium is released to the environment via the aqueous liquid effluent pathway.

7.2.4.3 Conservatism in the Discharge Assessments

Although they are based on "normal operations" RM PST, the current gaseous and aqueous liquid annual discharge activities for BWRX-300 presented later in this chapter (see

Section 7.5) are conservative and provide bounding values for the discharges. This is due to the assumptions that are included in the methodologies used to calculate the PST and EUST (described in Section 7.2.4).

An analogous discharge assessment for gaseous and aqueous liquid discharges was conducted for the UK ABWR (GA91-9901-0025-0001, "UK ABWR Generic Design Assessment, Quantification of Discharges and Limits," (Reference 7-28)). The conservatism in the PST for BWRX-300 is demonstrated if the BWRX-300 and UK ABWR RM PST are compared (Table 7-3). A like-for-like comparison is achieved by generating ratios of the geometric means of the radionuclide concentrations for each given class as BWRX-300:UK ABWR.

It should be noted that the UK ABWR PST is based on OPEX containing no fuel failures, while the ANSI/ANS-18.1-2020 (Reference 7-24) reference plant (utilised for derivation of the BWRX-300 PST) is underpinned by OPEX containing some plant data where fuel failures have occurred, as detailed in NEDC-34195P, PSR Ch. 23 (Reference 7-9).

Further examples of conservatism in the assessment of gaseous discharges are summarised below:

- In 007N1078 (Reference 7-25) it is stated that the containment releases are based upon the standard NUREG-0016 assumptions, and an assumed BWRX-300 containment steam and water leak rate of 3.79 litres per minute, and 24 purges per year. As normal operation of the BWRX-300 only requires purging of the containment at the start and end of an outage (Section 7.3.2.1, Containment Inerting System), with an assumed operating cycle of 12 months, the NUREG-0016 assumption of 24 purges per year for calculating the EUST may be considered conservative.
- A conservative noble gas release rate of 1.0E+03 microcuries per second (3.7E+01 megabecquerels per second) is assumed in 007N1078 (Reference 7-25), reflective of an additional contribution from fuel failure.

7.2.4.4 Anticipated Operational Occurrences

The environmental regulators have stated an expectation (see regulator GDA guidance for RPs (Reference 7-15)) that Anticipated Operational Occurrences (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 7-29)) 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.

The ANSI/ANS-18.1-2020 (Reference 7-24), GALE-BWR and NUREG-0016 (Reference 7-23) codes and standards discussed in Section 7.2.4 include AOOs based on OPEX from BWRs. The GALE-BWR code (see NUREG 0016 (Reference 7-23)) also includes a source term adjustment for AOOs of 1.0E-01 curies per year, equivalent to 3,700 megabecquerels per year (MBq/y).

A preliminary review of 005N3558, "BWRX-300 Fault Evaluation," (Reference 7-30), 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. It is recognised that 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. This is identified as a forward action (FAP. PER5-110).

7.2.5 Radionuclides Considered

Only the ANSI/ANS-18.1-2020 (Reference 7-24) generated nuclides are currently considered in the EUST for the BWRX-300 and reported in the annual activity releases for gaseous and aqueous liquid discharges.

It is recognised that the generated nuclide lists for the aqueous liquid and gaseous EUST (see Table 7-7 and Table 7-8) do not exactly match those in the 2004/2/Euratom recommendation, C(2003) 4832, “Commission Recommendation 2004/2/Euratom of 18 December 2003 on standardised information on radioactive airborne and liquid discharges into the environment from nuclear power reactors and reprocessing plants in normal operation,” (Reference 7-31).

Additional radionuclide activities can be calculated from the existing data, but this has not yet been completed and is recognised by GEH as a forward action in the radioactive discharge assessment (FAP.PER7-193).

7.3 Discharge Routes – Gaseous

This section considers the means by which radioactive gaseous discharges that arise from the operation of the reactor steam and water systems are collected, conveyed, treated, and discharged.

Figure 7-1 shows a simplified diagram of the components of the gaseous discharges., based on information from SDD document 006N7899, "BWRX-300 Offgas System" (OGS), (Reference 7-32), Ducting and Instrumentation Diagram (D&ID) 006N7782, "BWRX 300 Heating, Vent & Cooling System, HVS (U41)," (Reference 7-33), SDD 006N7948, "BWRX-300 Containment Inerting System" (CIS), (Reference 7-34), and 006N7717, "BWRX-300 Main Turbine Equipment," (MTE) (Reference 7-35).

The gaseous discharges from the BWRX-300 arise from:

- The HVS exhaust. This system includes the exhausts from:
  - The RB. This includes any purges of the containment via the CIS.
  - The TB. This includes the gaseous releases from the Turbine Gland Seal Subsystem (TGSS).
  - The RWB
  - The PLSA
- The OGS exhaust
- The occasional exhausts from the mechanical vacuum pump.

All the above exhausts discharge into the Continuous Exhaust Air Plenum (CEAP) and then the PVS. They are then discharged to atmosphere.

Each of the components above are described in the sections that follow. Additional information is provided in NEDC-34221P, PER Ch. E4 (Reference 7-7).

Discharges from potential sources outside of the power block are beyond the scope of a two-step GDA and so are not considered in this report. An assessment of discharges from other sources will be assessed at the site-specific stage, where relevant (FAP. PER7-194).

7.3.1 Offgas System

The BWRX-300 OGS is described in detail in 006N7899, OGS SDD (Reference 7-32) and Piping and Instrumentation Diagram (P&ID) 006N6528, "BWRX-300 K30 Offgas System," (Reference 7-36), and is summarised in this section.

The OGS processes Non-Condensable (NC) gases from the Main Condenser and Auxiliaries (MCA) system that are produced through normal nuclear power operations. The main process influent to the system is a mix of steam, air, hydrogen, and radioactive noble gases from the MCA Steam Jet Air Ejectors (SJAE). The objective of the OGS is to process this influent prior to release to the environment from the HVS. This processing reduces the release of gaseous radionuclides. The processing includes two main functions:

- Recombination of hydrogen and oxygen into water to maintain plant water inventory and reduce hydrogen detonation risk.
- Controlled adsorptive holdup of the radioactive isotopes of krypton, xenon and argon to achieve adequate decay, thereby reducing effluent radioactivity releases from the plant.

The OGS is comprised of the following components, as shown in 006N7899 (Reference 7-32):

- Offgas recombiner: preheater section, catalytic recombiner section, and condenser section
- Cooler condenser and moisture separator
- Refrigeration dryers (two)
- Gas analyser (hydrogen, oxygen) including humidity monitor
- Offgas reheater
- Charcoal adsorber vault with heating, ventilation, and air conditioning equipment
- Charcoal adsorber tanks (four)
- Offgas High Efficiency Particulate Air (HEPA) Filter

Further detail on the OGS is provided in NEDC-34221P, PER Ch. E4 (Reference 7-7).

7.3.1.1 Mechanical Vacuum Pump

During startup only, the vacuum flow path is maintained by the mechanical vacuum pump, and the OGS is bypassed, as stated in 006N7899, OGS SDD (Reference 7-32).

The mechanical vacuum pump, provided as a skid-mounted package, is used to remove the air from the condenser shells and associated turbine, creating the initial vacuum which allows the startup of the turbine unit. The mechanical vacuum pump is capable of creating a sufficient vacuum of 10 inHg from atmospheric pressure within two hours.

The condenser vacuum pump takes suction from the shell side of the condenser and discharges the air extracted, which contains NC gases, along with excess seal water to the seal water separator. The separator collects moisture in the mixture in the bottom and discharges the compressed air to the CEAP/PVS (006N7757, "BWRX-300 Main Condenser and Auxiliaries System," (Reference 7-37)).

7.3.2 Heating, Ventilation and Cooling System

The BWRX-300 HVS is described in detail in the 006N7781, HVS SDD (Reference 7-1), and 006N7782, HVS D&ID (Reference 7-1), and is summarised in this section.

The HVS serves all areas of the power block during normal operation, except for primary containment, which is serviced by the containment cooling system. The HVS maintains space design temperatures, quality of air, and pressurisation. It provides a controlled environment for personnel safety and comfort, and for the proper operation and integrity of equipment located in the power block. All of the potentially radioactive HVS subsystems exhaust to a common plant exhaust stack (via the CEAP) during all normal operation modes (006N7781, (Reference 7-1)). The BWRX-300 RB, TB, RWB, and PLSA are equipped with Air Handling Units (AHUs) to provide ventilation, which take suction on the respective buildings/areas. These AHUs are also provided with Adjustable Speed Drives (ASDs) to be able to adjust speed to maintain the buildings/areas at a negative pressure relative to outdoors. The design of the ventilation system thus ensures that air pressure in plant facilities handling radioactive substances are maintained at a lower level than atmospheric pressure, such that air flows into the facility from the external environment (006N7781 (Reference 7-1)). This prevents the uncontrolled discharge of any radioactive substances through doors, windows, and gaps in the building fabric. Furthermore, the HVS also makes efficient use of the air that is drawn in to the system by allowing it to flow from areas of lower contamination risk to areas of higher contamination risk (e.g., in the TB and RWB) (006N7781 (Reference 7-1)). This limits the spread of contamination within the plant.

HVS subsystems that serve areas of the plant where radioactive substances are present have filters to remove any particulate matter prior to discharge to the environment. Exhaust air from potentially contaminated areas including the TB, RB, and RWB are filtered using local area HEPA filters before being exhausted to the CEAP (006N7781 (Reference 7-1)).

Table 7-4 shows the main sources of radioactive gases exhausted from each building HVS (information extracted from 006N7781 (Reference 7-1) and 006N7782 (Reference 7-33)).

7.3.2.1 Containment Inerting System

The CIS function is described in NEDC-34221P, PER Ch. E4 (Reference 7-7). The principal objective of the CIS is to preclude the development of a combustible atmosphere by maintaining an oxygen deficient atmosphere inside containment, described in 006N7948, CIS SDD (Reference 7-34). Purging of the CIS results in a gaseous discharge via the PVS. Purging occurs only at the start of an outage (nitrogen), and at the end of an outage (air).

The containment exhaust flow path begins where it penetrates in upper containment, on the opposite side of containment from the supply injection point. The exhaust flow path connects to the HVS before discharging to the PVS (006N7948 (Reference 7-34)).

Figure 7-2 shows a simplified diagram of the CIS, from 006N7948 (Reference 7-34).

7.3.2.2 Turbine Gland Seal Subsystem

The TGSS supplies sealing steam (taken from the main steam supply) to the turbine shaft/casing penetrations and valve stems to prevent the escape of radioactive steam and to prevent air in-leakage through sub-atmospheric turbine glands (006N7717, MTE SDD (Reference 7-35)).

Two 100% capacity Gland Steam Condenser (GSC) exhaust blowers maintain a slight vacuum on the GSC shell to remove NC gases and seal the turbine prior to startup. NC gases are then exhausted to the TB HVS (006N7717 (Reference 7-35)). It is assumed in 007N1078, “Annual Average Gaseous Effluent Releases for the BWRX-300 Standard Plant” (Reference 7-25) that 0.1% of the main steam flow is released from the TGSS.

Further detail on the TGSS is provided in NEDC-34225P, PER Ch. E4 (Reference 7-7).

Figure 7-3 shows a simplified line diagram of the TGSS (adapted from 006N7717 (Reference 7-35)).

7.3.2.3 HEPA Filter Requirements

HEPA filters are specified for various building filtration systems and consist of -extended medium dry-type filters in a rigid frame, having a minimum particle-collection efficiency of 99.97% on 0.3-micron particles. Filters meet the applicable efficiency rating specified in ASME AG-1-2019, “Code on Nuclear Air and Gas Treatment,” (Reference 7-38), as described in 006N7781, HVS SDD (Reference 7-1).

The HVS and other system exhausts that are passed through HEPA filtration before being exhausted to the CEAP are:

- TB
- RB (note this includes any purges from the CIS)
- RWB
- PLSA
- OGS

7.3.2.4 Continuous Exhaust Air Plenum and Plant Vent Stack

The CEAP and PVS are integral to the TB and are located on the roof. Figure 7-4 shows a simplified flow diagram of the CEAP and PVS, as detailed in 006N7781, HVS SDD (Reference 7-1). The top of the PVS is at ~35 m above ground level (005N9751, “BWRX-300 General Description,” (Reference 7-39)).

The CEAP serves as a large mixing box where air collected by the HVS, OGS, TGSS, and the Mechanical Vacuum Pump will be mixed and diluted.

During normal operation, up to three PVS fans take suction on the CEAP and discharge to the nearby PVS. The PVS fans are provided with ASDs to be able to maintain the CEAP negatively pressurised relative to the outside and to adjust to varying flow inputs, which may vary based on the operation of the exhaust AHUs at each building (006N7781 (Reference 7-1)).

The RB, RWB, and PLSA will be provided with area and process radiation monitors to measure levels of radiation within each building. If radiation monitoring from any particular building is measured above setpoint, this will call to isolate that building. The PVS fans will adjust flow accordingly (006N7781 (Reference 7-1)). Further information on sampling and monitoring of radioactive discharges from the PVS is provided in NEDC-34225P, PER Ch. E8 (Reference 7-4).

Figure 7-4 shows a simplified flow diagram of the CEAP and PVS, from 006N7781 (Reference 7-1).

7.3.3 Operating Modes

It is assumed that the BWRX-300 is operating on a 12-month cycle with an outage of 10 to 20 days.

The BWRX-300 plant operational modes are defined in Table 7-5, adapted from SDD document 006N7828, “BWRX-300 Nuclear Boiler System,” (Reference 7-40). A description of the operational modes can be found in 006N7828 (Reference 7-40).

A discussion of the monthly and rolling monthly discharges based on the operating modes and cycles is presented in Section 7.5.1.2, Monthly Discharges.

The key differences between gaseous discharges during power operations, start-up and shutdown compared to those at outage are as follows:

- There is no discharge via the OGS and the TGSS during an outage, as the reactor is shut down during outage and no steam is produced.
- The OGS only functions when the reactor has exceeded 5% of rated power output and the SJAE are in service. During startup, the vacuum flow path is maintained by the mechanical vacuum pump of the MCA system and the OGS is bypassed, as desribed in 006N7899, OGS SDD (Reference 7-32).
- There are additional discharges via the HVS during an outage. This is due to increased evaporation as a result of the temporarily elevated fuel pool temperature as reactor water mixes with the fuel pool water and fuel is transferred from the reactor, as well as additional discharge routes from the reactor well, equipment pool, and the main condenser hotwell.
- Additional discharges also occur from the CIS during outages. The CIS exhausts containment air to the HVS to support containment inerting and de-inerting (006N7948, CIS SDD (Reference 7-34)). During shutdown and plant outages the nitrogen-interted atmosphere of the SCCV is purged to allow entry by plant workers (see SDD document 006N7823, “BWRX-300 Primary Containment System,” (Reference 7-41)). Breathable air is supplied by the HVS to personnel working within containment after containment has been de-inerted. The exhaust flow path is out through the containment hatches (expected to be open during the outage) (006N7948 (Reference 7-34)).

The conservative total annual radioactive gaseous discharge estimates include any transient discharges generated from the CIS and Mechanical Vacuum Pump.

7.4 Discharge Routes – Aqueous Liquid

This section considers the aspects of the design that facilitate the zero aqueous liquid discharge philosophy, the LWM and, should it be required, the discharge route for any aqueous liquids.

It is assumed that the BWRX-300 plant is situated in a coastal area and, should it be required, any aqueous liquids discharged will be into the marine environment. Details on the generic site description are provided in NEDC-34219P, PER Ch. E2 (Reference 7-6).

Discharges from potential sources outside of the power block are beyond the scope of a two-step GDA and so they are not considered in this report. An assessment of discharges from other sources will be assessed at the site-specific stage, where relevant (FAP.PER7-194).

It is shown in 006N7789, EFS SDD (Reference 7-5), that any non-aqueous liquids are managed by other systems.

7.4.1 BWRX-300 Process Water and Effluent Management

The BWRX-300 is a direct cycle plant and comprises one integral water circuit – from water in the RPV, to steam in the turbine, which is condensed in the main condenser prior to feedwater return to the RPV. Therefore, it is of fundamental importance that this 'loop' incorporates 100% flow purification. The water treatment systems utilised in the BWRX-300 design ensure that radioactivity removed from both the process water in the main steam circuit, and drained effluents, is concentrated and contained in filter backwash sludges and spent bead resins that are subsequently managed as wet solid radioactive wastes. The process water and effluent management arrangements in the BWRX-300 design can be summarised as follows:

- Process water is treated by the CFD to maintain water purity prior to return to the reactor.
- Effluents captured in drains etc. are cleaned by the LWM to meet the water quality specification prior to being returned to the steam circuit.
- Out of specification or excess aqueous liquids are discharged to the environment. It should however be noted that the LWM is a multi-stage, fully configurable system designed to mitigate the impact of in-leakage of off-spec inventory including oils, grease, and organics, if present.

An overview diagram of the BWRX-300 arrangements for process water and effluent management is provided in NEDC-34222P, PER Ch. E5 (Reference 7-3).

7.4.2 Zero Aqueous Discharge Plant

The BWRX-300 is capable of being operated, under normal operating conditions, without recourse to aqueous liquid discharges to the environment. This is achieved by use of highly effective treatment systems that clean process water and drainage effluents to meet the high purity standards detailed in the specification document 006N6766, "BWRX-300 Water Quality," (Reference 7-42). This allows the treated process liquids to be reused. This promotes sustainability and minimises the requirement to top up the water system with fresh, demineralised water. It also minimises the volume and activity of radioactive discharges to the environment.

GEH has formulated a Zero Release Plan, DBR-0060900, "BWRX-300 Zero Release Plan," (Reference 7-43), a philosophy of processing liquid effluents so that none is released into local bodies of water. The plant is designed with sufficient water storage capacity to contain the volumes of water needed for the full range of activities undertaken during the normal operating cycle, including refuelling outages. However, occasional aqueous liquid discharges may be required in order to maintain the overall water balance of the plant.

A review of publicly available data for U.S. NPPs, NEDC-34279P, “Analysis of Environmental Discharge Data for U.S. Nuclear Power Plants,” (Reference 7-44), shows that several U.S. BWR plants operate on a zero aqueous effluent discharge basis and have done so for many years. Some other plants generally operate on a zero aqueous effluent basis with occasional aqueous effluent discharges.

It will be for the BWRX-300 plant owner/operator to determine the operational requirements for aqueous liquid discharges at the site-specific stage (FAP.PER7-195).

7.4.3 The Liquid Waste Management System

The BWRX-300 LWM reclaims, processes, and stores treated water from various streams for use by other plant systems. The LWM cleans aqueous effluents collected from plant areas via the equipment and floor drains system. It also filters, stores, and refills the reactor cavity water volume during refuelling operations. The system is described in SDD document 006N7729, “BWRX-300 Liquid Waste Management System (LWM),” (Reference 7-45). The system is called the LWM, but it should be noted that liquids treated in the LWM are not wastes (unless discharged), but a valuable resource that is recycled and reused.

The LWM filtration skids (see NEDC-34221P, PER Ch. E4 (Reference 7-7)) process the collected effluents on a batch basis and then send the processed water to the waste sampling subsystem (see Section 7.4.3.1). Processed liquids that meet the criteria in accordance with the reactor water quality specification (006N6766 (Reference 7-42)), will be pumped to the Condensate Storage Tank (CST) for reuse within the plant (006N7729 (Reference 7-45)). The various water systems within the BWRX-300 are suitably sized such that the total water volume (within the systems) can be accommodated at all times under all normal operating conditions (including outages), as described in 006N7673, “GEH BWRX-300 Water Balance,” (Reference 7-46).

In the unlikely event that the plant’s overall water inventory will not allow for the water to be recycled, the treated water can be discharged to the environment. Any potential environmental discharge is controlled to ensure concentrations of contaminants are maintained within permissible discharge limits. Discharges to the environment are monitored by the Process Radiation and Environmental Monitoring System (PREMS). PREMS will automatically halt releases upon receiving a trip signal to ensure the release of radioactive liquid effluents meets any discharge permit requirements (006N7729 (Reference 7-45)). The trip will identify if any preset values/limits (aligned to permit requirements) are exceeded. NEDC-34225P, PER Ch. E8 (Reference 7-4) presents the PREMS in more detail.

Further detail on the systems for treatment of process water and drained effluents, and detailed design information on the LWM is provided in NEDC-34222P, PER Ch. E5 (Reference 7-3) and NEDC-34221P, PER Ch. E4 (Reference 7-7) respectively.

7.4.3.1 Aqueous Liquid Discharge

In the event that a discharge is required, the BWRX-300 Waste Sampling Subsystem (described below) is equipped with a discharge path to the Circulating Water System (CWS) for release to the environment. The discharge path contains a locked closed manual valve, a radiation monitor, sample line, flow control valve, flow element, and two air operated valves for automatic isolation if radiation greater than a preset limit is detected in the flow stream. A demineralised water line from the water, gas, and chemical system is provided for flushing the discharge line (006N7729 (Reference 7-45)).

The waste sampling subsystem consists of two sample tanks, two transfer pumps, and associated piping and valves. The sample tanks are the end process point of the LWM where effluent from the filtering skids is sampled. The water is returned to the CST if the reactor water quality specification (006N6766 (Reference 7-42)) is met or can be released to the environment if water inventory does not allow return to the CST. If the water quality specification is not met the tanks can be recycled to the collection tanks for reprocessing. The sample tanks may also receive overboarding[1] flow from the shutdown cooling system and the reactor water cleanup system.

Figure 7-5 shows a simplified diagram of the Waste Sampling Subsystem. The LWM discharge line connects with the outlet line of the main condenser, part of the CWS, within the TB, as shown in P&ID 006N7762, “BWRX-300 Circulating Water System (CWS),” (Reference 7-47). The system contains a return line to the collection tanks. Therefore, treated aqueous liquid that does not meet the required water quality for reuse can be returned for further treatment rather than having to be discharged.

7.4.4 Operating Modes Considered

It should be noted that the operating mode of the plant (see Table 7-5) does not influence the volume or frequency of aqueous liquid discharges from the BWRX-300, as aqueous effluents are collected and processed on a batch basis by the LWM. The BWRX-300 design also includes processing capabilities for the use of temporary storage if excess water is used or enters the plant (i.e., during an outage) (DBR-0060900 (Reference 7-43)). Refuelling outages typically place the greatest demands on NPP water storage and treatment facilities compared to other operational events. The water movement plan (006N7673 (Reference 7-46)), for BWRX-300 refuelling outages aims to stay within the available storage capacity limits to reduce, or avoid, discharges to the environment of processed aqueous effluents. Any necessary aqueous liquid discharges from the BWRX-300 will be determined by operational decisions to maintain the overall water balance of the plant.

[1] The term “overboarding” refers to how the system maintains the overall water balance and/or level control.

7.5 Radioactive Discharge Assessments

As the BWRX-300 is a First of a Kind (FOAK) plant, no discharge measurement data is readily available. The discharge assessments presented here are calculations based on U.S. codes and standards which produce conservative outputs. The basis of these calculations and the conservatisms within are discussed in Section 7.2.4 of this chapter.

As no owner/operator is yet in place, three scenarios for aqueous liquid discharge are presented and bounding cases, for both gaseous and aqueous liquid discharges, established.

In the sections that follow, these, and other aspects of the discharge assessments for gaseous and aqueous liquids from the BWRX-300, are presented.

7.5.1 Scenarios Presented and Bounding Case

As the operating decisions on liquid discharges have not yet been determined, three scenarios are presented for liquid and gaseous discharges under normal operations over a year. This will help the future operator/owner when making site-specific decisions on plant operation and applications for permit discharge limits. The lack of an operations decision on aqueous liquid discharges was identified earlier as a forward action (FAP.PER7-195).

The three scenarios presented for annual aqueous liquid discharge are:

- Zero liquid discharge
- 100% of aqueous liquids processed through the LWM are discharged.
- 600 cubic metres per year (m^3/y) of aqueous liquids processed through the LWM are discharged.

These scenarios are described in Table 7-6.

The conservative bounding discharge assessments have been used to calculate the dose assessments and impacts to members of the public at a generic site. This is discussed in NEDC-34226P, PER Ch. E9 (Reference 7-8).

The future owner/operator is not committed to the chosen scenarios.

7.5.1.1 Headroom Factors and Discharge Limits

The zero and 100% scenarios for aqueous liquid discharge represent the bounding cases for discharges to the environment from the BWRX-300. As a result of the conservatism built into the 100% aqueous liquid discharge scenario, no additional headroom factors have been applied at this stage of the GDA. To include a headroom factor onto the discharges presented in Sections 7.5.2 and 7.5.3 will only add further conservatism.

The discharge assessments that follow will require further refinement (after Step 2 of the GDA). Once refined PST and EUST are determined then updated assessments of gaseous and aqueous liquid discharges, headroom factors, and proposed discharge limits can be presented.

The requirement for a refined model of the source terms is recognised as a forward action (FAP.PER7-196).

The requirement to determine headroom factors (once refined models of the source terms are developed) is also recognised (FAP.PER7-197).

7.5.1.2 Monthly Discharges

A prediction of monthly and rolling monthly discharges is not presented in this chapter, as at this stage of the GDA, GEH considers this to be premature. This is for the following reasons:

- The gaseous discharge is relatively steady over an operating cycle with minor changes at outages.
- The refined EUST have not yet been determined.
- Design basis AOOs and their impacts on discharges have not yet been fully determined.
- The aqueous liquid discharge operating mode has not been determined.

Evidence of the steady nature of the discharges from BWR operation is provided in GA91-9901-0025-0001, "UK ABWR GDA Quantification of Discharges and Limits" (Reference 7-28). This contrasts with Pressurised Water Reactors (PWRs) where there can be spikes in discharge volumes when delay tanks are released.

GEH recognise that, in the future, monthly and rolling monthly discharge assessments will be required (FAP.PER7-198).

7.5.2 Gaseous Discharge Assessments

The anticipated annual gaseous discharge activities for the three scenarios discussed in Section 7.5.1 are presented in the following sections. For the 100% aqueous liquid discharge and the ~10% (by volume) aqueous liquid discharges, only the total annual activities of gaseous discharges are presented.

For the zero aqueous liquid discharge scenario, which is the conservative bounding scenario for gaseous discharges, a breakdown by discharge route is also provided in Table B-1 in Appendix B.

7.5.2.1 Gaseous Discharge Assessment for Zero Aqueous Liquid Discharge Scenario

The data presented in Table 7-7 is extracted from 007N1078, "Annual Average Gaseous Effluent Releases for the BWRX-300 Standard Plant" (Reference 7-25). The methodology for calculation of gaseous discharge activities is also described in detail in 007N1078 (Reference 7-25).

Table 7-7 is for normal operations, including AOOs. Relevant radionuclides are ordered by radionuclide class and atomic mass.

The total annual gaseous discharge activity is produced from summing the activity expected to be generated from the following sources:

- HVS:
  - RB
  - PLSA
  - TB
  - RWB
  - Mechanical Vacuum Pump
  - TGSS
  - Containment

- OGS

The annual gaseous activity contribution from each route is presented in Table B-1 in Appendix B.

7.5.2.2 Gaseous Discharge Assessment for 600 m^3/y Aqueous Liquid Discharge Scenario

In this scenario the gaseous discharges are as presented in Table 7-7, except that the tritium discharge will be reduced. The exact reduction has not been calculated.

7.5.2.3 Gaseous Discharge Assessment for 100% Aqueous Liquid Discharge Scenario

In this scenario the gaseous discharges are as presented in Table 7-7, except that the tritium discharge will be reduced. The exact reduction has not been calculated.

7.5.3 Aqueous Liquid Discharge Assessments

The aqueous liquid discharge activities for the three scenarios discussed in Section 7.5.1 are presented in the following sections.

7.5.3.1 Aqueous Liquid Discharge Assessment for Zero Aqueous Liquid Discharge Scenario

In this scenario there will be zero radioactive aqueous liquid discharges from the BWRX-300 plant.

7.5.3.2 Aqueous Liquid Discharge Assessment for 100% Aqueous Liquid Discharge Scenario

The data presented in Table 7-8 is for normal operations, including AOOs, and is taken directly from 007N1460, "BWRX-300 Annual Average Liquid Effluent Activity Releases" (Reference 7-27). The methodology for calculation of aqueous liquid effluent discharge activities is described in detail in 007N1460 (Reference 7-27). Relevant radionuclides are ordered by radionuclide class and atomic mass.

The concentration of tritium is expected to be the same as in the reactor coolant, as described in 005N4258, "BWRX-300 Coolant Radiation Concentrations," (Reference 7-48). Assuming a maximum volume of 5,968 m^3 per year (m^3/y) (calculated from data in 007N1460 (Reference 7-27)), this would equate to a maximum annual tritium discharge activity of 3.10E+12 Bq/y, assuming normal operation coolant concentrations. It is noted that this would effectively be as short-term releases (from the sample tank(s), see Section 7.4.3.1), rather than a continuous annual discharge.

This scenario represents the conservative bounding case.

7.5.3.3 Aqueous Liquid Discharge Assessment for 600 m^3/y Aqueous Liquid Discharge Scenario

The data presented in Table 7-9 is the data from Table 7-8 adjusted for a discharge of 600 m^3/y rather than a 100% aqueous liquid discharge (5,968 m^3/y).

The annual tritium discharge activity for a 600 m^3/y aqueous liquid discharge is 3.12E+11 Bq/y. This would be as short-term releases (from the sample tank(s), see Section 7.4.3.1), rather than a continuous annual discharge.

7.5.4 Significant Radionuclides

Based on the assessments undertaken in Sections 7.5.2 and 7.5.3 and NEDC-34226P, PER Ch. E9 (Reference 7-8), the current significant radionuclides (in terms of total radioactivity and dose considerations) identified for gaseous discharges are:

- Krypton-89
- Other noble gases
- Iodine-131
- Tritium
- Carbon-14

The current significant radionuclides identified for aqueous liquid discharges are:

- Tritium
- Cobalt-60
- Zinc-65
- Phosphourus-32

However, as has been established earlier in this chapter, the EUST require refinement, and this may impact the activity and dose contributions of significant radionuclides.

7.6 Comparison with International Plants

This section provides a comparison between the BWRX-300 discharge activities and the discharges from other NPPs.

As the BWRX-300 is a FOAK BWR SMR that has not yet been operated, a direct comparison of discharges to operational BWRX-300 reactors is not possible. Therefore, for the purposes of satisfying the requirements of the GDA, comparisons of environmental discharges have been made to the following:

- Proposed discharges from the BWRX-300 reactor being constructed at Darlington, Ontario, Canada.
- Proposed discharges from the UK ABWR.
- A range of operational U.S. BWRs.
- European and UK reactors
- Proposed discharges from the Rolls-Royce SMR.

All the discharge activities are presented as Becquerel per Gigawatt hour (Bq/GWh) as this normalises the discharges against power output and operating time.

When comparing discharges, it should be noted that the BWRX-300 gaseous and aqueous liquid discharges presented in this chapter are the bounding cases, based on a cautious and conservative EUST, and not operating data.

7.6.1 Comparison with Darlington BWRX-300 and UK ABWR

Ontario Power Generation (OPG) are planning to construct up to four BWRX-300 SMRs at the Darlington power plant in Ontario, Canada.

The UK ABWR was a proposed twin BWR conventional power plant that was to be built in the UK at Wylfa, Anglesey by Horizon, detailed in WN0908-HZCON-PAC-REP-00003, “Wylfa Newydd Project Radioactive Substances Regulation – Environmental Permit Application,” (Reference 7-49). The proposal was eventually withdrawn in the late-2010s.

These are useful comparisons as they are current/recent plants designed by GEH. The BWRX-300, while primarily a design evolution of the ESBWR, was also partially developed from the ABWR, and the Canadian SMR is essentially the same as the BWRX-300 presented in this GDA report. OPG have also refined the source terms to present a realistic EUST for liquid aqueous and gaseous discharges. The UK ABWR activities are also based on a refined RM PST for gaseous releases.

The comparison is based on data in GA91-9901-0025-0001, “UK ABWR GDA Quantification of Discharges and Limits” (Reference 7-28), 007N1078, “Annual Average Gaseous Effluent Releases for the BWRX-300 Standard Plant” (Reference 7-25), 007N1460, “BWRX-300 Annual Average Liquid Effluent Activity Releases” (Reference 7-27), WN0908-HZCON-PAC-REP-00003 (Reference 7-49), and NEDO-33970, “Darlington New Nuclear Project, BWRX-300 Preliminary Safety Analysis Report Ch. 20: Environmental Aspects,” (Reference 7-50).

7.6.1.1 Comparison of Gaseous Discharges

The comparison of the gaseous discharges of the three plants (based on single units) is presented in Table 7-10.

For clarity, the BWRX-300 presented for this GDA is referred to as BWRX-300 (GEH) in this section. The OPG Canadian BWRX-300 is referred to as the BWRX-300 (OPG).

The BWRX-300 (GEH) normalised gaseous discharge activity (Bq/GWh), as presented, is currently the largest out of the three units. This serves to highlight how conservative the BWRX-300 (GEH) estimated gaseous discharge activities are currently anticipated to be, based on the available EUST data. Significant decreases in the BWRX-300 (GEH) discharge activities can be expected when a EUST based on a refined RM PST is applied (as has been done for the BWRX-300 (OPG) and UK ABWR) (FAP. PER7-196). This will allow a more representative comparison to be made.

7.6.1.2 Comparison of Aqueous Liquid Discharges

The comparison of the aqueous liquid discharges of the three plants (based on single units) is presented in Table 7-11. This allows for comparison of power but does not consider the impact of volume of the aqueous liquid discharge. The BWRX-300 (GEH) discharge assumes that the full annual volume of water treated by the LWM is discharged (5,968 m^3/y) whereas the UK ABWR assumes a smaller aqueous liquid discharge volume (600 m^3/y). A discharge volume was not specified by OPG.

The discharge activities of the three plants per GWh are broadly similar and the activity is dominated by the tritium (H-3) activity.

7.6.2 Comparison with European and UK Reactors

A review of annual discharges of gaseous and aqueous liquid radioactive waste from similar reactor types in Europe and the UK was undertaken as part of the UK ABWR quantification of discharges and limits, presented in GA91-9901-0025-0001 (Reference 7-28).

It is considered useful to compare this data with the proposed BWRX-300 and the 470 MWe Rolls-Royce SMR estimated discharge data. U.S. BWR data is not included here, but a separate evaluation of discharges from U.S. BWR plants is included in Section 7.6.3.

The discharge data was extracted for the period 2005 to 2014 and averaged, except for the UK ABWR (taken from GA91-9901-0025-0001 (Reference 7-28)), BWRX-300 (taken from Sections 7.5.2 and 7.5.3 of this report) and the Rolls-Royce SMR (taken from SMR0004486, "Environment, Safety, Security and Safeguards Case Version 2, Tier 1, Ch. 29: Quantification of Radioactive Effluent Discharges and Proposed Limits," (Reference 7-51)).

7.6.2.1 Gaseous Discharge Comparison

Normalised data for gaseous discharges from selected European and UK reactors is reproduced in Table 7-12 from GA91-9901-0025-0001 (Reference 7-28). Estimated data for the proposed BWRX-300 (see Section 7.5.2) and the 470 MWe Rolls-Royce SMR (see SMR0004486 (Reference 7-51)) are included for comparative purposes.

The data indicates that the bounding case activity of the gaseous discharges for the BWRX-300 is at the top end of the comparable plant discharges when normalised for activity per GWh. It is not, however, orders of magnitude higher than other plants at the top end of discharges and GEH anticipates that activities will be reduced when refined EUST are produced.

7.6.2.2 Aqueous Liquid Discharges

Normalised data for aqueous liquid discharges from selected European and UK reactors is reproduced in Table 7-13 from GA91-9901-0025-0001 (Reference 7-28). Estimated data for the proposed BWRX-300 (see Section 7.5.3) and Rolls-Royce SMR (SMR0004486 (Reference 7-51)) are again included for comparative purposes.

The data indicates that when normalised for activity per GWh the bounding case activity of the tritium and beta/gamma aqueous liquid discharges for the BWRX-300 is comparable to Sizewell B and Heysham 2. It is an order of magnitude higher than comparable BWRs.

The bounding case for aqueous liquid discharges from the BWRX-300 is based on all treated process liquids being discharged to the environment rather than being recycled to the CST for reuse in the plant. This is an unlikely method of operation. When a discharge volume is determined by the future operator/owner and when refined EUST are produced, it is anticipated that these activities will be reduced (FAP.PER7-195 and FAP.PER7-196).

7.6.3 Comparison with U.S. BWRs

A review of annual discharges of gaseous and aqueous liquid radioactive waste from similar reactor types was undertaken as part of the UK ABWR quantification of discharges and limits, presented in GA91-9901-0025-0001 (Reference 7-28). The data is reproduced in Table 7-14 and Table 7-15 for the U.S. BWR data and includes data for the proposed BWRX-300 (see Section 7.5.2).

7.6.3.1 Gaseous Discharge Comparison

Table 7-14 presents a comparison between the GEH BWRX-300 and U.S. BWRs.

The data indicates that the bounding case activity of the highest activity gaseous discharges (noble gases, tritium, and carbon-14) for the BWRX-300 is at the top end of the comparable plant discharges when normalised for activity per GWh. It is not, however, orders of magnitude higher than other plants at the top end of discharges and it is anticipated that activities will be reduced when refined EUST are produced (FAP.PER7-196).

7.6.3.2 Aqueous Liquid Discharge Comparison

Table 7-15 presents a comparison between the GEH BWRX-300 and U.S. BWRs.

The data indicates that the bounding case activity of aqueous liquid discharges for the BWRX-300 (both tritium and beta/gamma) is shown to be an order of magnitude higher than comparable BWRs.

This is rationalised by the fact that the bounding case for aqueous liquid discharges from the BWRX-300 is based on all treated aqueous effluents being discharged rather than being recycled to the CST for reuse in the plant. This is an unlikely method of operation given the efficient treatment systems and water storage capabilities included in the BWRX-300 design. Additionally, extensive OPEX from U.S. BWRs indicates that similar NPPs may operate with zero aqueous liquid discharge for extended periods of time (up to ten years for selected plants studied), in accordance with NEDC-34279P, “Analysis of Environmental Discharge Data for U.S. Nuclear Power Plants” (Reference 7-44). When a discharge volume is determined by the future operator/owner and refined EUST are produced, it is anticipated that the estimated activity of aqueous liquid discharges will be significantly reduced (FAP.PER7-195 and FAP.PER7-196).

7.7 Conclusion

This chapter of the PER has presented conservative bounding activities for the gaseous and aqueous liquid radioactive discharges for the GEH BWRX-300. GEH considers that the radioactive discharge assessment presented satisfies Step 2 of the GDA.

The BWRX-300 conservative bounding discharges have been compared to international plants and are comparable, when normalised for power output and operating hours.

GEH fully expect the gaseous and aqueous liquid discharge activities to reduce once refined EUST have been produced, and the aqueous liquid discharge volume is confirmed.

Forward actions to develop the discharge assessments, beyond Step 2 of the GDA, have been identified and a FAP produced.

Table 7-1: Overview of Document Scope

Key Area	Document Scope	Relevant Section(s)
Origin of the radioactivity in gaseous and aqueous liquid radioactive waste	Sources and production mechanisms of relevant radionuclides are presented, including the radiological source terms used in calculating the activities of the gaseous and aqueous liquid discharges to the environment.	Section 7.2
Systems and processes from which gaseous and aqueous liquid radioactive waste arise	Relevant systems, processes, and plant areas are identified.	Section 7.2.1
Conveyance, collection, and segregation of gaseous and liquid aqueous radioactive waste	Plant systems and processes that perform these functions are identified, and high-level descriptions presented.	Section 7.3 and 7.4
Treatment of gaseous and aqueous liquid radioactive waste	• Systems and processes that reduce the radioactivity of gaseous and aqueous liquid radioactive waste prior to release are identified and described, • Design features that enable the BWRX-300 to operate, under normal operating conditions, without aqueous liquid discharges to the environment are presented.	Section 7.3.1, 7.3.2.3, 7.4.2, and 7.4.3
Sampling and monitoring of gaseous and aqueous liquid radioactive waste	It is identified where provision for sampling and monitoring of discharges has been incorporated into the BWRX-300 design. Detailed information on sampling and monitoring is provided in NEDC-34225P, "PER Ch. E8: Approach to Sampling and Monitoring" (Reference 7-4).	Section 7.3.2.4, 7.4.3, and 7.4.3.1
Gaseous and aqueous liquid discharge routes to the environment	Discharge routes are identified and described.	Section 7.3.2.4 and 7.4.3.1
Radioactivity of gaseous and aqueous liquid discharges	Radioactive discharge assessments are presented for gaseous and liquid aqueous discharges. As the aqueous liquid discharge volumes from the BWRX-300 are yet to be confirmed, three different aqueous liquid discharge scenarios are described. From these three scenarios, conservative bounding assessment of activities for the gaseous and aqueous liquid radioactive discharges to the environment from the normal operation of the BWRX-300 are generated.	Section 7.5

Key Area	Document Scope	Relevant Section(s)
Comparison of the gaseous and aqueous liquid discharges from BWRX-300 with other NPPs	A comparison is presented, with activities normalised for power output and operating hours, of the BWRX-300 gaseous and aqueous liquid discharges (based on the conservative bounding case) with operational reactors in the UK, U.S., and Europe. Additional comparisons are made to: • UK ABWR • Data provided by Ontario Power Generation (OPG) for BWRX-300 • Rolls Royce SMR	Section 7.6

Table 7-2: Regulatory Expectations and GDA Step 2 Scope

Regulatory Expectation (3 Step GDA)	GEH Response (2 Step GDA)
A requirement for quantitative estimates of discharges of gaseous and aqueous radioactive wastes for normal operation.	• Conservative bounding annual quantitative estimates are provided – Section 7.5. • The estimates include Anticipated Operational Occurrences (AOOs).
The RP must estimate the monthly discharges for significant radionuclides at each discharge point and route.	• Monthly estimates have not been provided – see Section 7.5.1.2. • The significant radionuclides are identified – Section 7.5.4. These are discussed further in NEDC-34225P, PER Ch. E8 (Reference 7-4).
The radionuclide selection should be consistent with 2004/2/Euratom.	• Radionuclide selection is discussed in Section 7.2.5. • Although this selection is not fully consistent with 2004/2/Euratom, GEH consider that the approach presented in this 2-Step GDA meets requirements.
Estimates of discharges and disposals should clearly show the contribution of each aspect of normal operations.	• Annual conservative bounding quantitative estimates are provided – Section 7.5. A breakdown by source for the bounding case gaseous discharge only is provided – Appendix B. GEH consider that this meets the requirements necessary for a 2-Step GDA. • Operating modes are discussed in Section 7.3.3 and AOOs are discussed in Section 7.2.4.4.
Discharge estimates must be supported with performance data from similar facilities, where such facilities exist. Where such data is unavailable, discharges could be derived from the primary coolant source term.	• Section 7.2 describes how the End User Source Terms (EUST) for the discharges have been derived. • As no decision has yet been taken on the volume of aqueous liquids that will be discharged, three scenarios are presented to allow a range of annual quantitative estimates to be calculated.
The RP must demonstrate that discharges will not exceed those of comparable power stations across the world, as required by UK government policy, according to CM 7296, “Meeting the Energy Challenge, A White Paper on Nuclear Power,” (Reference 7-17).	A comparison with other NPPs is provided – Section 7.6.
The RP must provide proposed limits for: • Gaseous discharges • Aqueous discharges	Conservative bounding annual quantitative estimates are provided – Section 7.5. GEH consider that these represent the maximum limit of gaseous and aqueous liquid radioactive discharges from the BWRX-300.

Regulatory Expectation (3 Step GDA)	GEH Response (2 Step GDA)
The RP must provide proposals for: • Annual site limits (on a rolling 12-month basis) for gaseous and aqueous discharges. • The RP must describe how they derived these limits. They can also propose limits to reflect an operating cycle (campaign limits).	GEH considers that this is premature for the submission of a 2-Step GDA. This is discussed under Section 7.5.1.2.

Table 7-3: Comparison of BWRX-300 and UK ABWR RM PST

	Geometric Mean of BWRX-300 RM: UK ABWR RM PST Nuclide Ratios by Class					
	Class 1	Class 2	Class 3	Class 4	Class 5	Class 6 (FPs Only)
Water	N/A	26.4	15.5	1.5	2.9	0.7
Steam	245.4	26.3	15.5	3.1	2.9	0.7

Table 7-4: Main Sources of Gaseous Radioactive Waste in Buildings/Areas Served by the HVS

Building HVS	Main Sources of Radioactive Gases
RB	• Equipment pool • Reactor cavity pool • Fuel pool • Operating deck • Entry/truck bay • CIS (additional description provided in Section 7.3.2.1) • General workspace
RWB	• Refuelling staging area • Chemistry laboratory • Tank/pump areas (includes sludge and spent resin storage tanks) • Part of OGS • Drum evaporator • General workspace
TB	• General workspace – includes filter/demineraliser and condenser areas • TGSS (additional description provided in Section 7.3.2.2) • Part of OGS
PLSA	• New and spent fuel staging area • Hot tool room • Decontamination room • Hot machine shop • Truck space (cask removal) • Storage area • General workspace

Table 7-5: BWRX-300 Operational Modes

Mode	Title
1	Power Operation
2	Startup
3	Hot Shutdown
4	Stable Shutdown
5	Cold Shutdown
6	Refuelling

Table 7-6: Annual Aqueous Liquid Discharge Scenarios

Scenario	Volume of Aqueous Liquid Discharged (m^3/y)	Comment
Zero discharge	0	• Plant design for normal operating conditions and AOOs. • Gives conservative bounding case for gaseous discharges to the environment. • Gives maximum tritium release in the gaseous discharges to the environment.
100% discharge	5968	• Total estimated annual aqueous liquid input to the LWM (during normal operations and AOOs), based on industry data from operating BWRs (NUREG-0016 (Reference 7-23) and 007N1460 (Reference 7-27)). It is assumed that all aqueous liquid treated by the LWM is discharged to the environment, with no recycling to the CST for plant reuse. • Gives conservative bounding case for aqueous liquid discharges to the environment. • Gives minimum tritium release in the gaseous discharges to the environment. • Increases the volume of fresh demineralised water that would have to be imported into the plant.
600 m^3/y discharge	600	• Approximately 10% of the 100% discharge scenario. • Similar volume to that considered for the UK ABWR High Chemical Impurity Waste System in GA91-9901-0025-0001 (Reference 7-28).

Table 7-7: BWRX-300 Annual Airborne Release

Nuclide	Annual Release (MBq/y)	Nuclide	Annual Release (MBq/y)	Nuclide	Annual Release (MBq/y)
Kr-83m	3.3E+05	Ar-41	3.2E+02	Mo-99	2.6E+00
Kr-85m	3.4E+04	Cr-51	2.0E+01	Tc-99m	2.2E-01
Kr-85	2.2E+06	Mn-54	1.2E+01	Ru-103	4.5E-01
Kr-87	1.2E+05	Mn-56	4.5E-01	Rh-103m	1.9E-03
Kr-88	1.2E+05	Fe-55	2.4E+01	Ru-106	7.3E-02
Kr-89	1.2E+07	Fe-59	5.8E+00	Rh-106	1.0E-02
Xe-131m	3.8E+04	Co-58	5.2E+00	Ag-110m	2.4E-02
Xe-133m	1.1E+03	Co-60	1.1E+01	Sb-124	4.9E-04
Xe-133	1.6E+06	Ni-63	2.5E-02	Te-129m	8.4E-01
Xe-135m	1.2E+06	Cu-64	5.8E+00	Te-131m	1.5E-01
Xe-135	1.3E+06	Zn-65	4.9E+00	Te-132	6.8E-02
Xe-137	1.7E+06	Rb-89	4.4E-02	Cs-134	6.6E-01
Xe-138	2.4E+06	Sr-89	8.0E-02	Cs-136	3.7E-01
I -131	5.2E+02	Sr-90	3.6E-03	Cs-137	1.0E+00
I -132	3.1E+03	Y-90	8.8E-04	Cs-138	1.1E-01
I -133	2.4E+03	Sr-91	1.7E+00	Ba-140	7.1E+00
I -134	8.7E+03	Sr-92	1.0E+00	La-140	1.6E+00
I -135	4.6E+03	Y-91	8.9E-01	Ce-141	4.5E-01
H-3	9.7E+05	Y-92	4.1E-01	Ce-144	7.2E-02
C-14	4.0E+05	Y-93	1.3E-01	Pr-144	8.4E-05
Na-24	1.4E+00	Zr-95	1.9E+00	W-187	5.3E-01
P-32	6.9E-01	Nb-95	1.8E+00	Np-239	1.8E+00
				Total	**2.44E+07**

Note: This scenario represents the conservative bounding case.

Table 7-8: BWRX-300 Annual Aqueous Liquid Release (100%)

Nuclide	Annual Release (Becquerel per year (Bq/y))	Nuclide	Annual Release (Bq/y)	Nuclide	Annual Release (Bq/y)
I-131	4.07E+07	Ni-65	1.48E+06	Ru-103	9.99E+06
I-132	5.55E+06	Cu-64	2.74E+08	Ru-105	2.92E+07
I-133	7.03E+07	Zn-65	9.99E+07	Ru-106	1.78E+07
I-135	3.18E+07	Zn-69m	1.55E+08	Ag-110m	2.59E+06
Cs-134	8.51E+07	Br-83	2.48E+07	Te-129m	1.85E+07
Cs-136	4.81E+07	Sr-89	1.85E+06	Te-131m	7.77E+06
Cs-137	1.30E+08	Sr-91	7.40E+07	Te-132	2.59E+06
Na-24	7.03E+07	Sr-92	1.78E+07	Ba-139	8.14E+06
P-32	1.74E+07	Y-91	2.48E+07	Ba-140	1.81E+08
Cr-51	4.44E+08	Y-92	5.55E+07	La-142	6.66E+06
Mn-54	2.41E+08	Y-93	5.92E+06	Ce-141	1.22E+07
Mn-56	7.40E+06	Zr-95	4.07E+07	Ce-143	5.92E+06
Fe-55	5.18E+08	Zr-97	7.40E+05	Ce-144	8.51E+06
Fe-59	1.30E+08	Nb-95	4.44E+07	Nd-147	1.48E+06
Co-58	1.26E+08	Nb-98	3.70E+05	Pr-143	2.18E+07
Co-60	2.44E+08	Mo-99	1.04E+08	W-187	2.74E+07
Ni-63	3.70E+06	Tc-99m	1.04E+08	Np-239	7.77E+07
				Total	**3.68E+09**

Table 7-9: BWRX-300 Annual Aqueous Liquid Release (600 m^3/y)

Nuclide	Annual Release (Bq/y)	Nuclide	Annual Release (Bq/y)	Nuclide	Annual Release (Bq/y)
I-131	4.09E+06	Ni-65	1.49E+05	Ru-103	1.00E+06
I-132	5.58E+05	Cu-64	2.75E+07	Ru-105	2.94E+06
I-133	7.07E+06	Zn-65	1.00E+07	Ru-106	1.79E+06
I-135	3.20E+06	Zn-69m	1.56E+07	Ag-110m	2.60E+05
Cs-134	8.56E+06	Br-83	2.49E+06	Te-129m	1.86E+06
Cs-136	4.84E+06	Sr-89	1.86E+05	Te-131m	7.81E+05
Cs-137	1.31E+07	Sr-91	7.44E+06	Te-132	2.60E+05
Na-24	7.07E+06	Sr-92	1.79E+06	Ba-139	8.18E+05
P-32	1.75E+06	Y-91	2.49E+06	Ba-140	1.82E+07
Cr-51	4.46E+07	Y-92	5.58E+06	La-142	6.70E+05
Mn-54	2.42E+07	Y-93	5.95E+05	Ce-141	1.23E+06
Mn-56	7.44E+05	Zr-95	4.09E+06	Ce-143	5.95E+05
Fe-55	5.21E+07	Zr-97	7.44E+04	Ce-144	8.56E+05
Fe-59	1.31E+07	Nb-95	4.46E+06	Nd-147	1.49E+05
Co-58	1.27E+07	Nb-98	3.72E+04	Pr-143	2.19E+06
Co-60	2.45E+07	Mo-99	1.05E+07	W-187	2.75E+06
Ni-63	3.72E+05	Tc-99m	1.05E+07	Np-239	7.81E+06
				Total	**3.70E+08**

Table 7-10: Comparison Table of Normalised Gaseous Discharges from BWRX-300 and UK ABWR

	BWRX-300 (GEH)	BWRX-300 (OPG)	UK ABWR
	Activity (Bq/y)		
Total Gaseous Discharge	2.44E+13	4.73E+12	5.56E+12[1]
	Power Output (Gigawatt electric (GWe))		
Power GWe	0.3	0.3	1.35
Operating Hours/y	8322[1]	8322[2]	8273.3[3]
	Normalised Activity (Bq/GWh)		
Total Gaseous Discharge	**9.77E+09**	**1.89E+09**	**4.98E+08**[1]

Notes:

[1] The UK ABWR PST does not include any contribution from leaking fuel. However, a gaseous discharge activity of 1.90E+11 Bq/y was postulated for an Expected Event of a fuel pin failure, anticipated to occur at a rate of once every 20 years (WN0908-HZCON-PAC-REP-00003 (Reference 7-49)). The total gaseous discharge as presented for UK ABWR in Table 7-10 includes a fuel failure contribution equivalent to 9.50E+10 Bq/y.

[2] Based on 8,760 hours per year and a 95% lifetime capacity factor. The lifetime capacity factor is defined as Lifetime GWe-years delivered / (GWe capacity × Design Life), including outages.

[3] Based on 8,760 hours per year and 94.4% capacity factor, assuming an 18-month operating cycle (17 months power operations and 1 month outage).

Table 7-11: Comparison Table of Normalised Aqueous Liquid Discharges from BWRX-300 and UK ABWR

	BWRX-300 (GEH)	BWRX-300 (OPG)	UK ABWR
	Activity (Bq/y)		
H-3	3.10E+12	4.81E+11[1]	2.00E+11
Other radionuclides	3.68E+09	3.92E+09	1.36E+06
Total	**3.10E+12**	**4.85E+11**	**2.00E+11**
	Power Output		
Power (GWe)	0.3	0.3	1.35
Operating Hours/y[2]	8322	8322	8273.3
	Normalised Activity (Bq/GWh)		
H-3	1.24E+09	1.93E+08	1.79E+07
Other radionuclides	1.47E+06	1.57E+06	1.22E+02
Total	**1.24E+09**	**1.94E+08**	**1.79E+07**

Notes:

[1] No data for H-3 in aqueous liquid discharges was provided by OPG. This figure was derived by halving the gaseous discharge activity value supplied by OPG.

[2] Operating hours based on assumptions as per Table 7-10.

Table 7-12: Normalised Annual Gaseous Discharges for Selected NPPs

NPP	Activity Bq/GWh				
	Total Noble Gases	**Total Iodine Gases**	**Total Beta/Gamma**	**H-3**	**C-14**
BWRX-300	**9.23E+09**	**7.74E+06**	**1.75E+05**	**3.89E+08**	**1.60E+08**
UK ABWR	**1.50E+08**	**2.70E+04**	**2.10E+01**	**2.30E+08**	**7.70E+07**
Olkiluoto	4.00E+08	3.40E+03	1.50E+03	2.70E+07	5.70E+07
Gundremmingen B+C	1.90E+08	2.70E+03	1.90E+01	3.60E+07	4.10E+07
Isar 1[1]	3.30E+08	4.50E+03	Not reported	1.70E+07	5.00E+07
Philippsburg 1[1]	2.70E+08	7.80E+03	3.80E+03	7.10E+06	6.10E+07
Cofrentes	2.30E+09	1.10E+06	6.50E+06	1.10E+08	5.20E+07
Santa Maria de Garona	3.20E+09	4.60E+05	6.70E+04	3.10E+08	6.00E+07
Forsmark	3.90E+08	1.20E+04	9.20E+03	3.80E+07	9.10E+07
Oskarshamn	8.10E+08	3.20E+04	2.00E+05	5.10E+07	4.80E+07
Ringhals 1	7.30E+08	2.80E+04	8.10E+06	3.00E+07	7.80E+07
Leibstadt	5.90E+07	1.00E+04	1.10E+03	2.00E+08	7.10E+07
Sizewell B PWR	4.00E+08	1.00E+04	1.40E+03	1.00E+08	2.90E+07
Heysham 2 AGR	1.60E+09	8.60E+03	1.20E+03	1.20E+08	1.70E+08
Rolls-Royce SMR	**2.90E+09**	**1.60E+04**	**8.80E+02**	**1.10E+07**	**5.40E+06**

Note:

[1] Power generation ceased in 2011.

Table 7-13: Normalised Annual Aqueous Liquid Discharges for Selected NPPs

NPP	Activity Bq/GWh	
	H-3	Beta/Gamma[1]
BWRX-300	**1.24E+09**	**1.47E+06**
UK ABWR	**1.70E+07**	**2.60E+02**
Olkiluoto	1.30E+08	2.20E+04
Gundremmingen B+C	1.80E+08	4.50E+04
Isar 1[2]	8.20E+07	9.80E+03
Philippsburg 1[2]	9.70E+07	2.80E+04
Cofrentes	6.50E+07	1.60E+04
Santa Maria de Garona	1.40E+08	9.10E+04
Forsmark	8.10E+07	7.80E+03
Oskarshamn	8.40E+07	1.40E+05
Ringhals 1	1.30E+08	5.30E+05
Leibstadt	2.50E+08	1.4E+04
Sizewell B PWR	5.00E+09	1.20E+06
Heysham 2 AGR	3.70E+10	7.40E+06
Rolls-Royce SMR	**2.20E+07**	**1.54E+02**

Notes:

[1] Beta/gamma refers to all detectable radionuclides excluding tritium.

[2] Power generation ceased in 2011.

Table 7-14: Normalised Annual Gaseous Discharges for Selected NPPs

NPP	Activity Bq/GWh				
	Total Noble Gases	Total Iodine Gases	Total Beta/Gamma	H-3	C-14
BWRX-300	**9.23E+09**	**7.74E+06**	**1.75E+05**	**3.89E+08**	**1.60E+08**
Clinton-1[1]	1.80E+07	7.30E+01	4.50E+02	8.80E+07	6.50E+07
Grand Gulf-1	3.10E+09	4.50E+03	5.90E+02	1.10E+08	4.00E+07
LaSalle county 1&2[1]	4.60E+09	8.80E+04	2.70E+04	5.00E+07	5.80E+07
Limeric-1&2	2.10E+08	1.70E+02	2.00E+03	9.70E+07	6.10E+07
Nine Mile Point-2[1]	9.10E+08	1.10E+04	1.60E+04	2.90E+08	6.70E+07
Perry-1	1.80E+08	6.60E+02	2.60E+01	2.20E+07	6.30E+07
Susquehanna-1&2	1.60E+07	< MDC[2]	4.00E+02	4.50E+07	6.60E+07

Notes:

[1] U.S. BWRs that have reported zero aqueous liquid discharge between 2012 and 2021 (NEDC-34279P (Reference 7-44)).

[2] MDC = minimum detectable concentration

Table 7-15: Normalised Annual Aqueous Liquid Discharges for Selected NPPs

NPP	Activity Bq/GWh	
	H-3	Beta/Gamma[1]
BWRX-300	**1.24E+09**	**1.47E+06**
Clinton-1[2]	NR[3]	NR
Grand Gulf-1	3.10E+08	1.90E+05
LaSalle county 1&2[2]	<LLD[4]	<LLD
Limeric-1&2	2.30E+07	2.80E+03
Nine Mile Point-2[2]	2.00E+07	1.10E+03
Perry-1	1.20E+08	1.80E+05
Susquehanna-1&2	1.40E+08	1.10E+05

Notes:

[1] Beta/gamma refers to all detectable radionuclides excluding tritium.

[2] US BWRs that have reported zero aqueous liquid discharge between 2012 and 2021 (NEDC-34279P (Reference 7-44)).

[3] NR = No Release, i.e., no releases occurred during this period.

[4] LLD = Lower Limit of Detection. No radioactivity was detected and represents the lower limit of detection value for samples within a data set.

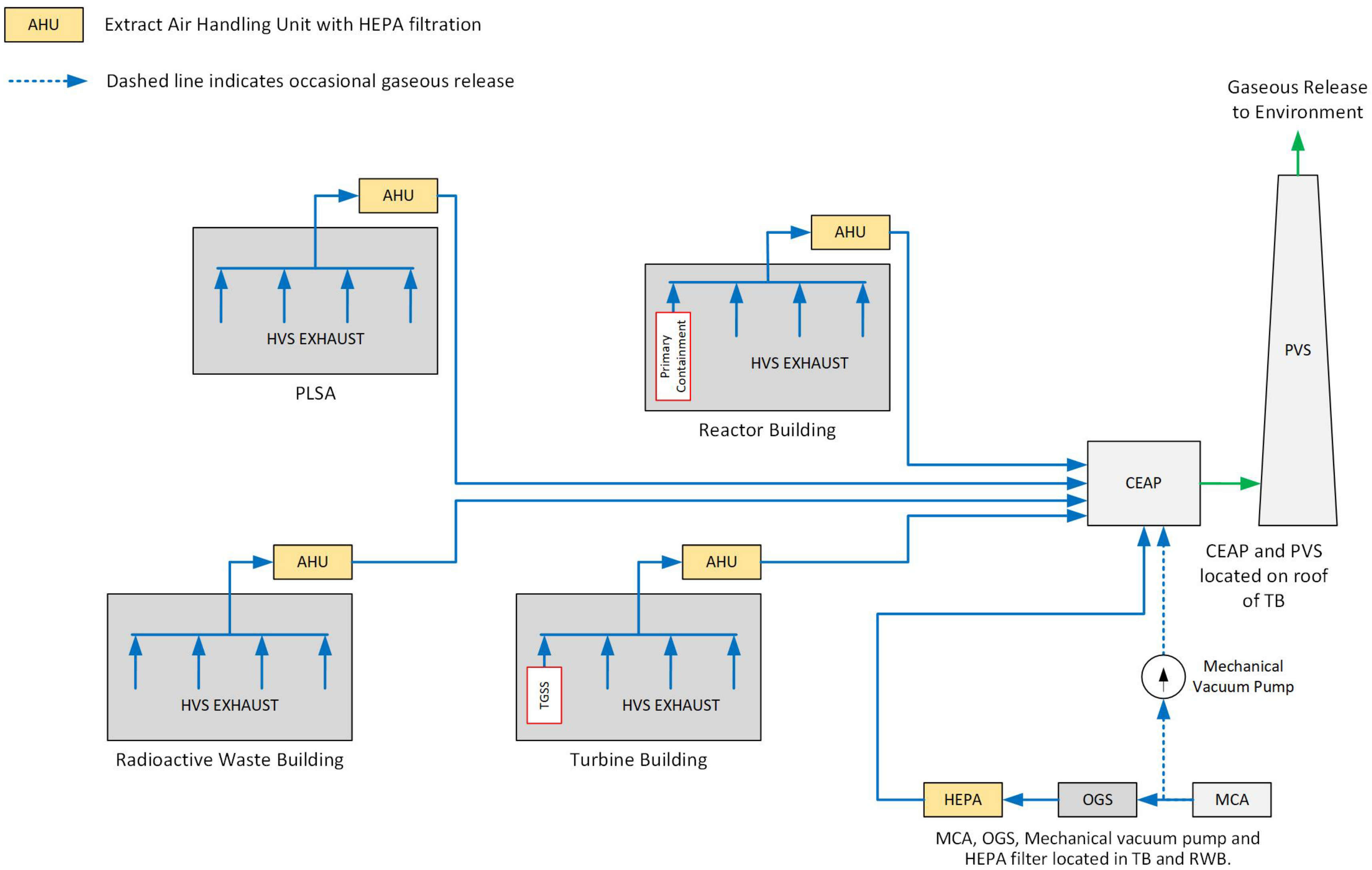

Figure 7-1: Simplified Diagram of the BWRX-300 Gaseous Releases

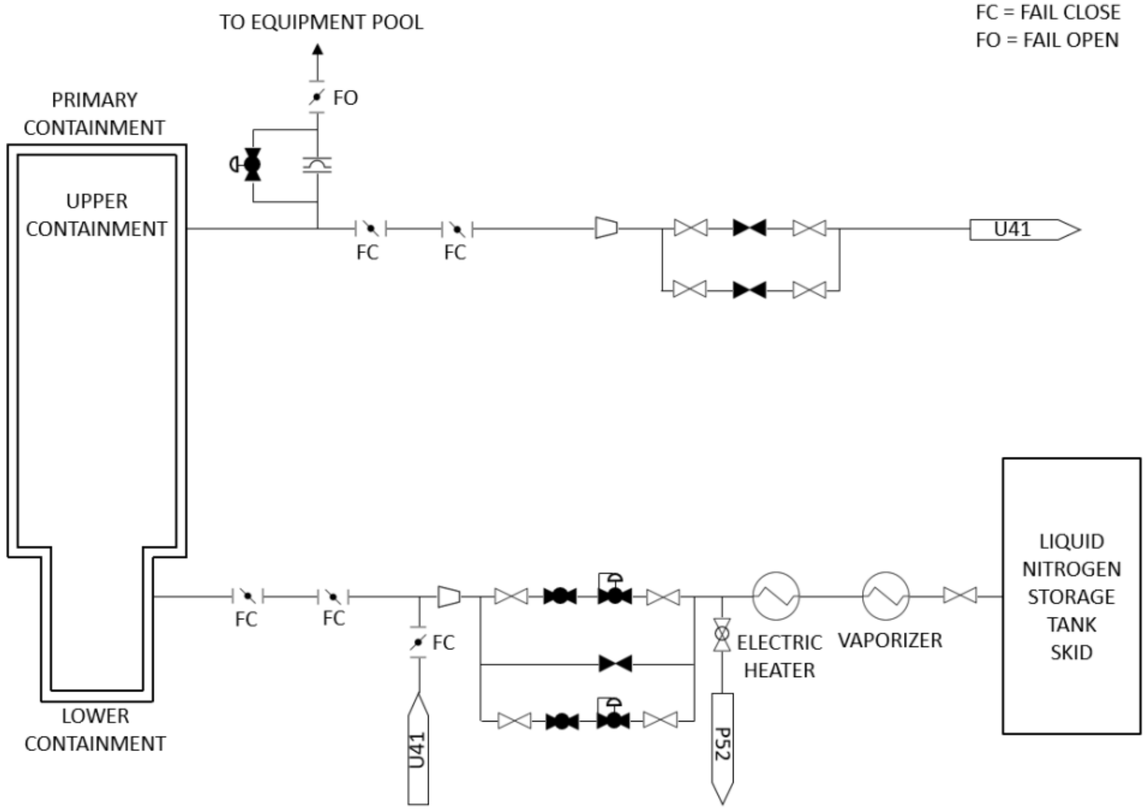

Figure 7-2: CIS Simplified Diagram

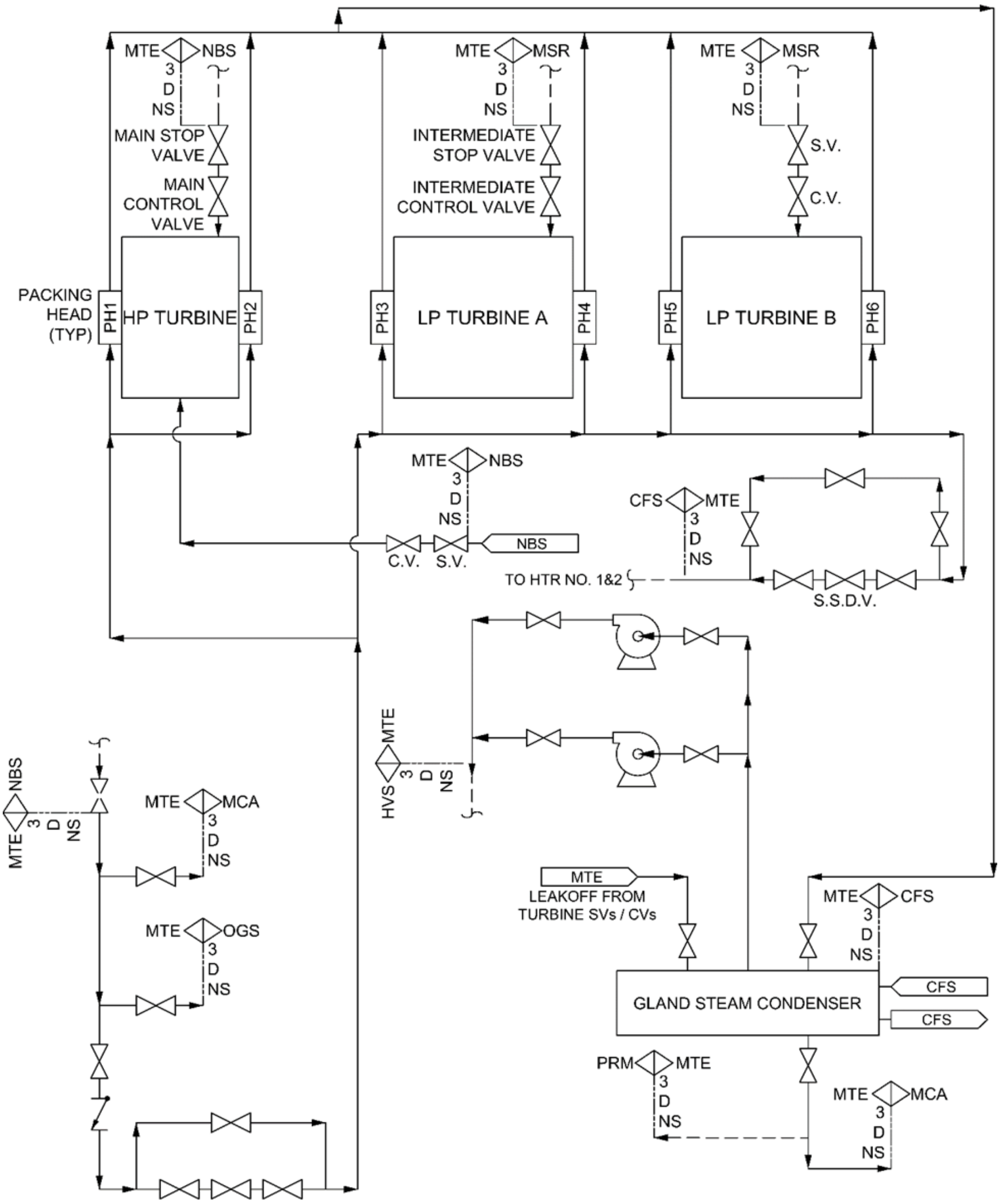

Figure 7-3: TGSS Simplified Single Line Diagram

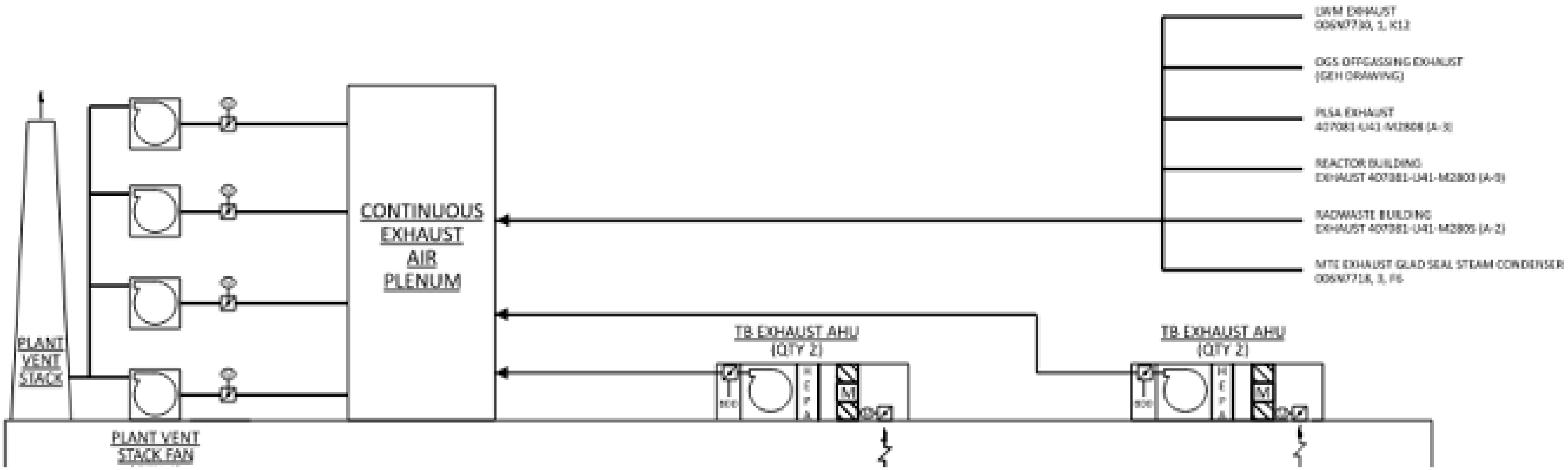

Figure 7-4: CEAP and PVS Simplified Flow Diagram

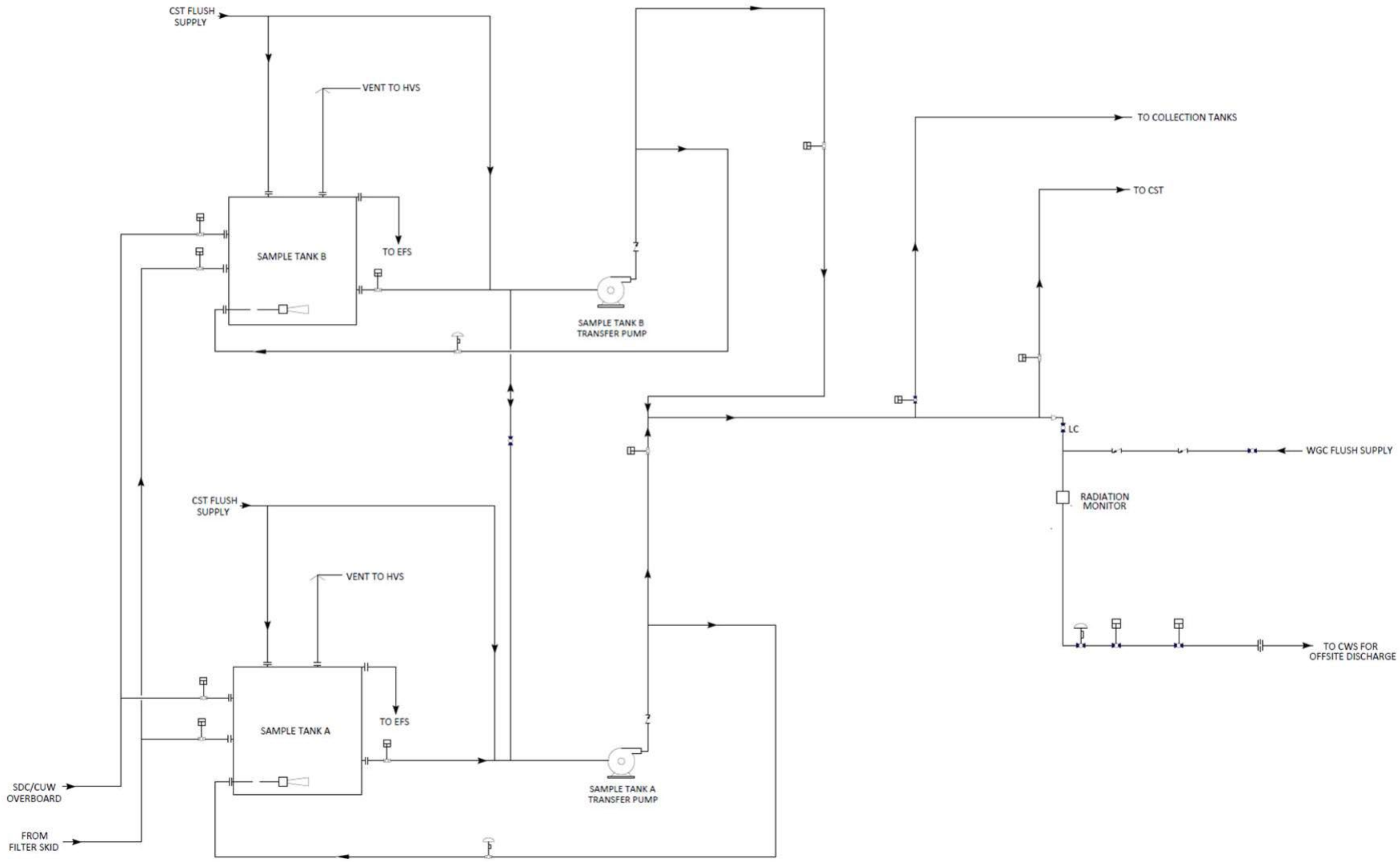

Figure 7-5: Waste Sampling Subsystem Simplified Diagram

7.8 References

7-1 006N7781, "BWRX-300 Heating, Ventilation and Cooling System (HVS)," Rev 3, GE-Hitachi Nuclear Energy, Americas, LLC, November 2023.

7-2 NEDC-34223P, "BWRX-300 UK GDA Preliminary Environmental Report Ch. E6: Demonstration of Best Available Techniques Approach," Rev A, GE-Hitachi Nuclear Energy, Americas, LLC.

7-3 NEDC-34222P, "BWRX-300 UK GDA Preliminary Environmental Report Ch. E5: Radioactive Waste Management Arrangements," GE Hitachi Nuclear Energy, Rev A, November 2024.

7-4 NEDC-34225P, "BWRX-300 UK GDA Preliminary Environmental Report Ch. E8: Approach to Sampling and Monitoring," Rev A, GE-Hitachi Nuclear Energy, Americas, LLC.

7-5 006N7789, "BWRX-300 Equipment and Floor Drain System (EFS)," Rev 2, GE-Hitachi Nuclear Energy, Americas, LLC, April 2023.

7-6 NEDC-34219P, "BWRX-300 UK GDA Preliminary Environmental Report Ch. E2: Generic Site Description," Rev A, GE-Hitachi Nuclear Energy, Americas, LLC, October 2024.

7-7 NEDC-34221P, "BWRX-300 UK GDA Preliminary Environmental Report Ch. E4: Information about the Design," Rev A, GE-Hitachi Nuclear Energy, Americas, LLC.

7-8 NEDC-34226P, "BWRX-300 UK GDA Preliminary Environmental Report Ch. E9: Prospective Radiological Assessment," Rev A, GE-Hitachi Nuclear Energy, Americas, LLC.

7-9 NEDC-34195P, "BWRX-300 UK GDA Preliminary Safety Report Ch. 23: Reactor Chemistry," Rev A, GE-Hitachi Nuclear Energy, Americas, LLC.

7-10 "The Environmental Permitting (England and Wales) Regulations 2016" (as amended), UK Parliament, Accessed September 2024.

7-11 "Criteria for setting limits on the discharge of radioactive waste from nuclear sites," Environment Agency, Version 1.0, June 2012.

7-12 "Nuclear sites RSR: environmental permits," Environment Agency, June 2024.

7-13 EP-RSR-B3, "Application for an environmental permit Form RSR-B3 – New bespoke radioactive substances activity permit (nuclear site – unsealed sources and radioactive waste)," Environment Agency, Version 4, January 2021.

7-14 "RSR permits for nuclear licensed sites: how to comply," Environment Agency, February 2020.

7-15 "New nuclear power plants: Generic Design Assessment guidance for Requesting Parties," Environment Agency, Natural Resources Wales, Office for Nuclear Regulation, October 2023.

7-16 "Environment: Introductions and Expectations," Environment Agency, Natural Resources Wales, Office for Nuclear Regulation, February 2024.

7-17 CM 7296, "Meeting the Energy Challenge, A White Paper on Nuclear Power," Department for Business, Enterprise & Regulatory Reform, January 2008.

7-18 "Radioactive Substances Regulation (RSR): objective and principles," Environment Agency, December 2021.

7-19 "RSR generic developed principles: regulatory assessment," Environment Agency, Updated May 2024.

7-20 NEDC-34231P, BWRX-300 UK GDA “Alignment with Sustainability, the Radioactive Substances Regulation Objective and Principles & Generic Developed Principles,” Rev A, GE-Hitachi Nuclear Energy, Americas, LLC.

7-21 NAS-NS-3119, “Radiochemistry in Nuclear Power Reactors,” C. C. Lin, GE Nuclear Energy, 1996 (ISBN 978-0-309-30330-9).

7-22 NS-TAST-GD-088, “Chemistry of Operating Civil Nuclear Reactors,” Office for Nuclear Regulation, Issue 3.1, January 2024.

7-23 NUREG-0016, “Calculation of Release of Radioactive Materials in Gaseous and Liquid Effluents from Boiling-Water Reactors,” Rev 2, U.S. Nuclear Regulatory Commission, July 2020.

7-24 ANSI/ANS-18.1-2020, “Radioactive Source Term for Normal Operation of Light Water Reactors,” American Nuclear Society, July 2020.

7-25 007N1078, “Annual Average Gaseous Effluent Releases for the BWRX-300 Standard Plant,” Rev 2, GE-Hitachi Nuclear Energy, Americas, LLC, June 2023.

7-26 RG 1.112, “Calculation of Releases of Radioactive Materials in Gaseous and Liquid Effluents from Light-Water-Cooled Nuclear Power Reactors,” Rev 1, U.S. Nuclear Regulatory Commission, March 2007.

7-27 007N1460, “BWRX-300 Annual Average Liquid Effluent Activity Releases,” Rev 3, GE-Hitachi Nuclear Energy, Americas, LLC, May 2023.

7-28 GA91-9901-0025-0001, “UK ABWR Generic Design Assessment, Quantification of Discharges and Limits,” Rev G, GEH, 2017.

7-29 NS-TAST-GD-006, “Nuclear Safety Technical Assessment Guide – Design Basis Analysis,” Office for Nuclear Regulation, Issue 5.1, December 2022.

7-30 005N3558, “BWRX-300 Fault Evaluation,” Rev 2, GE-Hitachi Nuclear Energy, Americas, LLC, December 2023.

7-31 C(2003) 4832, “Commission Recommendation 2004/2/Euratom of 18 December 2003 on standardised information on radioactive airborne and liquid discharges into the environment from nuclear power reactors and reprocessing plants in normal operation,” Official Journal of the European Union, February 2004.

7-32 006N7899, “BWRX-300 Offgas System,” Rev 1, GE-Hitachi Nuclear Energy, Americas, LLC, August 2023.

7-33 006N7782, “BWRX-300 Heating, Vent & Cooling System, HVS,” (U41), Rev 2, GE-Hitachi Nuclear Energy, Americas, LLC, December 2022.

7-34 006N7948, “BWRX-300 Containment Inerting System,” Rev 1, GE-Hitachi Nuclear Energy, Americas, LLC, August 2023.

7-35 006N7717, “BWRX-300 Main Turbine Equipment,” Rev 1, GE-Hitachi Nuclear Energy, Americas, LLC, May 2023.

7-36 006N6528, “BWRX-300 K30 Offgas System,” (P&ID) Rev 2, GE-Hitachi Nuclear Energy, Americas, LLC, May 2024.

7-37 006N7757, “BWRX-300 Main Condenser and Auxiliaries System,” Rev 2, GE-Hitachi Nuclear Energy, Americas, LLC, February 2024.

7-38 ASME AG-1-2019, “Code on Nuclear Air and Gas Treatment,” The American Society of Mechanical Engineers, Section FC, HEPA Filters, 2019.

7-39 005N9751, “BWRX-300 General Description,” Rev F, GE-Hitachi Nuclear Energy, Americas, LLC, December 2023.

7-40 006N7828, "BWRX-300 Nuclear Boiler System," Rev 2, GE-Hitachi Nuclear Energy, Americas, LLC, September 2023.

7-41 006N7823, "BWRX-300 Primary Containment System," Rev 2, GE-Hitachi Nuclear Energy, Americas, LLC, March 2024.

7-42 006N6766, "BWRX-300 Water Quality," Rev 4, GE-Hitachi Nuclear Energy, Americas, LLC, March 2024.

7-43 DBR-0060900, "BWRX-300 Zero Release Plan," Rev 2, GE-Hitachi Nuclear Energy, Americas, LLC, September 2023.

7-44 NEDC-34279P, "BWRX-300 UK GDA Analysis of Environmental Discharge Data for U.S. Nuclear Power Plants," Rev A, GE-Hitachi Nuclear Energy, Americas, LLC.

7-45 006N7729, "BWRX-300 Liquid Waste Management System (LWM)," Rev 1, GE-Hitachi Nuclear Energy, Americas, LLC, March 2023.

7-46 006N7673, "GEH BWRX-300 Water Balance," Rev B, GE-Hitachi Nuclear Energy, Americas, LLC, October 2022.

7-47 006N7762, "BWRX-300 Circulating Water System" (P&ID), Rev 1, GE-Hitachi Nuclear Energy, Americas, LLC, October 2022.

7-48 005N4258, "BWRX-300 Coolant Radiation Concentrations," Rev 2, GE-Hitachi Nuclear Energy, Americas, LLC, April 2023.

7-49 WN0908-HZCON-PAC-REP-00003, "Wylfa Newydd Project Radioactive Substances Regulation – Environmental Permit Application," Horizon Nuclear Power, 2017.

7-50 NEDO-33970, "Darlington New Nuclear Project, BWRX-300 Preliminary Safety Analysis Report Ch. 20: Environmental Aspects," Rev 1, Ontario Power Generation Inc., October 2022.

7-51 SMR0004486, "Environment, Safety, Security and Safeguards Case Version 2, Tier 1, Ch. 29: Quantification of Radioactive Effluent Discharges and Proposed Limits," Rolls-Royce SMR Ltd, Issue 3, 2024.

APPENDIX A RADIOACTIVE DISCHARGES FORWARD ACTION PLAN

Table A-1: Radioactive Discharges Forward Action Plan

Action ID	Source	Finding	Forward Actions	Lead Discipline	Delivery Phase
PER5-110	Radioactive Discharges – AOO (Section 7.2.4.4)	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 Pre-Construction Safety Report (PCSR) / Pre-Construction Environmental Report (PCER).
PER7-193	Radioactive Discharges – EUST (Section 7.2.5)	The current BWRX-300 EUST listed radionuclides for gaseous and aqueous liquid discharges do not exactly match those in the 2004/2 Euratom recommendation.[1]	Refine BWRX-300 EUST for gaseous and aqueous liquid radioactive discharges so that it includes radionuclides listed in the 2004/2 Euratom recommendation.	Environment – Radioactive Discharges	For PCSR/PCER.
PER7-194	Radioactive Discharges – additional sources (Section 7.3 and 7.4)	Any sources of gaseous or aqueous liquid radioactive discharge introduced outside of the nuclear island need to be included in future discharge assessments.	If any additional sources of gaseous or aqueous liquid radioactive discharge outside of the nuclear island are introduced into the design (e.g., spent fuel store) then these need to be included in future discharge assessments.	Environment – Radioactive Discharges	For PCSR/PCER.

Action ID	Source	Finding	Forward Actions	Lead Discipline	Delivery Phase
PER7-195	Radioactive Discharges – operational requirements (Section 7.4.2, 7.5.1, 7.6.2.2, and 7.6.3.2)	The BWRX-300 plant owner/operator will need to determine the operational requirements for aqueous liquid discharges at site specific stage. This will allow final radioactive discharge assessments, including discharge limits, to be made to support an environmental permit application.	Future owner/operator to specify aqueous liquid discharges.	Environment – Radioactive Discharges	For Site License Application
PER7-196	Radioactive Discharges – EUST (Section 7.5.1.1, 7.6.1.1, 7.6.2.2, 7.6.3.1, and 7.6.3.2	The lack of refined EUST means that the discharge assessments at Step 2 are conservative.[1]	Refine the PST and EUST data to allow less conservative and more realistic updated radioactive discharge assessments to be produced.	Chemistry	For PCSR/PCER.
PER7-197	Radioactive Discharges – headroom factors (Section 7.5.1.1)	Due to the current conservative nature of the BWRX-300 EUST for radioactive discharges, headroom factors have not been applied. Headroom factors will need to be applied once refined EUST for BWRX-300 radioactive discharges have been determined.[1]	Once refined EUST for the BWRX-300 have been produced, justifiable headroom factors must be produced. This will allow an updated radioactive discharge assessment to be produced.	Environment – Radioactive Discharges	For PCSR/PCER.

Action ID	Source	Finding	Forward Actions	Lead Discipline	Delivery Phase
PER7-198	Radioactive Discharges – monthly discharge assessments (Section 7.5.1.2)	Due to the current conservative nature of the BWRX-300 EUST for radioactive discharges and the AOO fault analysis for environmental impact requiring further assessment, monthly and rolling monthly discharge assessments have not been applied. Monthly and rolling monthly discharge assessments will need to be applied once refined EUST for radioactive discharges and AOO fault analysis for BWRX-300 have been determined.[1]	Once refined EUST and AOO fault analysis for the BWRX-300 have been provided, monthly and rolling monthly discharge assessments must be produced. This will allow an updated radioactive discharge assessment to be produced.	Environment – Radioactive Discharges	For PCSR/PCER.

Note:

[1] A wider action relating to source terms has also been identified in **PSR23-133**, originating from NEDC-34195P, PSR Ch. 23 (Reference 7-9).

APPENDIX B ANNUAL GASEOUS ACTIVITY CONTRIBUTION BY ROUTE

Table B-1 is taken from 007N1078, “Annual Average Gaseous Effluent Releases for the BWRX-300 Standard Plant” (Reference 7-25). This is for normal operations and includes AOOs, as also described in 007N1078 (Reference 7-25). Cells marked with – represent no release.

Table B-1: Annual Gaseous Activity Contribution by Route

Nuclide	Release Route of Gaseous Discharge/Activity in MBq/y							
	RB	PLSA	TB	RWB	Mechanical Vacuum Pump	TGSS	OGS	Containment
Kr-83m	-	-	-	-	-	3.30E+05	4.80E-07	3.10E+02
Kr-85m	8.90E+02	2.60E+03	2.20E+04	-	-	8.90E+03	7.80E+00	2.10E+01
Kr-85	-	-	-	-	-	2.20E+03	2.20E+06	3.00E+02
Kr-87	-	1.80E+03	5.20E+04	-	-	6.30E+04	2.70E-14	4.10E+01
Kr-88	8.90E+02	2.60E+03	8.10E+04	-	-	3.40E+04	9.60E-03	5.20E+01
Kr-89	-	1.80E+03	5.20E+05	2.60E+04	-	1.20E+07	-	3.20E+02
Xe-131m	-	-	-	-	-	1.90E+03	3.60E+04	1.60E+02
Xe-133m	-	-	-	-	-	1.10E+03	6.70E-04	3.00E+01
Xe-133	2.40E+04	7.40E+04	1.30E+05	1.90E+05	1.10E+06	1.70E+04	2.40E+03	9.60E+02
Xe-135m	1.30E+04	4.10E+04	3.50E+05	4.80E+05	-	3.00E+05	-	4.10E+01
Xe-135	2.90E+04	8.10E+04	2.90E+05	2.50E+05	4.40E+05	1.70E+05	1.70E-45	8.10E+02
Xe-137	4.10E+04	1.20E+05	8.90E+05	7.40E+04	-	5.60E+05	-	1.90E+01
Xe-138	1.80E+03	5.20E+03	8.90E+05	1.80E+03	-	1.60E+06	-	1.90E+02
I-131	7.00E+00	3.60E+01	2.50E+02	1.60E+01	8.90E+01	2.20E+00	-	1.30E+02
I-132	7.00E+01	3.60E+02	2.50E+03	1.60E+02	-	-	-	2.10E+01
I-133	5.20E+01	2.70E+02	1.90E+03	1.10E+02	-	4.40E+00	-	1.40E+02
I-134	2.00E+02	1.00E+03	7.00E+03	4.40E+02	-	-	-	2.30E+01

Nuclide	Release Route of Gaseous Discharge/Activity in MBq/y							
	RB	PLSA	TB	RWB	Mechanical Vacuum Pump	TGSS	OGS	Containment
I-135	1.10E+02	5.60E+02	3.70E+03	2.30E+02	-	-	-	8.90E+01
H-3	4.80E+05	-	4.80E+05	-	-	-	-	-
C-14	-	-	-	-	-	-	4.10E+05	-
Na-24	-	-	-	-	-	-	-	1.40E+00
P-32	-	-	-	-	-	-	-	7.00E-01
Ar-41	-	-	-	-	-	-	3.30E+02	-
Cr-51	4.40E-04	2.00E-03	2.00E-03	1.60E-03	-	-	-	2.00E+01
Mn-54	8.90E-04	2.30E-03	1.30E-03	8.90E-03	-	-	-	1.10E+01
Mn-56	-	-	-	-	-	-	-	4.40E-01
Fe-55	-	-	-	-	-	-	-	2.40E+01
Fe-59	2.00E-04	6.70E-04	2.30E-04	6.70E-04	-	-	-	5.90E+00
Co-58	2.30E-04	4.40E-04	2.30E-03	4.40E-04	-	-	-	5.20E+00
Co-60	2.30E-03	8.90E-03	2.30E-03	1.60E-02	-	-	-	1.10E+01
Ni-63	-	-	-	-	-	-	-	2.40E-02
Cu-64	-	-	-	-	-	-	-	5.90E+00
Zn-65	2.30E-03	8.90E-03	1.30E-02	6.70E-04	-	-	-	4.80E+00
Rb-89	-	-	-	-	-	-	-	4.40E-02
Sr-89	6.70E-05	4.40E-05	1.30E-02	-	-	-	-	6.70E-02
Sr-90	6.70E-06	1.60E-05	4.40E-05	-	-	-	-	3.60E-03
Y-90	-	-	-	-	-	-	-	8.90E-04
Sr-91	-	-	-	-	-	-	-	1.70E+00

Nuclide	Release Route of Gaseous Discharge/Activity in MBq/y							
	RB	PLSA	TB	RWB	Mechanical Vacuum Pump	TGSS	OGS	Containment
Sr-92	-	-	-	-	-	-	-	1.00E+00
Y-91	-	-	-	-	-	-	-	8.90E-01
Y-92	-	-	-	-	-	-	-	4.10E-01
Y-93	-	-	-	-	-	-	-	1.30E-01
Zr-95	6.70E-04	1.60E-03	8.90E-05	1.80E-03	-	-	-	1.90E+00
Nb-95	2.30E-03	2.00E-02	1.30E-05	8.90E-06	-	-	-	1.80E+00
Mo-99	1.30E-02	1.30E-01	4.40E-02	6.70E-06	-	-	-	2.40E+00
Tc-99m	-	-	-	-	-	-	-	2.30E-01
Ru-103	4.40E-04	8.90E-03	1.10E-03	2.30E-06	-	-	-	4.40E-01
Rh-103m	-	-	-	-	-	-	-	1.90E-03
Ru-106	-	-	-	-	-	-	-	7.40E-02
Rh-106	-	-	-	-	-	-	-	1.00E-02
Ag-110m	-	-	-	-	-	-	-	2.40E-02
Sb-124	4.40E-05	6.70E-05	2.30E-04	1.60E-04	-	-	-	-
Te-129m	-	-	-	-	-	-	-	8.50E-01
Te-131m	-	-	-	-	-	-	-	1.50E-01
Te-132	-	-	-	-	-	-	-	6.70E-02
Cs-134	1.60E-03	8.90E-03	4.40E-04	5.60E-03	-	-	-	6.30E-01
Cs-136	2.30E-04	8.90E-04	2.30E-04	-	-	-	-	3.70E-01
Cs-137	2.30E-03	1.10E-02	2.30E-03	8.90E-03	-	-	-	1.00E+00
Cs-138	-	-	-	-	-	-	-	1.10E-01

Nuclide	Release Route of Gaseous Discharge/Activity in MBq/y							
	RB	PLSA	TB	RWB	Mechanical Vacuum Pump	TGSS	OGS	Containment
Ba-140	4.40E-03	4.40E-02	2.30E-02	8.90E-06	-	-	-	7.00E+00
La-140	-	-	-	-	-	-	-	1.60E+00
Ce-141	4.40E-04	1.60E-03	2.30E-02	1.60E-05	-	-	-	4.40E-01
Ce-144	-	-	-	-	-	-	-	7.40E-02
Pr-144	-	-	-	-	-	-	-	8.50E-05
W-187	-	-	-	-	-	-	-	5.20E-01
Np-239	-	-	-	-	-	-	-	1.80E+00