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Content

1. Introduction

This document provides the methodology and results of the updated annual authorised discharge quantities (AADQs) for liquid and gaseous discharges for KNPS.

The methodology follows the guidance provided for in IAEA Tecdoc 1638 [6] and IAEA GSG-9 [5], and complies with the requirements of SSRP R388 [2], RD-0022 [3] and IAEA GSR Part 3 [14].

The requirements of [14], Section 3.123 follows: *The regulatory body shall establish or approve operational limits and conditions relating to public exposure, including authorized limits for discharges. These operational limits and conditions:*

(a) Shall be used by registrants and licensees as the criteria for demonstration of compliance after the commencement of operation of a source;
(b) Shall correspond to doses below the dose limits with account taken of the results of optimisation of protection and safety;
(c) Shall reflect good practice in the operation of similar facilities or activities;
(d) Shall allow for operational flexibility;
(e) Shall take into account the results of the prospective assessment for radiological environmental impacts that is undertaken in accordance with requirements of the regulatory body (see paras 3.9(e) and 3.15(d)).

Section 3.123 (e) above requires consideration of the prospective assessment means that the public impact shall be considered. Additionally the impacts on non-human biota have also been addressed.

More specifically, the updated AADQs in this document ensures:

- That the public exposure is less than the dose limit of 1 mSv/y and dose constraint of 0,25 mSv/y and is as-low-as reasonably achievable (ALARA);
- That the environment is protected;
- That the reference level for the minimisation of discharges and as an indicator of plant performance.

To ensure that the updated AADQs are appropriately optimised, best expected performance has been established considering more recent historical performance, good practice, and optimisation studies. Headroom to allow for operational flexibility for plant occurrences was added to the best expected performance results to establish the updated AADQ.

The updated AMM results were also considered when establishing the discharge levels and to ensure flexibility with expected occurrences such as fuel leaks.

Section 4.5.2.2 of the SSRP R388 [2] specify the dose constraint:

'For members of the public, the dose constraint applicable to the average member of the critical group within the exposed population is 0,25 mSv per year specific to the authorised action unless otherwise agreed by the Regulator on a case-by-case basis, considering the dose limit specified in Annexure 2 for exposure of members of the public from all sources.'

The NNR requirements document on radiation dose limitation at KNPS (RD-022 [3]) has a dose limit specified as '*the individual dose <u>limit</u> applicable to Koeberg Nuclear Power Station for the average representative of the critical group is 250 μSv/y.*

The updated AADQs ensure that the dose constraint in the SSRP R388 [2] and RD-0022 [3] is met. Holders of nuclear authorisations must demonstrate compliance with a dose constraint and must ensure that exposures are kept ALARA. Compliance is achieved by setting AADQs for normal operations that comply with the dose constraint and ensure ALARA.

The information in Table 5-1 shows that the updated AADQs were derived to demonstrate acceptability of the levels of public exposure at airborne and liquid discharges. The combined public dose from liquid and gaseous updated AADQs and updated DCFs using PC-CREAM code is 19,4 μSv/y assuming that important radionuclides will be at 100% of the group AADQ but for less active radionuclides a maximum % of the group AADQ is estimated. The maximum % of each group is mainly based on historical data and the updated Activity Migration Model where historical data is not available.

The dose constraint value reflects the upper bound optimisation level as part of applying the ALARA principle and the AADQs must be periodically reviewed and consider operating experience [5]. Nuclear power installations of EDF (Électricité de France), for example, derive AADQs based on operational experience together with site specific environmental dispersion, radio-ecological models, and exposure pathways [6]. The methodology used to update the KNPS AADQs demonstrates sufficient margin to ensure that other potential future nuclear installation and sources of radioactive discharges meet the Duynefontyn Site dose constraint. In addition to this, the development of the updated AADQs also considered Periodic Safety Review (PSR) findings (discussed in Section 3).

2. Supporting Clauses

2.1 Scope

The focus of the report is to describe a methodology to revise the KNPS AADQs and the associated results. The report also addresses changes required when estimating releases in the gaseous pathway for iodines and tritium to reduce unnecessary over conservatism.

The methodology for the AADQ update considers KNPS operating experience, historical annual discharge data and international developments in respect of AADQs. The methodology provides for AADQ groups and largely replaces AADQs for individual radionuclides for regulatory control of discharges (albeit some individual radionuclide AADQs will be retained). This approach avoids a situation where a temporary spike in a specific radionuclide discharge concentration may be experienced while a large margin still exists in respect of the dose constraint and regulatory dose limit.

This document discusses the establishment of updated AADQs and the associated environmental reporting levels (with corresponding LLDs for the analysis of environmental samples) and the revised list of principal radionuclides. It does not address the establishment of KRT set points as these will be aligned to the updated AMM [17] and not the updated AADQs.

The LLDs in [11] related to analysis of effluent are not set from any AADQs but the list of radionuclides that require LLDs may need to change since the list of principal radionuclides has now changed. This document discusses the need to change the list of radionuclides that the LLDs applies.

2.1.1 Purpose

This document describes the methodology used to update the current KNPS AADQs and the associated results in terms of liquid and airborne discharges during normal operation of KNPS. The current methodology to estimate liquid discharges and gaseous particulates and noble gases is still appropriate.

The original methodology used to derive the current KNPS AADQs is outdated and not aligned to international practice in many respects. AADQs should be periodically reviewed at least every 10 years to ensure the following [5]:

- AADQs should be reviewed to consider operating experience;
- All significant radionuclides should be considered including C-14;
- Any changes in the discharge source terms, exposure pathways or in the characteristics of the representative person that could affect the assessment of doses due to the discharges need to be considered; and
- The methodology should consider the latest safety guide of the International Atomic Energy Agency (IAEA) on regulatory control of radioactive discharges to the environment [5].

In addition, the updated DCFs [10] that have been developed require a review of the AADQs.

2.1.2 Applicability

This document shall apply to the Nuclear Operating Unit.

2.1.3 Effective date

The document will become effective from the date of authorisation.

2.2 Normative/Informative References

Parties using this document shall apply the most recent edition of the documents listed in the following paragraphs.

2.2.1 Normative

[1] ISO 9001, Quality Management Systems

[2] Department of Minerals and Energy, R.388, Regulations in Terms of Section 36, Read with Section 47 of the National Nuclear Regulator Act, 1999 (Act No. 47 of 1999), on Safety Standards and Regulatory Practices.

[3] RD-0022, National Nuclear Regulator (NNR) Requirements Document, Radiation Dose Limitation at the Koeberg Nuclear Power Station.

2.2.2 Informative

[4] Koeberg Safety Analysis Report, Part III, Chapter 4.1, Revision 5

[5] International Atomic Energy Agency (2018), Regulatory Control of Radioactive Discharges to the Environment. General Safety Guide No. GSG-9.

[6] International Atomic Energy Agency (2010), Setting Authorised Limits for Radioactive Discharges: Practical Issues to Consider Report for Discussion, TecDoc 1638.

[7] Eskom Standard Nuclear Operating Unique Identifier 32-21, Framework on the Public Dose Assessment Methodology for Normal Discharges at Koeberg Nuclear Power Station.

[8] Activity Migration Model SAR.xls, (2003) Koeberg Nuclear Power Station, Eskom.

[9] Eskom KNPS Report SGR/1274/16, Assessment of Radioactivity Concentrations in Reactor Coolant System following Steam Generator Replacement and the associated effects thereof.

[10] NSIP04129, A revised methodology to assess the ionising radiation dose for members of the public from normal operation at the Duynfontyn site.

[11] 238-49, Rev 1, Eskom, Liquid and Gaseous Effluent Management Requirements for KNPS.

[12] United Kingdom Environment Agency (2013), Environmental Permitting (England and Wales) Regulations 2010, Application by NNB Generation Company Ltd (NNB Gen Co) to carry on radioactive substance activities at Hinkley Point C Power Station. EPR/ZP 3690SY/A001.

[13] 238-47, Rev 1, Eskom, Radiological Environmental Surveillance Requirements.

[14] International Atomic Energy Agency (2014), IAEA Safety Standards Series No. General Safety Requirements GSR Part 3

[15] 2004/2/Euratom, Euratom (2004), Standardised information on radioactive airborne and liquid discharges into the environment from nuclear power reactors and reprocessing plants in normal operation

[16] International Atomic Energy Agency (2018), Safety Glossary

[17] Updated Activity Migration Model (2022)

[18] SAR II-5.2.3.6 Rev 5b, Leakage from the secondary circuit

[19] Site Safety Report: Potential Radiological Impact on the Public and the Environment, Rev 2

[20] United States Nuclear Regulatory Commission, NUREG 1301 (1991), Off-site Dose Calculation Manual Guidance: Standard Radiological Effluent Controls for Pressurized Water Reactors

[21] United Kingdom European Pressurised Water Reactor (2011), Radioactive Substances Regulation Environmental Permit Application

[22] EDF (2019), Nuclear and the Environment

[23] United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) (2008), Report Volume I: Sources Report to the General Assembly Scientific Annexes A and B

[24] International Commission of Radiation Protected (ICRP) Publication 108 (2008): Environmental Protection: The concept and use of reference plants and animals

[25] NSIP 01351 Rev 2 (2020), Nuclear Siting Studies Glossary of Definitions, Terms and Abbreviations

[26] RG-0011 Rev 0, Interim Guidance for the Siting of Nuclear Facilities

2.3 Definitions

2.3.1 Annual Authorised Discharge Quantities: These are releases from an authorised action, e.g. the Koeberg Nuclear Power Station (KNPS), into the environment, as a legitimate practice, within limits authorised by the National Nuclear Regulator, of liquid and gaseous radioactive materials (adapted from [6]).

2.3.2 Discharge: A discharge is a planned and controlled release of gaseous, aerosol or liquid radioactive substances to the environment [2]. As such, the term does not include releases to the environment in an accident.

2.3.3 Dose Conversion Factor: The term dose conversion factor used in this document is the public dose per unit activity discharged from KNPS.

2.3.4 Site Safety Report: The SSR defines the characteristics of the site and, its environs and assesses the magnitude and probability of occurrence of external events and hazards associated with the site (both human induced and natural), which must be considered in the design and operation of the nuclear installation(s). In addition the SSR also assesses the suitability of a site from a security perspective, risks to public exposure, physical characteristics that could pose a significant impediment to the development of the emergency plan and the feasibility of developing and implementing the emergency plan. The SSR provides baseline data, proposes the implementation of monitoring programmes prior to construction and operation and ensures the ongoing durability of the site specific design parameters. Furthermore, the SSRs also provide the preliminary technical basis for the site characteristics chapter of the safety analysis report (SAR) used for the construction and operation of nuclear installations [25].

2.3.5 Headroom (as it relates to discharges): A measure of operational flexibility is required to deal with an upset condition that will not result in exceeding AADQ limits. The flexibility is provided by including headroom in respect of discharges.

2.3.6 Normal Operation: Normal operation includes all conditions which are expected to occur during the lifetime of the nuclear installation including hypothetical events with expected mean frequencies of greater than 0,01 per annum [3].

2.3.7 Optimisation: The process of determining what level of protection and safety would result in the magnitude of individual doses, the number of individuals (workers and members of the public) subject to exposure and the likelihood of exposure being As Low as Reasonably Achievable (ALARA), economic and social factors being taken into account [16].

2.3.8 Principal Radionuclide: Any radionuclide contributes a significant dose to the representative person or contributes a significant amount of activity to the release.

2.3.9 Reference Animal or Plant: A hypothetical entity, with the assumed basic biological characteristics of a particular type of animal or plant, as described to the generality of the taxonomic level of family, with defined anatomical, physiological, and life history properties, that can be used for the purposes of relating exposure to dose, and dose to effects, for that type of living organism [24].

2.3.10 Representative Person: An individual receiving a dose that is representative of the more highly exposed individuals in the population [16]. This term is the equivalent of, and replaces the term, '*average member of the critical group*'.

2.3.11 Source Term: The amount and radionuclide composition of radioactive material discharged from KNPS during normal operations and used in modelling the dispersion of discharges in the environment. It is equivalent to discharge in the context of this document.

2.4 Abbreviations

Abbreviation	Explanation
AADQ	Annual Authorised Discharge Quantity
ALARA	As Low as Reasonably Achievable
AMM	Activity Migration Model
AMM-BE	AMM – Best estimate model
AMM-LTO	AMM – LTO model
BEP	Best Expected Performance
Bq	Becquerel
CAP	Condenser Make-up System
CEX	Condenser extraction system
CVI	Condenser vacuum system
DCF	Dose Conversion Factor
SSR	Site Safety Report
DVN	Nuclear auxiliary building ventilation system (KNPS)
FP+AP	Fission and Activation Product
EDF	Électricité de France
EPR	European Pressurised Water Reactor
ERL	Environmental Reporting Level
GCT	Turbine Bypass System
GSR	General Safety Requirements
GWe	Gigawatt electrical
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
IRP	Interim Representative Person
IRSN	L'Institut de Radioprotection et de Sûreté Nucléaire
KER	Monitoring and discharge of nuclear island liquid radwaste (KNPS)
KNPS	Koeberg Nuclear Power Station
KRT	Plant radiation monitoring system
LLD	Lowest Level of Detection
LTO	Long Term Operation
NG	Noble gases
NNR	National Nuclear Regulator
Nuclide	Radionuclide
OE	Operating Experience
PSR	Periodic Safety Review
RCP	Reactor coolant system
REPAP	Representative Animal or Plant
RRI	Component cooling system
SFP	Spent fuel pool
SG	Steam generator

Abbreviation	Explanation
SSRP	Safety Standards and Regulatory Practices
Sv	Sievert
TEG	Gaseous waste treatment system (KNPS)
TEP	Boron recycle system
TEU	Liquid waste treatment system
TISF	Transient Interim Storage Facility (for spent nuclear fuel)
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation

2.5 Roles and Responsibilities

Nuclear Engineering is responsible for establishing the updated AADQs and the implementation of these updated AADQs is described in the effluent standard [11].

2.6 Process for Monitoring

Nuclear Engineering is required to maintain the updated AADQs and ensure they are incorporated into the business.

2.7 Related/Supporting Documents

None.

3. Process in determining AADQs

The process involved in setting updated AADQs is illustrated in Figure 3-1 and is aligned to the process from the IAEA [6]. As indicated in [6] the first stage is the characterisation of the discharge and establishing the dose pathways. An assessment of the radioactive discharges to the environment has been performed using the PC-CREAM code and the discharges have been characterised and documented in [10] and it considers:

- Nuclear power generation and any other activities that result in radioactive discharges;
- The radionuclide composition of discharges;
- The chemical and physical form of the radionuclides that influence the behaviour of radionuclides in the environment;
- The routes and the location of discharge points, including discharge characteristics, for example in the case of airborne discharges the stack height, exit velocity, exit temperature, maximum and average discharge rates;
- The total amount of various radionuclides expected to be discharged in one year; and
- The expected time pattern of discharges, including the need for and likelihood of enhanced short-term discharges, for example during refuelling outages.

An understanding of the atmospheric and liquid dispersion characteristics for the Duynefontyn site of each radionuclide species and the associated exposure pathways are essential for determining updated AADQs. Note that in Figure 3-1, testing the dose assessment results against the dose constraint, is followed by a test against the ALARA principle of optimisation. The updated AADQ has been established taking ALARA into account and also compared to the dose constraint. The dose constraint of 250 µSv/y serves as an upper bound and optimisation and thus it is expected that the updated AADQs would be below the dose constraint if aligned to good practice.

The estimation of the source term for the updated AADQs and the dose assessment results is described in Section 3.1 below and the final phase of the process in Figure 3-1 which related to optimisation is described in Section 3.2. A summary of the approach to establish the updated AADQ source term is described in Section 3.3.

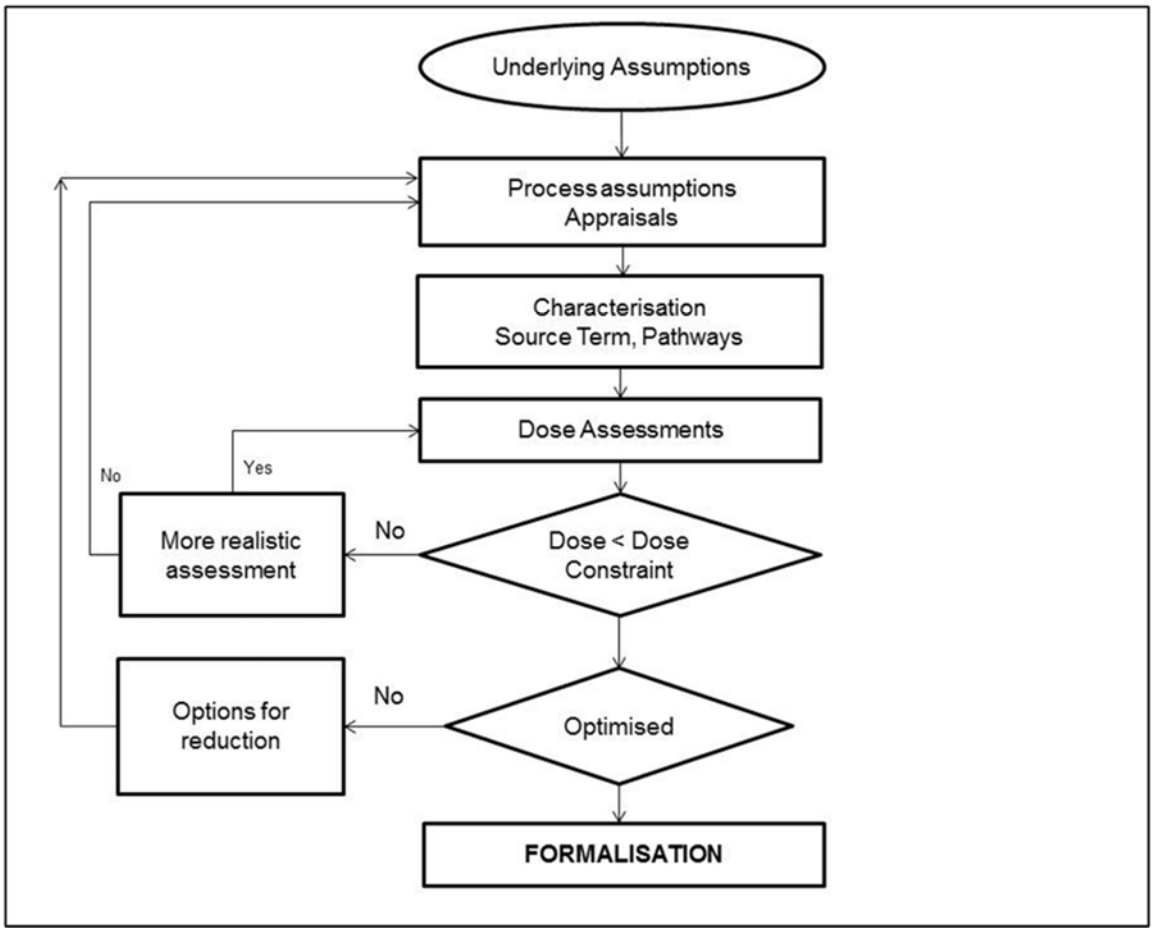

Figure 3-1: Process for Derivation of updated AADQs

3.1 Process assumptions to estimate updated AADQ source term

Given that KNPS has been in operation for several decades the main input in setting the updated AADQs is based on the plant specific operating experience (OE).

For liquid discharges a significant change occurred in effluent processing capability since the TEU evaporator set-point change was implemented in 2014 so recent performance (since 2015) represents best expected performance.

The PSR highlighted some possible improvements (deviation 14A-03-D1 and 14A-03-D2) but these improvements if adopted will only be implemented in the future. The deviations relate to design or operating practice limitations associated with the lack of use of the TEG charcoal delay beds, segregation of highly active effluent in TEP, lack of chemical drains in RRI, TEU evaporator performance and design and lastly the inappropriate testing of iodine filters.

The updated AADQs will not take any improvements that may follow into account, but it is recommended that the updated AADQs are reviewed as soon as sufficient data is available to quantify the change after some of the improvements are implemented.

The plant specific OE is complemented with the use of international plant OE [21][22], where relevant to highlight good practice that may be relevant at KNPS and to ensure that the updated AADQs are optimised.

Given that the updated AADQs need to be optimised, a review of the current practice has been performed and compared to benchmarks [21][22] to ensure that good practice in effluent reduction is being practised. More recent OE reflects current practice but more recent data needs to be augmented with a bigger data set when establishing head room. The key assumption is that more recent KNPS data reflects the best expected performance but models and historical operating data since 1984 is required to establish headroom.

The process boundaries or assumptions for the update of the AADQs have been established as follows:

- The updated AADQs will be derived using realistic data. The gaseous tritium and iodine releases have been overestimated at KNPS historically and hence the historical data has been adjusted to derive the updated AADQs. More realistic estimation of these discharges will be introduced before the updated AADQs are adopted.

Annual discharges from KNPS if released at the current AADQ limits [11] and current DCFs [11] deliver an estimated dose of 226 μSv/y to the critical group, a dose almost equal to the KNPS dose limit of 250 μSv/y [2]. The current Dose Conversion Factors (DCFs) together with the current AADQs does not allow sufficient margin between the estimated dose and the dose constraint. The methodology to update the KNPS AADQs creates the necessary margin by using a reference dose for the derivation of updated AADQs that is significantly lower than the NNR dose limit for KNPS and provides a method to establish updated AADQs as radionuclide groups.

The NNR has established the dose constraint at 250 μSv/y which is in line with the international approach to setting a dose constraint that is below the dose limit and higher than a dose of the order of 10 μSv/y [6].

As defined in [2], a dose constraint should be used in planning measures for radiation safety and should not be used as an alternative dose limit to be applied during plant operation. More specifically, exceeding a dose constraint should not represent a regulatory infraction, as would be the case if the site dose limit were to be exceeded.

It is assumed that a new nuclear power facility on the Duynefontyn site will have its own NNR licence but the dose from KNPS and the new plant combined would need to meet the dose constraint.

Apart from considering new nuclear power stations on the Duynefontyn site the only other developments that need to be considered when setting updated AADQs is long term operation (LTO). LTO operation involves changing the SGs which is discussed in Section 3.3. The City of Cape Town sea water reverse osmosis plant location and attributes are still not clear and will be ignored at this stage. The Transient Interim Storage Facility (TISF) will not have any gaseous or liquid discharges and will also be ignored.

3.2 ALARA, optimisation and operational flexibility

The principle of optimisation is used to keep the magnitude of individual doses, the number of people exposed, and the likelihood of potential exposure as low as reasonably achievable below the appropriate dose constraint, with economic and social factors being considered.

The application of the optimisation process depends on the operational status of the facility, the dose and risk to the public and the environment, regulatory requirements as well as balancing the safety considerations of the facility (e.g. minimising discharges may increase generation of solid waste versus the trade-off between reduced public and occupational exposure). For ongoing discharges, optimisation of public protection can be achieved by considering the configurations of the available technical options and associated procedures, based on operation experience, in an interactive manner with the regulator whereas protection and safety for new facilities can be optimized through the design [5]. There may be fewer options available to optimise protection and safety during operational and decommissioning stages. Ultimately, the protection and safety measures should provide the highest level of safety that can be achieved throughout the lifetime of the facility or activity without unduly limiting the operation of the facility or activity. The establishment of discharge limits for facilities and activities are aimed at optimisation of the protection of members of the public (i.e. to control the effective dose to the representative person with appropriate consideration given to the radiation protection of workers at the discharging facility).

Results of a representative person dose assessment are used to determine acceptable optimised discharge levels that meet the regulatory radiological criteria [2]. Dose calculation assumptions that are unrealistically conservative are likely to significantly overestimate the doses and could lead to decisions that do not meet the radiation protection principle of optimisation. As a result, more realistic activity estimation methods are used in conjunction with more realistic dose conversion factors.

The general approach to derive updated AADQs is illustrated in Figure 3-2 and shows that optimisation and operational flexibility are important aspects of setting updated AADQs.

It is important to differentiate between optimisation in respect of dose (ALARA) and optimisation beyond the requirements of ALARA, e.g. following best practice as discussed in a KNPS concept design document for liquid waste treatment [9]. The following statement is included in the [9]: '*The primary goal of the design is for the power station to achieve minimal activity releases in line with the top performing international nuclear power stations with a specific station liquid activity release goal of a total of 1E+08 Bq per unit per year*.'

The international reference dose of 10 μSv/y is an annual dose rate below which optimisation in respect of public dose is not recommended [5] from a regulatory perspective. As such a reference dose less than 10 μSv/y should not be used to derive updated AADQs.

The protection of the public and the environment is achieved if the relevant dose constraint is met, and radiological protection is optimised. In line with [5] for facilities already in operation and activities being conducted, the safety assessment should be periodically reviewed and updated at predefined intervals, in accordance with regulatory requirements, this is also done to consider possible changes in the assumptions used originally.

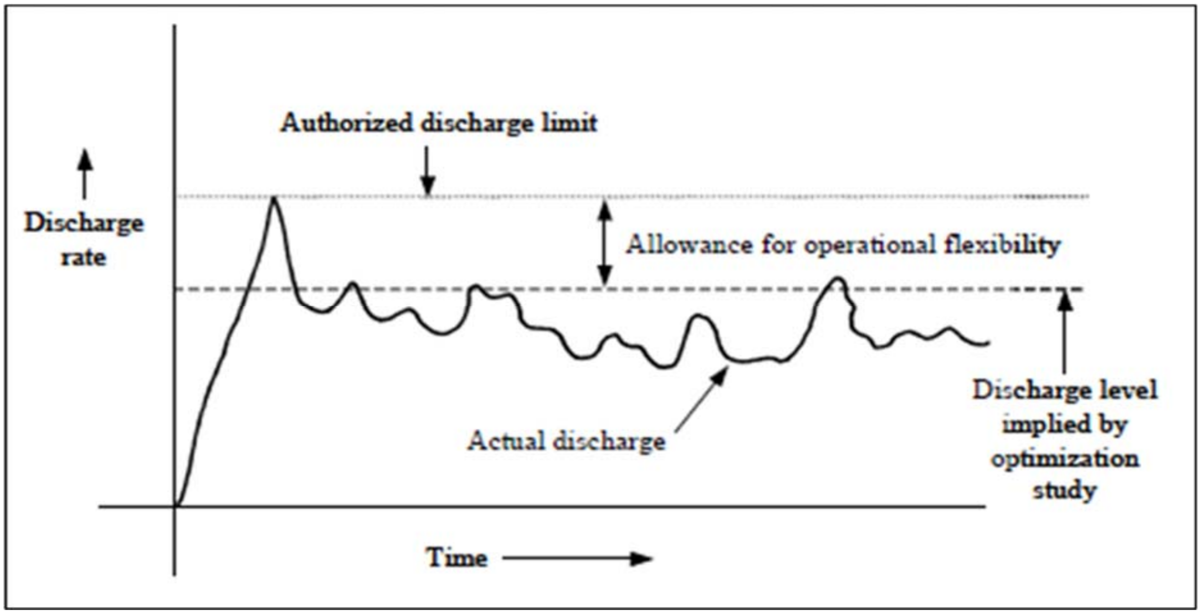

Figure 3-2: IAEA guidance on operational AADQs

3.3 Summary of the method for the updated AADQs

When developing the updated KNPS AADQs, the following characteristics for each group of radionuclides have been considered:

- Its contribution to public dose;
- The annual quantity of the radioactivity of the group discharged during more recent operation but ignoring outliers is used to establish best expected performance (BEP and shown as the '*discharge level implied by optimisation study*' in Figure 3-2);
- Using historical and international OE, and the updated AMM [17], the headroom (shown as '*allowance for operational flexibility*' in Figure 3-2) can be determined to ensure operational flexibility;
- The contribution of individual radionuclides to overall dose and activity to establish principal radionuclides. The impact of individual radionuclides on the environment taking radioactive half-life and environmental build-up into account which could flag the need to remove some radionuclides from the group and instead establish individual radionuclide updated AADQ to ensure special focus;
- Whether a radionuclide is a good indicator of the nuclear fuel and plant performance, as well as discharge control procedures, could be the reason to remove individual radionuclides from their respective groups; and

- Contribution to non-human biota dose.

To reduce the uncertainty with the setting of the AADQs, the process of establishing the AADQs are benchmarked against the updated AMM (best estimate), other nuclear plants operating experience, KNPS historical discharges and a consideration of good practise.

The main differences between the methods used to establish the current AADQs and the updated AADQs are the following:

- Measured historical discharges at KNPS are the main source of data to establish updated AADQs instead of the updated AMM predicted discharges [10] but the updated AMM (best estimate version of the model) [17] will be used to establish headroom as potentially not all scenarios have been considered in the historical data set and for benchmarking.
- The PC CREAM 08 code was used with the updated habitational data to derive the updated DCFs [10]. The more realistic IRP01 (child) DCFs from [10] were used to determine dose. Given that the updated AADQs need to demonstrate ALARA a more realistic DCFs were used and the use of realistic assumptions is recommended by [6].
- An update of the AADQs also considered the impact of the Steam Generator Replacement project. The thermal power uprates of the two KNPS reactor units was not considered since it is not an approved project. An Eskom study submitted and accepted by the NNR for SG replacement has shown that the new steam generators will result in lower activated cobalt products (Co-58 and Co-60) in the primary coolant in the longer term and no significant change to public dose is expected [9]. In the short term, an increase in Co-58 and Co-60 may occur in the liquid discharges but this is not expected to result in any noteworthy increase in the activity discharged given that the performance of the waste treatment systems is expected to increase given higher activity in the treatment influent. The large increase in primary circuit activity (about ten times increase of Co-58) when zinc injection commenced, demonstrates that a higher primary circuit activity does not necessarily translate into much higher discharges since the increase in discharge was not noticeable.
- C-14, Fe-55 and Ni-63 which are principal radionuclides that were not previously added are now included.

3.3.1 Public dose limit

The national public dose limit is an effective dose of 1 000 μSv in a year from all NNR authorised nuclear related activities in the country (nuclear, radiation and mining and mineral processing facilities).

4. AADQ and radionuclide groups

It is proposed that the updated AADQs be based on groups of radionuclides. This is an approach implemented internationally by numerous nuclear power installations and supported by the IAEA. The IAEA safety guide on AADQs includes the following statement [6]:

"…*for larger facilities, such as a nuclear power station, that may discharge a variety of nuclides, limits are generally imposed on groups of nuclides that share relevant characteristics, although limits may also be imposed on specific nuclides that are deemed to be of special significance. For example, airborne discharges for nuclear plants are often grouped as follows: noble gases, halogens or iodine isotopes, and particulates. This grouping reflects dosimetric considerations: noble gases result in external exposure to the whole body, iodine isotopes result in thyroid doses, and particulates usually present a potential inhalation or ingestion hazard to all the organs and tissues of the body. They also reflect different ways of sampling and quantifying the discharges*."

The radionuclides most frequently measured in effluent according to [15] and assigned to radionuclide groups are listed in Table 4-1. The table does not represent the complete spectrum of radionuclides to be considered for updating AADQs but is seen as the most important. As indicated in Table 4-1, [11] will need to be updated by adding C-14 (liquid and gaseous pathway) and Fe-55 and Ni-63 in the liquid release pathway. The list of principal radionuclides and their bases are discussed in Appendix K.

Table 4-1: Radionuclides included in Euratom [15]

Radionuclide	Liquid or Gas pathway	Half-life	Currently included in [11]	Mechanism and source of production of radionuclide (fission, activation, or corrosion product)	Comments
Ag-110m	Both	249,9 d	Yes	Corrosion product: Ag-109 is present in silver-containing seals and is activated to form Ag-110m. Corrosion results in its presence in the primary coolant.	
Am-241	Both	432, 2 y	No	Fission product	Gross alpha is performed which is adequate given low levels of alpha recorded
Ar-41	Gas	1,8 h	Yes	Activation: Ar-41 is formed during normal operation by activation of the natural content of Ar-40 in the air around the reactor pressure vessel by the neutron radiation, in the Reactor Building.	
Ba-140	Both	12,8 d	Yes	Fission product	
C-14	Both	5730 y	No	Activation product in the primary coolant.	Will be added to [11]
Ce-141	Both	32,5 d	Yes	Fission product	
Ce-144	Both	284,9 d	Yes	Fission product	
Cm-242	Both	162,8 d	No	Fission product	Gross alpha is performed which is adequate given low levels of alpha recorded
Cm-243	Both	29,1 y	No	Fission product	
Cm-244	Both	18,1 y	No	Fission product	
Co-58	Both	70,8 d	Yes	Activation of corrosion product in the primary coolant system.	

Radionuclide	Liquid or Gas pathway	Half-life	Currently included in [11]	Mechanism and source of production of radionuclide (fission, activation, or corrosion product)	Comments
Co-60	Both	5,3 y	Yes	Activation of corrosion product in the primary coolant system.	
Cr-51	Both	27,7 d	Yes	Activation of corrosion product in the primary coolant system.	
Cs-134	Both	2,06 y	Yes	Fission of uranium: Cs-134 is not a direct fission product but is created in the fuel by the activation of Cs-133 (which is a direct fission product). Fission products are usually present in the reactor cooling water. Despite a high standard of cleanliness, a trace of uranium always remains on fuel surfaces after the manufacturing process. Once the fuel is in the reactor, this “tramp” uranium will fission, producing fission products in the reactor cooling water. Another route for fission products to enter the reactor coolant system is because of fuel pin cladding leaks.	
Cs-137	Both	30 y	Yes	Fission of uranium.	
Fe-55	Liquid	2,7y	No	Corrosion product	Will be added to [11]
Fe-59	Both	45,1 d	Yes	Activation of corrosion product in the primary coolant system.	
H-3	Both	12,33 y	Yes	Activation.	
I-131	Both	8,04 d	Yes	Fission: Iodine isotopes are formed in the fuel by fission and can escape into the reactor coolant water via fuel defects. Also, like other fission products, small quantities are produced from uranium contamination on fuel surface (“tramp” uranium) within the reactor which can also be found in the primary coolant.	
I-132	Gas	2,3 h	Yes	Fission product	
I-133	Gas	20,8 h	Yes	Fission product	
I-135	Gas	6,61 h	Yes	Fission product	
Kr-85	Gas	10,72 y	Yes	Fission: Radioactive noble gases are formed by fission. They are usually confined in the fuel but, in the event of fuel leaks, they can pass into the primary coolant via defects in the fuel cladding. Their presence in the primary coolant is also due to the occurrence of traces of uranium (“tramp” uranium).	

Radionuclide	Liquid or Gas pathway	Half-life	Currently included in [11]	Mechanism and source of production of radionuclide (fission, activation, or corrosion product)	Comments
Kr-85m	Gas	4,48 h	Yes	As for Kr-85	
Kr-87	Gas	1,27 h	Yes	As for Kr-85.	
Kr-88	Gas	2,84 h	Yes	As for Kr-85.	
Kr-89	Gas	3,2 min	No	As for Kr-85	Will not be included in [11] due to low contribution (<0,1%) of noble gas activity and other noble gas limits will ensure that Kr-89 is also limited
La-140	Both	1,7 d	Yes	Fission Product	
Mn-54	Both	312,5 d	Yes	Activation of corrosion product in the primary coolant system.	
Ni-63	Liquid	100 y	No	Activation of corrosion product in the primary coolant system.	Will be added to [11]
Nb-95	Both	35,0 d	Yes	Corrosion product mainly from fuel cladding	
Pu-238	Both	87,7 y	No	Fission product	Gross alpha is performed which is adequate given low levels of alpha recorded
Pu-239	Both	24 000 y	No	Fission product	
Pu-240	Both	6 600 y	No	Fission product	
Ru 103	Liquid	39,3 d	Yes	Fission product	
Ru-106	Liquid	371,5 d	No	Fission product	Will not be included in [11] due to low contribution (<0,01%) of liquid activity (excl. H-3 / C-14) and < 0,01% of dose in liquid pathway. Other FP limits (e.g. Cs-137) will ensure that Ru-106 is also limited
Sb-122	Both	2,7 d	Yes	Activation of corrosion product in the primary coolant system.	
Sb-124	Both	60,2 d	Yes	Activation of corrosion product in the primary coolant system.	
Sb-125	Both	2,73 y	Yes	Activation of corrosion product in the primary coolant system.	
Sr-89	Both	50,5 d	Yes	Fission: Isotopes of strontium are formed because of fission. They are usually confined in the fuel but, in the event of	

Radionuclide	Liquid or Gas pathway	Half-life	Currently included in [11]	Mechanism and source of production of radionuclide (fission, activation, or corrosion product)	Comments
				fuel leaks, they can pass into the primary coolant via defects in the fuel cladding. Their presence in the primary coolant is also due to the occurrence of traces of uranium (“tramp” uranium).	
Sr-90	Both	29,2 y	Yes	See Sr-89.	
Te-123m	Liquid	119,2 d	Yes	Corrosion product.	
Xe-131m	Gas	11,9 d	Yes	As for Kr-85	
Xe-133	Gas	5,25 d	Yes	As for Kr-85.	
Xe-133m	Gas	2,19 d	Yes	As for Kr-85.	
Xe-135	Gas	9,09 h	Yes	As for Kr-85.	
Xe-135m	Gas	15,3 min	Yes	As for Kr-85	
Xe-137	Gas	3,8 min	No	As for Kr-85	Will not be included in [11] due to low contribution (<0,01%) of noble gas activity and < 0,001% of gaseous dose. Other noble gas limits will ensure that Kr-89 is also limited
Xe-138	Gas	14,2 m	Yes	As for Kr-85.	
Zn-65	Both	244 d	Yes	Mainly activation product from zinc injection to reduce primary activity	
Zr-95	Both	65 d	Yes	Corrosion product mainly from fuel cladding	
Total alpha	Both		Yes		

The first step in the process of establishing updated AADQs was to establish the AADQ groups and identify which radionuclides should be treated individually and not in groups. The individual radionuclides and group AADQ originally proposed for Koeberg were aligned to EDF namely:

Table 4-2: EDF AADQ groups

Gaseous	Liquid
Individual radionuclide limits	
Tritium	Tritium
C-14	C-14
Groups	
Noble gases	Iodines
Iodines	Others
Others	

One of the benefits of having the same groupings and individual radionuclide with separate limits as EDF is for benchmarking purposes and this is arguably the simplest approach, but it is acknowledged that there are important differences and reasons why a different approach is needed for KNPS. As a starting point alignment to EDF was proposed.

When deciding which radionuclides require specific limits or which groups need limits activity and dose are the main factors to consider [20] but in some countries such as the United Kingdom [12], radionuclide half-life and the value of the radionuclide as an indicator of plant performance is also considered. In the case of KNPS, there are no identified radionuclides that are important from half-life or an indicator of plant performance that requires a radionuclide specific updated AADQ that are not already identified as such.

The updated DCFs [10] have been developed and the best estimate IRP01 [10] DCFs of the two more realistic IRP01 and IRP02 were selected for use to determine the dose of each updated AADQ. A number of additional DCFs have been developed (e.g. C-14, Fe-55, Ni-63, Xe-127, and Xe-137) based on insights with international practice [15][21][22].

The proposed radionuclide specific updated AADQ groups are proposed as follows:

- Updated AADQ groups for airborne discharges:
  - Noble gases;
  - Tritium;
  - C-14;
  - Iodine isotopes; and
  - Other Fission and activation products.

Rb-88 is not a noble gas but will be included in the noble gas group AADQ which is aligned to EDF practice and also given:

- its activity is too high to be added to the Other (FP+AP) group;
- it is the daughter product of the short-lived noble gas Kr-88 which it is in equilibrium with;
- Rb-88’s behaviour being similar to a noble gas; and

- Rb-88 is not important enough ito dose and activity to have an individual radionuclide AADQ.

KNPS liquid discharges are grouped in a similar manner to airborne discharges except it excludes noble gases. Noble gases are only considered for airborne discharges.

- Updated AADQ groups for liquid discharges is proposed:
  - Tritium
  - C-14
  - Iodine isotopes
  - Fission and activation product particulates

The public dose assuming all radionuclides are discharged at 100% of the EDF AADQ groups AADQ activity has been conservatively determined. The public dose is 77,9 µSv/y for gaseous discharges and around 281,6 µSv/y for liquid discharges which is too high and overly conservative. In reality many radionuclides will only be at a very small fraction of the group AADQ when the limit is triggered by a more important radionuclide. As a result, historical data was used to determine the highest % of group activity in all years from 1984 to 2020. The maximum % of group activity was multiplied by the group AADQ to determine the maximum % of the group AADQ that is expected. Based on this approach, some radionuclides were allocated 100% of group AADQ whereas other a lot less. Where some radionuclides were not detected or measured historically, the updated best estimate AMM [17] was used to estimate the % of each radionuclide in the group and the scale this in the AADQ group. Also removing some important radionuclides with high activity from the group such as Ag-110m, Co-58, Co-60, etc. dropped the total liquid pathway dose from 281,6 µSv/y to 7,8 µSv/y and for the gaseous discharges this drops from 77,9 µSv/y to 11,6 µSv/y.

As discussed, apart from using the method above where it is argued that certain radionuclides will not exceed some % of the group AADQ, one can also reduce the dose by (1) removing one or more of the dominant radionuclides from the group and reduce group AADQ or (2) a combination of the two methods.

Candidates for single radionuclide updated AADQs in the context of the group above is discussed further below:

Tritium

- Given that tritium dominates the activity discharge both in the gaseous and liquid pathways it is argued that tritium should have its own limit both in the liquid and gaseous pathway. This is consistent with international practice.

Iodines

- I-131 dominates the dose of the gaseous iodine group so a case could be made to have I-131 as an individual radionuclide and not be part of an iodine group but the I-131 contribution to gaseous dose is around 7 µSv/y at 100% of the group AADQ but is expected to be significantly less than this normally. Given that BEP is 100 times lower it can be argued that there are merits in having I-131 as a separate radionuclide AADQ this is considered unnecessary. EDF does not have I-131 as an individual radionuclide.

Carbon-14

- C-14 should be treated as an individual radionuclide and not included in a group in the liquid and gaseous pathway in terms of its potentially significant contribution to activity and dose. This is in line with international practice.

Noble gases

- The noble gas group includes Ar, Xe and Kr isotopes but it is proposed that Rb-88 is included within this group. The activity of Rb-88 is relatively high and if added to the 'Other' group it will dominate the 'Other' group too much and require the 'other group' limit to be too large. It is proposed that Rb-88 is added to the noble gas group, also since Rb-88 is progeny of NGs and its half-life is relatively short like most noble gases. Rb-88's dose is relatively high at around 4 μSv/y, but the activity is expected to be less than 0,5% of the noble gas group so an individual radionuclide is not considered necessary.

Other radionuclides

- In the liquid pathway, if all radionuclides (apart from C-14 and H-3) are added to one large group ('Other') group and the activity of each is assumed to be at 100% of the group, the group's dose is unacceptably high (around 286 μSv/y). One could take credit for the fact that some radionuclides only occur as a small % of the overall group. For example the maximum % of the group historically for Ag-110m was 23%. Table 4-3 below shows the maximum % of the total activity (except H-3 and C-14).
- If one removes the higher activity radionuclides of Co-60, Co-58, Fe-55, Ni-63, Ag-110m, Cs-134 and Cs-137 from the group and introduces radionuclide specific AADQs as an alternative approach the group dose drops to 13,2 μSv/y. The approach of removing principal radionuclides from the group is preferred to the one above where the % group proportionality argument is used. While either approach is acceptable, removing some radionuclides is a more conservative approach and ensures a higher focus on the principal radionuclides especially since some are a good indicator of fuel or plant performance (Cs-134, Cs-137, Ag-110m, Co-58 and Co-60). Also, many of the radionuclides removed from the group contribute more than 1 μSv/y dose and are principal radionuclides (Ag-110m and Fe-55 contribute more than 1 μSv/y of dose).
- A combination of removing the high dose nuclides from the liquid 'Other' group above and then use the maximum percentage possible of the group of the remaining nuclides in the group will result in a drop from 13,2 to 7,8 μSv/y.
- In the gaseous pathway, there are no radionuclides apart from H-3, C-14, noble gases and Iodines that contribute significantly towards activity discharged (more than 1 TBq/y) and only C-14 contributes significantly towards dose (more than 1 μSv/y) so there are no other candidates for individual radionuclides.

Table 4-3: Maximum % of liquid group (excl C-14, H-3) using historical data 1984 to 2020

Ag-110m	23,1
Co-58	72,5
Co-60	11,2
Cs-134	24
Cs-137	41,5
Fe-55	25,2
Ni-63	40,1
Sb-124	2,2
Others	1

5. Methodology to derive updated AADQs

5.1 Introduction

The updated AADQs are calculated using KNPS historical data of annual liquid and gaseous discharges to the environment. C-14, Ni-63 and Fe-55 are not currently measured so these have been estimated using scaling factors (GWh for C-14 and using a scaling factor using Co-60 to estimate Fe-55 and Ni-63). The discharge data since KNPS commenced operation includes all upset conditions experienced by KNPS to date. It generally allows for appropriate headroom for operational flexibility to be provided in the updated AADQs. In some cases, operational practices and plant design has changed allowing lower updated AADQs than earlier historical outliers, most notably the TEU evaporator set-point change and the updated gaseous tritium bubblers.

After establishing the updated AADQs, the next step is the calculation of the prospective annual effective dose for KNPS. The annual effective dose is calculated for a representative person defined in terms of a survey of habits of members of the public. If the public dose is deemed to be too high, then one can re-arrange the groups or assumptions made in terms of % activity contribution of the group or one can lower the updated AADQ (headroom).

A description of the methodology is provided and the results of an example updated AADQ calculation are included in Sections 10. An Excel file is also available to show the data used to derive the updated AADQ.

5.2 Description of the methodology

(1) The discharge data was obtained according to the list of the radionuclides in Appendix A. It is longer than the list in [11] and the list will be revised (shortened) before adding a list of radionuclides to be analysed before updating [11]. The list includes additional radionuclides that are important internationally such as C-14, Fe-55 and Ni-63.
(2) The discharge data was grouped into the EDF categories.
(3) The best expected performance was derived using more recent discharge data (typically since the TEU evaporator modification (2014) for liquid activity and since 2010 for gaseous activity. For radionuclides not always measured at KNPS, the historical data was derived using scaling factors such as MWh for C-14. Given the very limited data for Te-123m, Fe-55 and Ni-63, the limited data was used to determine the scaling factor to Co-60 and then the scaling factor was used to extrapolate the Te-123m, Fe-55 and Ni-63 from 1984 to 2020.
(4) Conservatively estimated discharge data was corrected to establish a more realistic information for gaseous tritium and iodines.
(5) The required headroom was added to the BEP using the updated AMM, international benchmarks and KNPS historical data. Where the headroom required was significantly greater than benchmarks the difference was justified or explained. The updated AADQ was also compared to the best estimate version of the updated AMM as described in Appendix L).
(6) The annual effective prospective dose to the representative person using updated DCFs [10]. The results were determined to be too high for liquid releases and the two approaches discussed above were considered.

5.3 Demonstration of the method application to derive AADQs

The method described above was used to derive the updated AADQs. Table 4-4 shows the updated AADQ results compared with the current AADQs.

Some of the results of the updated AADQs have been compared to the Hinkley Point C nuclear power station (EPR) that is being constructed in the United Kingdom is shown in Table 5-3 which also includes some of the current KNPS radionuclide specific AADQs (I-131 and H-3). The current AADQs are high in comparison to those for Hinkley Point C nuclear power station and the example operational AADQ values.

The basis of the updated AADQs is described in Appendixes B to J. The gaseous tritium and iodine AADQs are based on a more realistic approach for estimating discharge activity. This is also described in Appendix B and D respectively.

Although there is currently no requirement in 238-49 to apply quarterly limits apart from the annual group operational AADQs the need for quarterly AADQs was assessed. Appendix O describes the variability of releases per quarter over the year and proposes that quarterly limits are not introduced but that the current practice continues that each quarter’s discharge is compared to 50% of the annual AADQ in the quarterly reports.

Table 5-1: Updated AADQ for liquid and gaseous discharges

	Liquid						Gaseous					
	Current AADQ Bq	Updated AADQ Bq	Max % of group activity	uSv at 100% updated AADQ	uSv at max % of group	Updated DCF uSv/Bq	Current AADQ Bq	Updated AADQ Bq	Max % of group activity	uSv at 100% updated AADQ	uSv at max % of group	Updated DCF uSv/Bq
Ag-110m	4,62E+09	2,50E+09	100,0	1,41E+00	1,41E+00	5,65E-10	4,12E+06	1,00E+09	7,5	8,79E-02	6,59E-03	8,79E-11
Ar-41						1,77E-18	4,79E+13	4,10E+14	10,8	5,49E+00	5,93E-01	1,34E-14
As-76		2,20E+09	1,0	2,90E-03	2,90E-05	1,32E-12		1,00E+09	0,1	4,37E-04	4,37E-07	4,37E-13
Ba-139	2,72E+05	2,20E+09	0,1	3,61E-07	3,61E-10	1,64E-16		1,00E+09	1	2,47E-05	2,47E-07	2,47E-14
Ba-140	2,37E+09	2,20E+09	1,4	4,84E-04	7,01E-06	2,20E-13	2,68E+06	1,00E+09	1	4,94E-03	4,94E-05	4,94E-12
Be-7	1,04E+10	2,20E+09	18,6	7,68E-06	1,42E-06	3,49E-15	9,72E+06	1,00E+09	1	2,91E-04	2,91E-06	2,91E-13
Br-82	1,29E+09	2,20E+09	1,0	8,62E-04	8,62E-06	3,92E-13	1,02E+08	1,00E+09	4,2	7,88E-04	3,31E-05	7,88E-13
Br-84	2,64E+07	2,20E+09	1,0	4,86E-06	4,86E-08	2,21E-15	9,67E+07	1,00E+09	19	2,94E-05	5,59E-06	2,94E-14
C-14		8,00E+10	100,0	2,42E+00	2,42E+00	3,03E-11		1,40E+12	100	6,38E+00	6,38E+00	4,56E-12
Ce-141	3,10E+08	2,20E+09	0,2	2,62E-04	4,07E-07	1,19E-13	3,01E+05	1,00E+09	1	1,50E-03	1,50E-05	1,50E-12
Ce-144	2,87E+08	2,20E+09	1,6	2,40E-03	3,73E-05	1,09E-12	2,56E+05	1,00E+09	1	1,78E-02	1,78E-04	1,78E-11
Co-57	1,26E+08	2,20E+09	9,6	4,20E-03	4,03E-04	1,91E-12	1,12E+05	1,00E+09	1	2,37E-03	2,37E-05	2,37E-12
Co-58	5,22E+10	2,40E+10	100,0	1,17E-01	1,17E-01	4,88E-12	4,82E+07	1,00E+09	100	6,04E-03	6,04E-03	6,04E-12

	Liquid						Gaseous					
	Current AADQ Bq	**Updated AADQ Bq**	**Max % of group activity**	**uSv at 100% updated AADQ**	**uSv at max % of group**	**Updated DCF uSv/Bq**	**Current AADQ Bq**	**Updated AADQ Bq**	**Max % of group activity**	**uSv at 100% updated AADQ**	**uSv at max % of group**	**Updated DCF uSv/Bq**
Co-60	2,47E+10	4,00E+09	100,0	4,36E-01	4,36E-01	1,09E-10	2,19E+07	1,00E+09	100	2,36E-01	2,36E-01	2,36E-10
Cr-51	3,09E+10	2,20E+09	74,7	1,02E-04	7,61E-05	4,63E-14	3,05E+07	1,00E+09	37	9,65E-05	3,57E-05	9,65E-14
Cs-134	1,40E+12	1,50E+10	100,0	5,84E-02	5,84E-02	3,89E-12	1,24E+09	1,00E+09	50	1,12E-01	5,60E-02	1,12E-10
Cs-136	3,75E+11	2,20E+09	3,9	1,45E-03	5,67E-05	6,57E-13	4,20E+08	1,00E+09	1	5,01E-03	5,01E-05	5,01E-12
Cs-137	6,94E+11	2,00E+10	100,0	9,04E-02	9,04E-02	4,52E-12	6,10E+08	1,00E+09	100	1,76E-01	1,76E-01	1,76E-10
Cs-138	7,20E+07	2,20E+09	0,2	1,08E-06	1,87E-09	4,90E-16	1,37E+07	1,00E+09	1	3,20E-05	3,20E-07	3,20E-14
Cu-64		2,20E+09	0,0	1,89E-02	1,89E-06	8,57E-12		1,00E+09	1	8,28E-05	8,28E-07	8,28E-14
Fe-55		1,10E+10	100,0	2,95E+00	2,95E+00	2,68E-10		1,00E+09	1	1,69E-03	1,69E-05	1,69E-12
Fe-59	1,46E+09	2,20E+09	8,2	2,46E+00	2,01E-01	1,12E-09	1,38E+06	1,00E+09	14,3	6,25E-03	8,94E-04	6,25E-12
H-3	5,73E+14	1,20E+14	100,0	5,30E-03	5,30E-03	4,42E-17	5,72E+14	1,60E+13	100	3,89E-01	3,89E-01	2,43E-14
Hf-181		2,20E+09	0,0	2,00E-03	2,00E-07	9,11E-13		1,00E+09	1	3,86E-03	3,86E-05	3,86E-12
Hg-203		2,20E+09	0,1	3,94E-01	3,94E-04	1,79E-10		1,00E+09	0,1	3,08E-03	3,08E-06	3,08E-12
I-129		1,00E+10	0,2	2,78E-02	5,56E-05	2,78E-12		7,00E+10	0,2	2,35E+02	4,69E-01	3,35E-09
I-130	7,64E+08	1,00E+10	0,2	2,09E-04	4,60E-07	2,09E-14	4,36E+08	7,00E+10	0,22	8,47E-02	1,86E-04	1,21E-12

	Liquid						**Gaseous**					
	Current AADQ Bq	**Updated AADQ Bq**	**Max % of group activity**	**uSv at 100% updated AADQ**	**uSv at max % of group**	**Updated DCF uSv/Bq**	**Current AADQ Bq**	**Updated AADQ Bq**	**Max % of group activity**	**uSv at 100% updated AADQ**	**uSv at max % of group**	**Updated DCF uSv/Bq**
I-131	1,52E+12	1,00E+10	92,7	6,67E-03	6,18E-03	6,67E-13	2,37E+10	7,00E+10	32,2	7,56E+00	2,43E+00	1,08E-10
I-132	8,36E+10	1,00E+10	0,4	7,01E-06	3,08E-08	7,01E-16	4,38E+09	7,00E+10	7,8	1,33E-02	1,04E-03	1,90E-13
I-133	9,90E+10	1,00E+10	4,5	6,27E-04	2,85E-05	6,27E-14	2,49E+10	7,00E+10	36,1	1,53E-01	5,51E-02	2,18E-12
I-134	8,38E+08	1,00E+10	0,2	9,50E-07	2,19E-09	9,50E-17	4,00E+09	7,00E+10	4	6,02E-03	2,41E-04	8,60E-14
I-135	1,47E+10	1,00E+10	1,1	6,24E-05	6,55E-07	6,24E-15	1,08E+10	7,00E+10	19,4	3,51E-02	6,82E-03	5,02E-13
Kr-85						1,66E-16	3,57E+14	4,10E+14	2,5	5,37E-02	1,34E-03	1,31E-16
Kr-85m						1,28E-18	1,39E+13	4,10E+14	1,6	8,90E-01	1,42E-02	2,17E-15
Kr-87						5,55E-19	9,71E+12	4,10E+14	1,5	3,36E+00	5,18E-02	8,20E-15
Kr-88						2,37E-15	2,30E+13	4,10E+14	2,6	1,07E+01	2,84E-01	2,61E-14
La-140	2,84E+09	2,20E+09	49,8	3,89E-04	1,94E-04	1,77E-13	5,33E+06	1,00E+09	1	8,75E-04	8,75E-06	8,75E-13
Mn-54	5,72E+09	2,20E+09	76,5	1,85E-02	1,42E-02	8,43E-12	5,09E+06	1,00E+09	42,4	1,89E-02	8,01E-03	1,89E-11
Mn-56	1,04E+08	2,20E+09	23,1	5,87E-05	1,35E-05	2,67E-14	1,48E+07	1,00E+09	1	8,95E-05	8,95E-07	8,95E-14
Mo-99	2,66E+11	2,20E+09	2,8	8,58E-04	2,40E-05	3,90E-13	7,35E+08	1,00E+09	5,4	4,98E-04	2,69E-05	4,98E-13
Na-24	1,39E+09	2,20E+09	14,0	1,61E-06	2,25E-07	7,33E-16	1,01E+08	1,00E+09	100	3,70E-04	3,70E-04	3,70E-13

	Liquid						**Gaseous**					
	Current AADQ Bq	**Updated AADQ Bq**	**Max % of group activity**	**uSv at 100% updated AADQ**	**uSv at max % of group**	**Updated DCF uSv/Bq**	**Current AADQ Bq**	**Updated AADQ Bq**	**Max % of group activity**	**uSv at 100% updated AADQ**	**uSv at max % of group**	**Updated DCF uSv/Bq**
Nb-94	4,62E+06	2,20E+09	0,9	4,58E-01	4,16E-03	2,08E-10		1,00E+09	1	5,62E-01	5,62E-03	5,62E-10
Nb-95	3,02E+08	2,20E+09	21,6	1,77E-03	3,82E-04	8,06E-13	2,91E+05	1,00E+09	2,5	2,71E-03	6,78E-05	2,71E-12
Nd-147	1,35E+08	2,20E+09	2,2	1,66E-02	3,73E-04	7,55E-12	1,60E+05	1,00E+09	1	1,14E-03	1,14E-05	1,14E-12
Ni-59		2,20E+09	1,0	5,70E-04	5,70E-06	2,59E-13		1,00E+09	1	9,33E-05	9,33E-07	9,33E-14
Ni-63		1,50E+10	100,0	7,26E-03	7,26E-03	4,84E-13		1,00E+09	1	2,74E-04	2,74E-06	2,74E-13
Np-239	1,39E+08	2,20E+09	1,0	3,61E-04	3,61E-06	1,64E-13	4,64E+05	1,00E+09	1	4,11E-04	4,11E-06	4,11E-13
P-32		2,20E+09	0,0	5,43E-01	5,43E-05	2,47E-10		1,00E+09	1	1,45E-02	1,45E-04	1,45E-11
Pr-143		2,20E+09	1,0	7,59E-05	7,59E-07	3,45E-14		1,00E+09	1	1,10E-03	1,10E-05	1,10E-12
Pr-144	2,83E+08	2,20E+09	0,1	2,64E-08	2,64E-11	1,20E-17	2,62E+05	1,00E+09	1	5,72E-06	5,72E-08	5,72E-15
Rb-88	2,55E+08	2,20E+09	5,7	5,98E-07	3,42E-08	2,72E-16	2,30E+13	4,10E+14	0,5	4,02E+00	2,01E-02	9,81E-15
Rb-89	6,22E+06	2,20E+09	19,0	3,37E-07	6,40E-08	1,53E-16	1,21E+06	1,00E+09	18	1,73E-05	3,11E-06	1,73E-14
Rh-105	2,84E+07	2,20E+09	0,1	5,21E-04	5,21E-07	2,37E-13	2,08E+05	1,00E+09	1	2,31E-04	2,31E-06	2,31E-13
Rh-106		2,20E+09	0,1	2,29E-14	2,29E-17	1,04E-23		1,00E+09	1	1,37E-11	1,37E-13	1,37E-20

	Liquid						Gaseous					
	Current AADQ Bq	**Updated AADQ Bq**	**Max % of group activity**	**uSv at 100% updated AADQ**	**uSv at max % of group**	**Updated DCF uSv/Bq**	**Current AADQ Bq**	**Updated AADQ Bq**	**Max % of group activity**	**uSv at 100% updated AADQ**	**uSv at max % of group**	**Updated DCF uSv/Bq**
Ru-103	3,60E+08	2,20E+09	0,5	8,01E-04	4,35E-06	3,64E-13	3,43E+05	1,00E+09	1	2,45E-03	2,45E-05	2,45E-12
Ru-105	2,53E+05	2,20E+09	0,1	7,59E-05	7,59E-08	3,45E-14		1,00E+09	1	1,08E-04	1,08E-06	1,08E-13
Ru-106		2,20E+09	0,1	5,76E-03	5,76E-06	2,62E-12		1,00E+09	1	1,91E-02	1,91E-04	1,91E-11
Sb-122	2,05E+09	2,20E+09	9,0	4,53E-03	4,09E-04	2,06E-12	5,77E+06	1,00E+09	1	6,54E-04	6,54E-06	6,54E-13
Sb-124	1,92E+09	2,20E+09	63,1	9,09E-03	5,74E-03	4,13E-12	1,78E+06	1,00E+09	53,4	1,20E-02	6,41E-03	1,20E-11
Sb-125	7,68E+08	2,20E+09	30,0	4,31E-03	1,29E-03	1,96E-12	6,78E+05	1,00E+09	1	2,78E-02	2,78E-04	2,78E-11
Sb-126		2,20E+09	1,0	7,88E-03	7,88E-05	3,58E-12		1,00E+09	1	4,56E-03	4,56E-05	4,56E-12
Sb-127		2,20E+09	1,0	5,70E-03	5,70E-05	2,59E-12		1,00E+09	1	1,04E-03	1,04E-05	1,04E-12
Se-75		2,20E+09	1,0	1,43E-01	1,43E-03	6,49E-11		1,00E+09	0,1	6,27E-02	6,27E-05	6,27E-11
Sn-113	1,05E+07	2,20E+09	0,9	6,73E-02	6,26E-04	3,06E-11		1,00E+09	1	3,88E-03	3,88E-05	3,88E-12
Sn-123		2,20E+09	1,0	1,87E-01	1,87E-03	8,51E-11		1,00E+09	1	5,11E-03	5,11E-05	5,11E-12
Sr-89	8,96E+08	2,20E+09	0,3	3,76E-04	9,98E-07	1,71E-13	8,40E+05	1,00E+09	1	3,73E-03	3,73E-05	3,73E-12
Sr-90	1,97E+08	2,20E+09	1,3	3,96E-03	5,24E-05	1,80E-12	1,77E+05	1,00E+09	2,7	8,06E-02	2,18E-03	8,06E-11

	Liquid						**Gaseous**					
	Current AADQ Bq	**Updated AADQ Bq**	**Max % of group activity**	**uSv at 100% updated AADQ**	**uSv at max % of group**	**Updated DCF uSv/Bq**	**Current AADQ Bq**	**Updated AADQ Bq**	**Max % of group activity**	**uSv at 100% updated AADQ**	**uSv at max % of group**	**Updated DCF uSv/Bq**
Sr-91	2,73E+06	2,20E+09	1,0	2,53E-05	2,53E-07	1,15E-14	3,68E+05	1,00E+09	1	2,29E-04	2,29E-06	2,29E-13
Sr-92	5,65E+05	2,20E+09	0,1	1,57E-05	2,03E-08	7,13E-15	7,97E+04	1,00E+09	1	1,31E-04	1,31E-06	1,31E-13
Tc-99m	2,35E+11	2,20E+09	7,2	1,17E-05	8,50E-07	5,34E-15	9,72E+08	1,00E+09	100	1,25E-05	1,25E-05	1,25E-14
Te-123m		2,20E+09	5,2	1,16E-02	5,98E-04	5,27E-12		1,00E+09	1	4,39E-03	4,39E-05	4,39E-12
Te-127m		2,20E+09	0,1	2,15E-02	2,15E-05	9,76E-12		1,00E+09	1	6,33E-03	6,33E-05	6,33E-12
U-237	2,49E+07	2,20E+09	0,1	4,05E-05	4,05E-08	1,84E-14		1,00E+09	1	7,61E-04	7,61E-06	7,61E-13
W-187	5,48E+08	2,20E+09	5,5	2,33E-02	1,28E-03	1,06E-11	1,04E+07	1,00E+09	1	2,34E-04	2,34E-06	2,34E-13
Xe-127						1,30E-15		4,10E+14	0,1	1,41E+00	1,41E-03	3,45E-15
Xe-131m						5,38E-17	7,75E+13	4,10E+14	1,45	6,48E-02	9,39E-04	1,58E-16
Xe-133						5,14E-17	5,42E+15	4,10E+14	65,1	2,32E-01	1,51E-01	5,66E-16
Xe-133m						4,19E-17	6,50E+13	4,10E+14	0,8	1,87E-01	1,49E-03	4,55E-16
Xe-135						7,02E-18	8,24E+13	4,10E+14	4	1,33E+00	5,33E-02	3,25E-15
Xe-135m						2,14E-19	5,80E+13	4,10E+14	0,11	1,19E+00	1,31E-03	2,90E-15

	Liquid						**Gaseous**					
	Current AADQ Bq	**Updated AADQ Bq**	**Max % of group activity**	**uSv at 100% updated AADQ**	**uSv at max % of group**	**Updated DCF uSv/Bq**	**Current AADQ Bq**	**Updated AADQ Bq**	**Max % of group activity**	**uSv at 100% updated AADQ**	**uSv at max % of group**	**Updated DCF uSv/Bq**
Xe-137						0,00E+00		4,10E+14	0,03	1,27E-01	3,81E-05	3,10E-16
Xe-138						2,14E-16	7,23E+12	4,10E+14	2,1	5,86E+00	1,23E-01	1,43E-14
Y-90		2,20E+09	1,0	5,52E-04	5,52E-06	2,51E-13		1,00E+09	1	8,02E-04	8,02E-06	8,02E-13
Y-91		2,20E+09	3,8	7,90E-04	3,00E-05	3,59E-13		1,00E+09	1	4,31E-03	4,31E-05	4,31E-12
Y-92	1,56E+05	2,20E+09	1,0	1,56E-05	1,56E-07	7,07E-15		1,00E+09	1	9,49E-05	9,49E-07	9,49E-14
Zn-65	1,81E+09	2,20E+09	8,5	1,23E+00	1,04E-01	5,58E-10	1,61E+06	1,00E+09	1	2,29E-02	2,29E-04	2,29E-11
Zr-95	3,16E+08	2,20E+09	5,3	6,69E-03	3,54E-04	3,04E-12	2,92E+05	1,00E+09	0,7	9,24E-03	6,47E-05	9,24E-12
Zr-97	6,35E+07	2,20E+09	7,7	3,92E-04	3,03E-05	1,78E-13	1,60E+05	1,00E+09	1,5	5,81E-04	8,72E-06	5,81E-13
Another	5,00E+05						1,00E+06					
Total				13,2	7,8					285,6	11,5	

Table 5-2: Updated AADQs as Groups - liquid and gaseous discharges

Liquid	Current AADQ Bq	Updated AADQ Bq	Dose μSv/y IRP01(child)	Gaseous	Current AADQ Bq/y	Updated AADQ Bq/y	Dose μSv/y IRP01(child)
Ag-110m	4,62E+09	2,50E+09	1,41E+00	Other	4,64E+12	1,00E+09	8,79E-02
Co-58	5,22E+10	2,40E+10	1,17E-01	Noble Gas	6,18E+15	4,10E+14	5,49E+00
Co-60	2,47E+10	4,00E+09	4,36E-01	C-14		1,40E+12	6,38E+00
Cs-134	1,40E+12	1,50E+10	5,84E-02	H-3	5,72E+14	1,60E+13	3,89E-01
Cs-137	6,94E+11	2,00E+10	9,04E-02	Iodines	6,82E+10	7,00E+10	7,56E+00
Fe-55		1,10E+10	2,95E+00				
Ni-63		2,20E+10	1,06E-02				
Iodines	1,2E+12	1,10E+11	2,30E-03				
C-14		8,00E+10	2,42E+00				
H-3	5,73E+14	1,20E+14	5,30E-03				
Other	5,76E+14	2,20E+09	3,61E-04				

Table 5-3: A comparison with Hinkley Point C nuclear power station AADQ values

Airborne	**Hinkley Point C Power Station (Bq/y)**	**Updated AADQ (Bq/y)**	**Current KNPS AADQ (Bq/y)[1]**
H-3	6,00E+12	1,60E+13	5,72E+14
C-14	1,40E+12	1,40E+12	None specified
Noble Gasses	4,50E+13	4,10E+14	
I-131	4,00E+08	7,00E+10 (total iodines)	2,37E+10
Other fission and activation products	1,20E+08	1,00E+09	(No group)
Liquid	**Hinkley Point C Power Station (Bq/y)**	**Updated AADQ (Bq/y)**	**Current KNPS AADQ (Bq/y)[1]**
H-3	2,00E+14	1,20E+14	5,73E+14
C-14	1,90E+11	8,00E+10	None specified
Co-60	6,00E+09	4,00E+09	2,47E+10
Cs-137	1,90E+09	2,00E+10	6,94E+11
Other (includes Iodine)	1,20E+10	2,09E+11	(No group)

5.4 Non-human biota considerations

Explicit consideration of the exposure of flora and fauna will usually not influence the setting of AADQs [6]. A study was performed in the Site Safety Report [19] which assessed the non-human biota impacts. The results of this study were adjusted taking into account the updated AADQ source term which then showed that the non-human biota dose of the updated AADQ source term using the ERICA Tool remains below the screening dose rate value of 10 µGy/h for liquid discharges and 40 µGy/h for the terrestrial environment (gaseous discharges). The screening criteria are recommended by the ICRP [24] and UNSCEAR [23] to evaluate whether the total dose rate to REPAPs is acceptable. Appendix M lists the results of the impacts to non-human biota.

6. Concluding remarks and recommendations

This report describes the methodology and associated results to update the current AADQs for KNPS. A series of steps aligned to IAEA guidance were described and implemented to arrive at updated AADQs.

[1] The current KNPS AADQs are not grouped.

Following NNR approval of these updated AADQs a few additional approvals or steps are required either before or after implementation:

- Approval of updated DCFs [10] which used updated habit data and dispersion modelling using PC-CREAM 08 models.
- Update standard [11] with updated AADQs, DCFs, expanded list of radionuclides and updated effluent LLDs.
- Confirmation and approval of updated environmental reporting levels (ERL) combined with environmental LLDs, taking the updated AADQs into account and include in 238-47 [13] as required. Appendix N describes the methodology and results of the updated ERLs and associated LLDs.
- Prepare implementation processes, guidelines and instructions etc. for practical implementation of the updated AADQs at KNPS.
- Update software (e.g. EffMan and LIMS) to capture the updated radionuclide results and ensure adequate reporting.
- Revise the Koeberg Safety Analysis Report.

The dose for the updated KNPS AADQs is well below the dose constraint and provides adequate headroom for operational flexibility whilst ensuring optimised discharges.

7. Acceptance

This document has been seen and accepted by:

Name	Designation
L Mahlangu	DPSA Manager
S Movalo	Nuclear Engineering
S Pietersen	Radiation Protection

8. Revisions

Date	Rev.	Compiler	Remarks
July 2022	2	DB Jeannes	To address NNR comments and add Appendixes K to O
November 2021	1	DB Jeannes	To document method for updating AADQs.

9. Development Team

The following people were involved in the development of this document:

- N Tlape
- J Slabbert
- M Modise
- H Morland
- E Khoza

10. Acknowledgements

N/A.

Appendix A: KNPS current AADQs

The current KNPS AADQs are included in Eskom Standard [11] and are reproduced in **Table A-1**.

Table A-1: KNPS current AADQs and DCFs

Isotope	Liquid AADQ Bq	Liquid DCF Sv/Bq	Gaseous AADQ Bq	Gaseous DCF Bq/Sv
H-3	5,73E+14	1,19E-21	5,72E+14	1,54E-20
Be-7	1,04E+10	2,12E-16	9,72E+06	3,39E-19
Na-24	1,39E+09	0,00E+00	1,01E+08	7,55E-20
Ar-41	0,00E+00	2,93E-25	4,79E+13	1,49E-20
Cr-51	3,09E+10	6,38E-17	3,05E+07	3,52E-19
Mn-54	5,72E+09	6,79E-18	5,09E+06	7,11E-17
Mn-56	1,04E+08	1,83E-20	1,48E+07	2,94E-20
Fe-59	1,46E+09	2,76E-16	1,38E+06	1,73E-19
Co-57	1,26E+08	4,15E-17	1,12E+05	2,81E-17
Co-58	5,22E+10	2,95E-16	4,82E+07	2,54E-17
Co-60	2,47E+10	3,72E-17	2,19E+07	1,14E-15
Zn-65	1,81E+09	9,41E-16	1,61E+06	2,21E-16
Br-82	1,29E+09	2,25E-20	1,02E+08	7,99E-20
Br-84	2,64E+07	1,25E-35	9,67E+07	1,77E-20
Kr-85m	0,00E+00	0,00E+00	1,39E+13	3,25E-20
Kr-85	0,00E+00	0,00E+00	3,57E+14	1,44E-21
Kr-87	0,00E+00	0,00E+00	9,71E+12	1,81E-19
Kr-88	0,00E+00	0,00E+00	2,30E+13	4,56E-19
Rb-88	2,55E+08	3,34E-44	2,30E+13	8,65E-21
Rb-89	6,22E+06	1,12E-48	1,21E+06	1,88E-20
Sr-89	8,96E+08	2,98E-18	8,40E+05	7,22E-18
Sr-90	1,97E+08	6,02E-17	1,77E+05	8,32E-16

Isotope	Liquid AADQ Bq	Liquid DCF Sv/Bq	Gaseous AADQ Bq	Gaseous DCF Bq/Sv
Sr-91	2,73E+06	9,70E-20	3,68E+05	3,65E-20
Sr-92	5,65E+05	7,80E-22	7,97E+04	2,94E-20
Y-92	1,56E+05	2,12E-19	0,00E+00	1,40E-20
Zr-95	3,16E+08	3,94E-18	2,92E+05	1,91E-17
Zr-97	6,35E+07	2,93E-18	1,60E+05	6,62E-20
Nb-94	4,62E+06	2,74E-14	0,00E+00	0,00E+00
Nb-95	3,02E+08	2,93E-18	2,91E+05	2,47E-17
Mo-99	2,66E+11	2,25E-19	7,35E+08	6,88E-20
Tc-99m	2,35E+11	3,34E-21	9,72E+08	8,80E-21
Ru-103	3,60E+08	3,43E-17	3,43E+05	3,69E-17
Ru-105	2,53E+05	2,93E-19	0,00E+00	2,12E-20
Rh-105	2,84E+07	2,17E-17	2,08E+05	2,58E-20
Ag-110m	4,62E+09	1,28E-15	4,12E+06	2,02E-16
Sn-113	1,05E+07	1,72E-15	0,00E+00	1,69E-19
Sb-122	2,05E+09	7,34E-17	5,77E+06	9,11E-20
Te-123m	5,4 E+07	8,75E-16		
Sb-124	1,92E+09	1,44E-16	1,78E+06	2,89E-17
Sb-125	7,68E+08	6,65E-17	6,78E+05	7,78E-19
I-130	7,64E+08	9,38E-19	4,36E+08	1,78E-19
I-131	1,52E+12	3,74E-17	2,37E+10	6,14E-17
I-132	8,36E+10	3,55E-22	4,38E+09	4,88E-20
I-133	9,90E+10	3,67E-18	2,49E+10	3,54E-19
I-134	8,38E+08	9,38E-28	4,00E+09	5,74E-19
I-135	1,47E+10	1,36E-19	1,08E+10	9,29E-20
Xe-131m	0,00E+00	0,00E+00	7,75E+13	2,67E-21
Xe-133	0,00E+00	0,00E+00	5,42E+15	8,03E-21

Isotope	Liquid AADQ Bq	Liquid DCF Sv/Bq	Gaseous AADQ Bq	Gaseous DCF Bq/Sv
Xe-133m	0,00E+00	0,00E+00	6,50E+13	6,76E-21
Xe-135m	0,00E+00	0,00E+00	5,80E+13	1,00E-19
Xe-135	0,00E+00	0,00E+00	8,24E+13	5,33E-20
Xe-138	0,00E+00	0,00E+00	7,23E+12	2,17E-19
Cs-134	1,40E+12	3,17E-17	1,24E+09	9,60E-16
Cs-136	3,75E+11	4,08E-18	4,20E+08	3,10E-19
Cs-137	6,94E+11	1,56E-17	6,10E+08	1,43E-15
Cs-138	7,20E+07	4,87E-33	1,37E+07	2,51E-20
Ba-139	2,72E+05	1,90E-24	0,00E+00	4,00E-21
Ba-140	2,37E+09	7,82E-18	2,68E+06	2,40E-18
La-140	2,84E+09	3,48E-17	5,33E+06	9,19E-19
Ce-141	3,10E+08	1,08E-17	3,01E+05	1,83E-18
Ce-144	2,87E+08	8,11E-17	2,56E+05	2,96E-17
Pr-144	2,83E+08	1,09E-43	2,62E+05	1,49E-21
Nd-147	1,36E+08	2,57E-17	1,60E+05	1,68E-19
W-187	5,48E+08	4,42E-19	1,04E+07	2,15E-20
U-237	2,49E+07	1,27E-18	0,00E+00	1,33E-19
Np-239	1,39E+08	2,83E-19	4,64E+05	7,37E-20
Another	5,00E+05	2,74E-14	1,00E+06	8,90E-16

Appendix B: Gaseous tritium

Proposed Limit

Best Expected Performance (BEP)	Limit (including headroom)	Basis Summary
2 900 GBq	12 000 GBq	The BEP is based on adjusted (more realistic) historical data to envelope previous performance. Headroom of approximately 4 times will allow for potential higher SFP activity and increased SG leaks.

Basis

a) Best expected Performance

Figure B-1 below shows the gaseous tritium release in TBq.

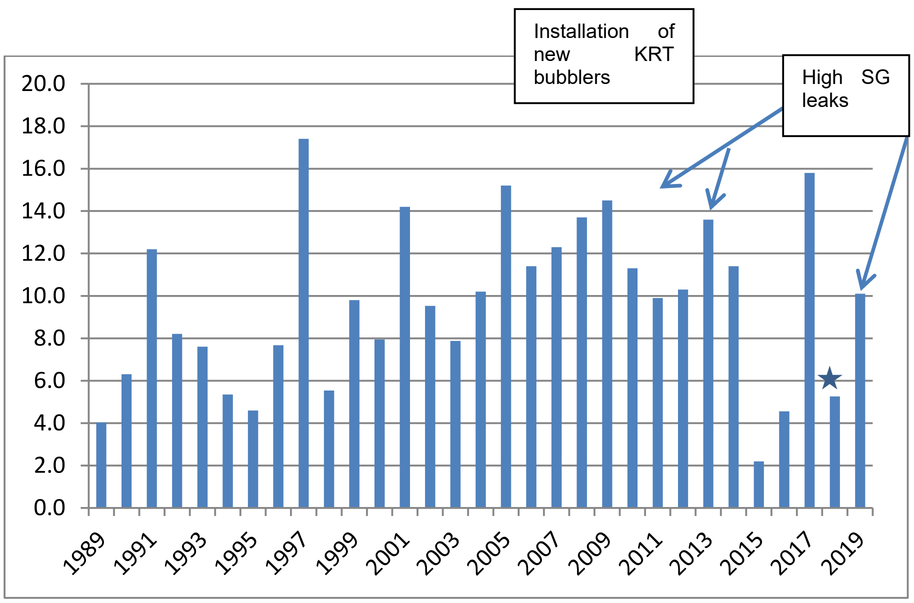

Figure B-1: Gaseous tritium from 2005 until 2019

The sudden drop in tritium seen in 2015 onwards was due to the new KRT bubblers which were installed in mid-2014. The relatively high levels shown in 2017 and 2019 compared to 2015 / 2016 / 2018 were due to large SG leaks which increased secondary system releases, but the methods used to determine secondary releases conservatively assumes highest activity of any one unit to be applicable to both units and 100% of CAP make-up is released as steam. It is assumed that no steam released is re-condensed in the plant. If a more realistic method was used (i.e., as assumed in the SAR II-5.2.3.6 [18]) where 1/3 of CAP make-up is steam leaks (i.e., does not include CVI which discharges to DVN) and ½ of that is re-condensed in the plant then this would reduce the secondary release significantly.

As an example of the impacts of the conservative methods, if one ignores the conservatism due to the highest CEX activity of the two units assumed to be applicable to both units, the adjusted release can be found in Figure B-2 below. Data between 2016 and 2019 indicates that using the highest activity of the two units will tend to overestimate the numbers by 40% on average and 600% overestimation with high SG leaks.

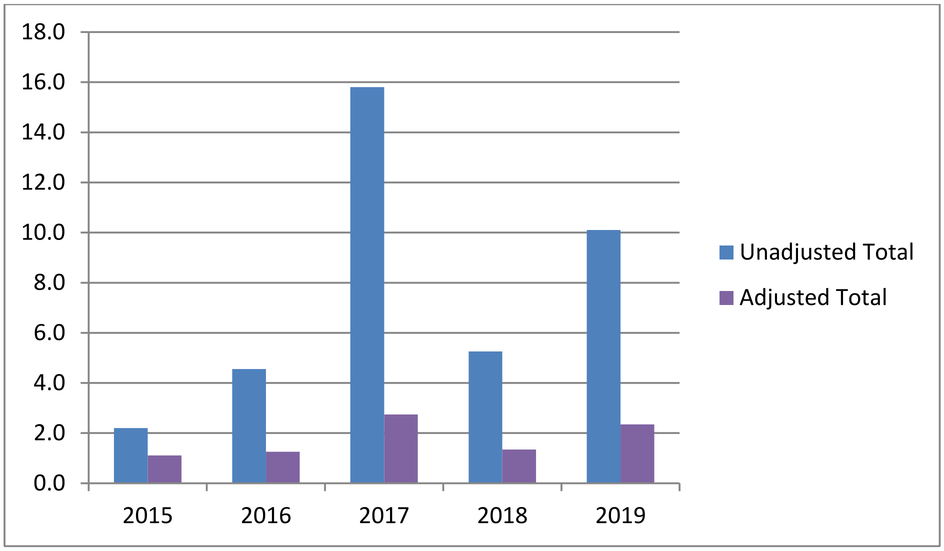

Figure B-2: Adjusted (realistic) and unadjusted tritium release (TBq)

The adjusted release in 2017 drops from 15,8 TBq to 2,2 TBq with almost equal contribution from DVN and secondary (from 84% secondary contribution previously).

Figure B-3 below shows the adjusted historical data as if the new bubblers were installed since 1988 and Figure B-4 shows the adjusted historical data as if new bubblers were installed in 1988 and with the estimation conservatism removed.

Without high SG leaks, gaseous tritium is dominated by the evaporation from the SFPs which is released via DVN (see 2015 as a typical scenario) but when higher SG leaks are experienced, one would get a higher DVN due to high activity via CVI which releases via DVN and higher secondary discharges. Figure B-5 shows that when one of the SFPs tritium increased (doubled) from June to November 2013, a 40% increase in gaseous tritium was discharged in 2013 compared to 2012. This confirms the case of SFP dominating discharges when SG leaks are low.

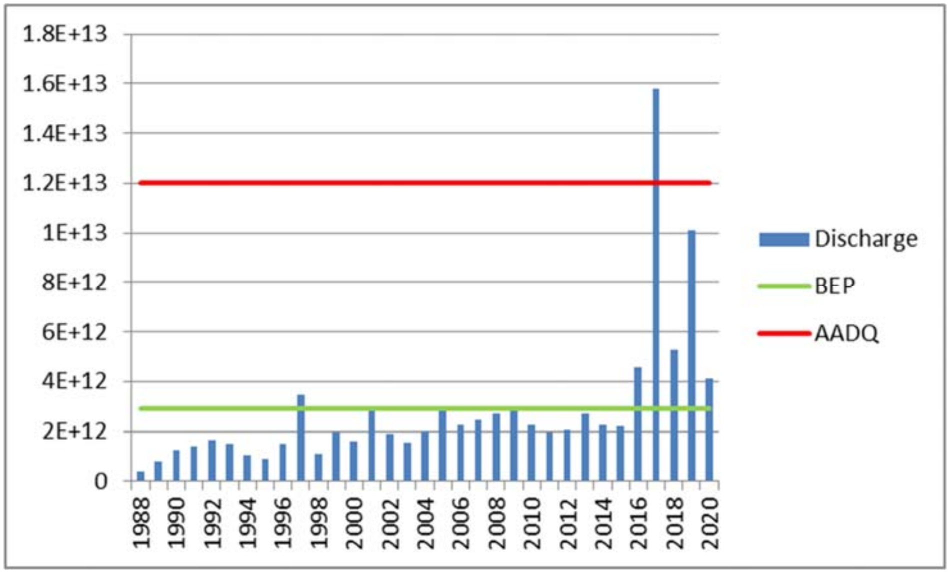

Figure B-3: Adjusted gaseous tritium assuming new bubblers were installed in 1988

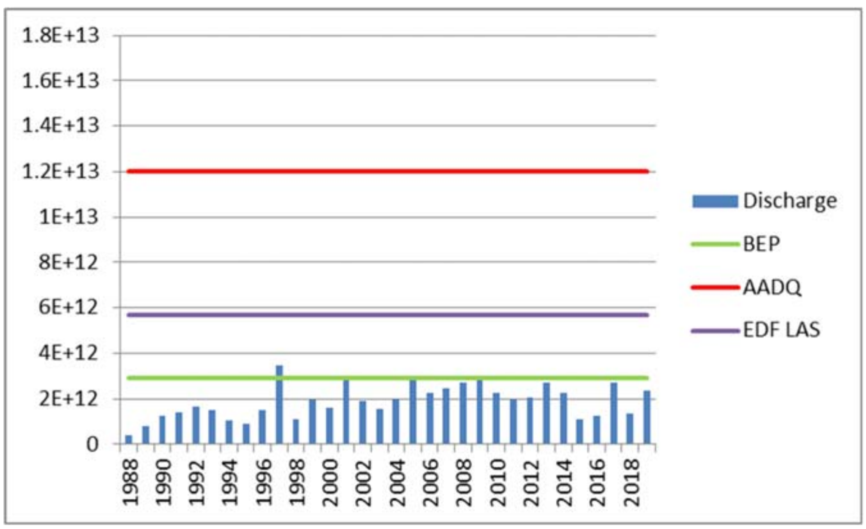

Figure B-4: Adjusted gaseous tritium assuming new bubblers were installed in 1988 and more realistic estimation of secondary tritium releases

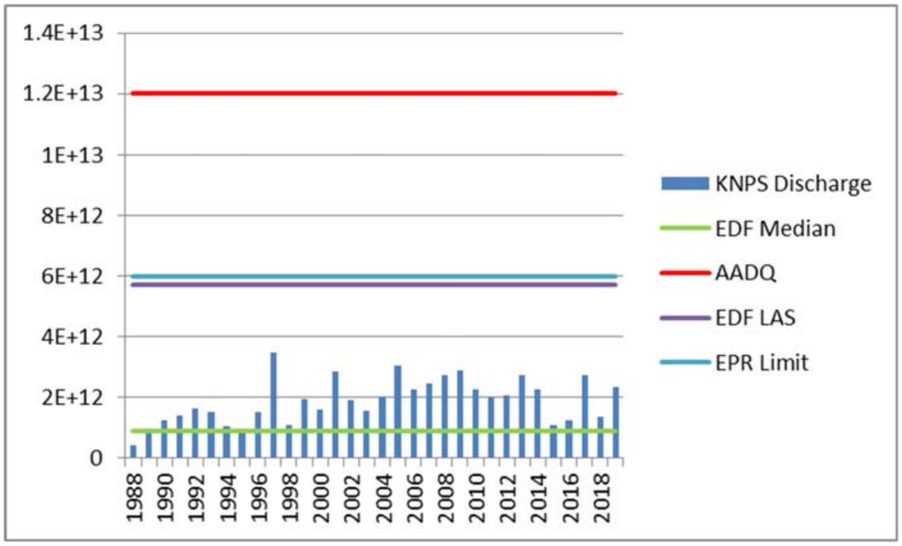

Figure B-5: Adjusted gaseous tritium with updated AADQ and benchmarked information

b) Headroom / Limit

Headroom has been established by a factor of approximately 4 to cater for higher-than-normal SG leaks and higher than normal SFP activity. There is an order of magnitude difference between SFP activity and RCP activity (about 3E9 Bq/m^3 and 3E10 Bq/m^3), so a 3-times increase is estimated as the worse-case scenario should RCP activity contaminate SFP activity. Figure B-7 shows that historically an increase from about 2 (from 1,8E9 to around 3,3E9). The conservatism found in the current methods to estimate secondary activity has been removed (i.e. using more realistic secondary activity and more realistic DVN activity as explained above). The expectation being that the methods will become more realistic before the updated AADQs are implemented. The maximum tritium since 2012, adjusted down to remove conservative estimation methods is 2,74 TBq and is enveloped by the AADQ with sufficient margin.

Figure B-6 below shows the CEX activity increase due to SG leaks. The blue colour (highest activity) is associated with Unit 1 and the red (or lower activity is Unit 2). The average CEX activity for Unit 1 was 3,3E7 Bq/m^3 in 2015 vs 2,0E8 Bq/m^3 in 2017 (6 times increase).

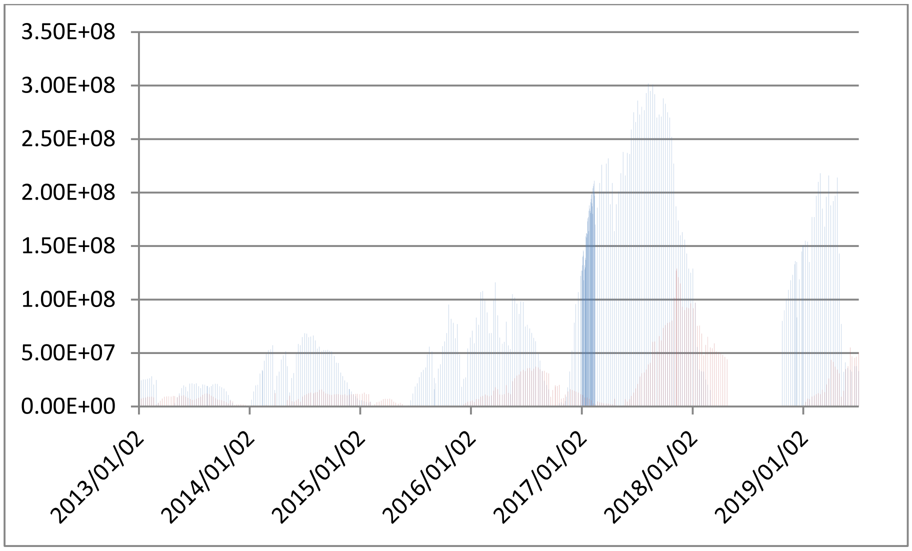

Figure B-6: CEX activity in Bq between 2013 and 2019 (Unit 1 in blue and Unit 2 in red)

Figure B-7 below shows the SFP activity with time. During outages if reactor cavity water which is at a higher activity is mixed with SFP water then one can expect a sudden increase in SFP activity. Problems with spent fuel handling equipment on Unit 1 (green line) in 2013 resulted in a transfer of highly active reactor cavity water to the spent fuel pools and this increase is shown in mid-2013 until late 2013.

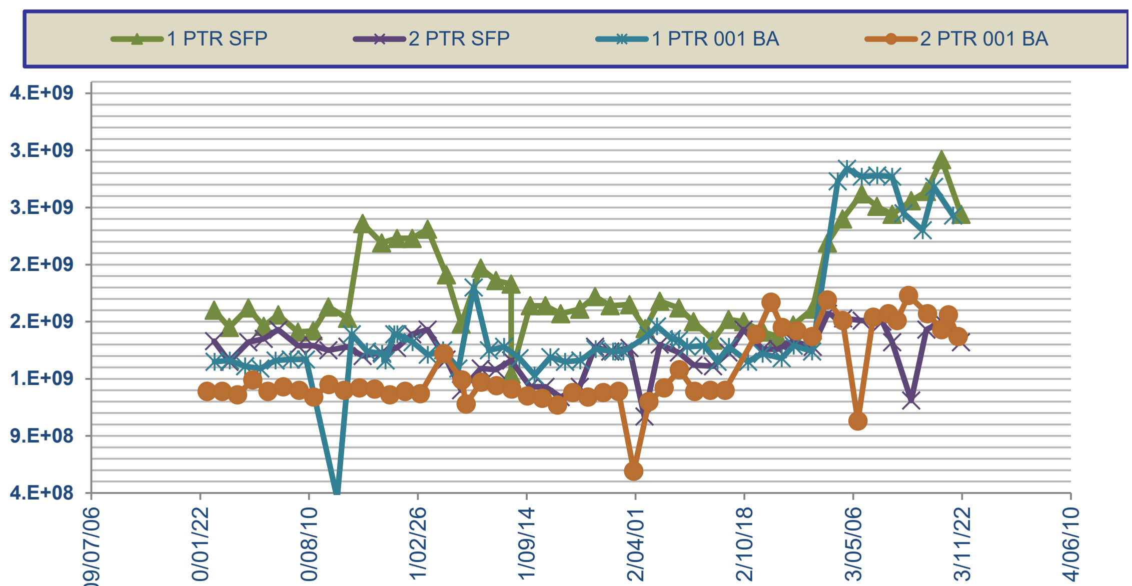

Figure B-7: SFP activity Bq/m³ with time vs water used for reactor cavity activity

c) Updated gaseous tritium release estimation method

As discussed above in Section (a), the current estimation of activity method is overly conservative.

The proposed updated method to estimate releases is as follows:

- CEX activity x 0,16 x CAP make-up (aligned to SAR assumptions)

Table B-8 below shows results of the current method and updated method for some randomly selected months (January 2018, December 2017, November 2017 and for the year of 2017).

Table B-8: Estimated tritium discharged using various methods (Bq)

Discharge in Bq	Jan 2018	Dec 2017	Nov 2017	Jan to Dec 2017
Current method	3.4E11	4.96E11	9.9E12	1.1E13
Updated method	3.98E10	8.18E10	1.73E10	1.3E12

Table B-8 shows that for the updated method, the tritium release is signficnatly lower.

The public dose for 1,0+E12 Bq/y tritium discharge is 0,024 uSv/y which is not signficant so it is not necessary to develop a highly accurate estimation method.

The only time when the steam (gaseous) discharge is greater than the 16% of CAP make-up is during GCT operation but since GCT operation is usually only a few days during the unit shutdown or start-up this will not signficantly affect the overall numbers.

Appendix C: Noble Gaseous

Proposed Limit

Best Expected Performance (BEP) GBq	Limit (including headroom) GBq	Basis Summary
70	410 000	The BEP is based on the 2019 release which is typical. Atypical years involve larger fuel leaks. While fuel leaks were more common in the past, improved fuel performance over the years has created a new normal.

Basis

a) Best expected Performance

Figure C-1 below shows the 1985 to 2019 noble gas performance. Figure C-2 shows the BEP with trace levels of activity from a fuel leaker (1500 GBq). The years 2016, 2017 and 2018 has no fuel leaks with noble gas activity of around 100 GBq. Given this is not sustained, the year has been selected with a fuel leak but at the lowest level and in line with the EDF mean.

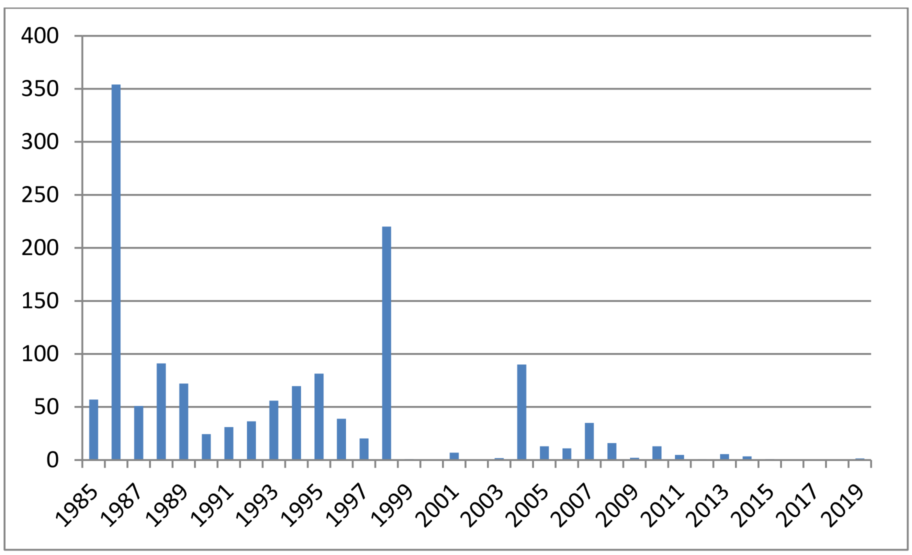

Figure C-1: Noble Gas from 1985 until 2019 (TBq)

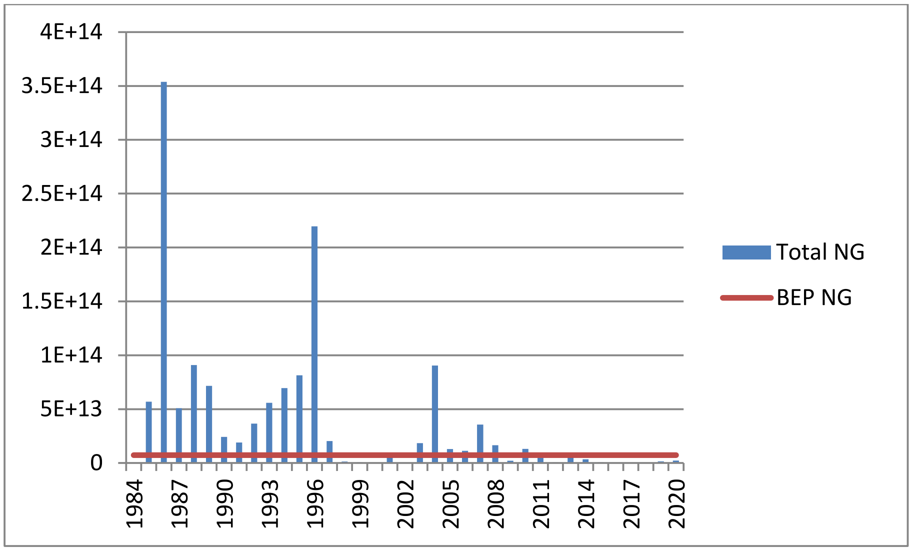

Figure C-2: Noble gas discharge showing BEP (Bq)

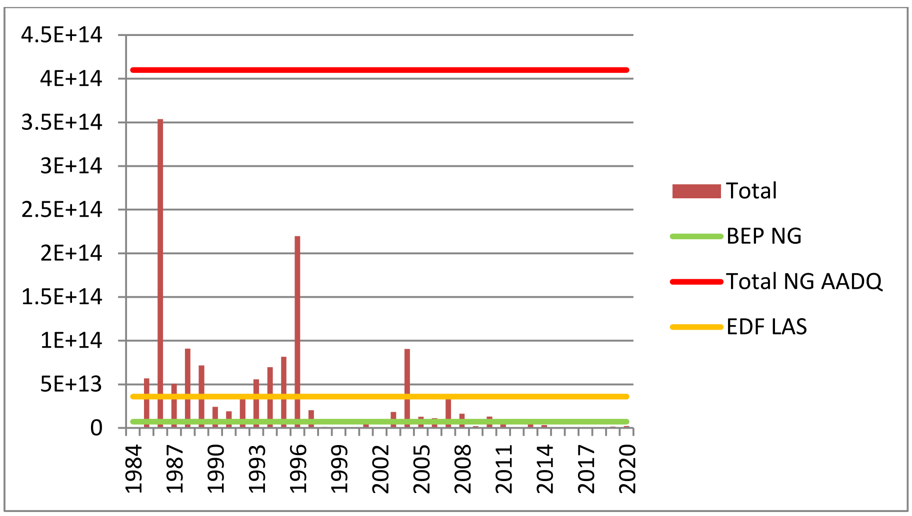

Figure C-3: Noble gas discharge showing updated AADQ with benchmarks (Bq)

b) Headroom / Limit

Headroom shown in Figure C-3 has been established by multiplying the BEP by 60 times to cater for higher-than-normal fuel leaks. This is substantially more than EDF, one of the reasons being that Koeberg does not have the TEG decay tanks that EDF has installed and the TEG delays beds at Koeberg are not used. The non-operation of these delay beds was reviewed by the PSR and the PSR recommended further investigation. This will take some time to resolve but for now the reason for the much higher release than EDF is a different design.

Appendix D: Gaseous Iodines

Proposed Limit

KNPS		**Basis Summary**
Best Expected Performance (BEP)	Limit (including headroom)	
0,68 GBq	70 GBq	The BEP is based on historical release but adjusting the historical data to remove over-conservatism. The head room of about 100 times BEP caters for fuel leaks and the lack of the use of the TEG delay beds. It should be noted that the DVN charcoal filters are available to mitigate batch releases if required. While fuel leaks were more common in the past, improved fuel performance over the years has created a new normal.

Basis

a) Best expected Performance

Figure D-1 below shows the iodine gaseous performance using conservative estimation methods. A comparison between conservative and more realistic results is shown in Figure D-2. The highest discharge in years 2013 to 2019 were selected as the BEP using best estimate methods (shown in Figure D-3) with trace levels of activity from a fuel leaker plus the activity from the source used for filter testing. For these years, it is estimated that about 90% of the normal activity comes from filter testing. Historically this may vary depending on the amount of filter failures and re-tests required. As shown in 2019 operation with a small fuel leaker did not noticeably affect the discharges since filter testing dominated. In the years 2007, 2008 and 2010 operation with larger fuel leakers than in 2019, the iodine release was dominated by the fuel leakers and not the filter testing. There are plans in place to start using a lower filter source for testing and this will reduce the BEP number by more than an order of magnitude. More recent changes in 2020 to test some filters more frequently (6 monthly testing of TEG filters rather than the regular 18 monthly testing) may increase the overall releases. This could affect the BEP but is unlikely to challenge the updated AADQ given the headroom in place for fuel leakers.

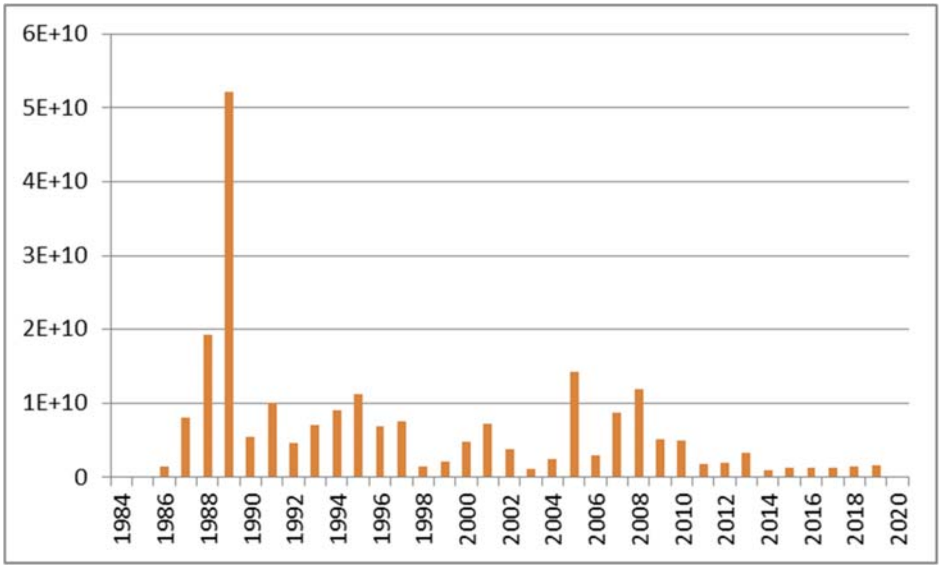

Figure D-1: Iodine Gaseous reported release from 1984 until 2020 (Bq)

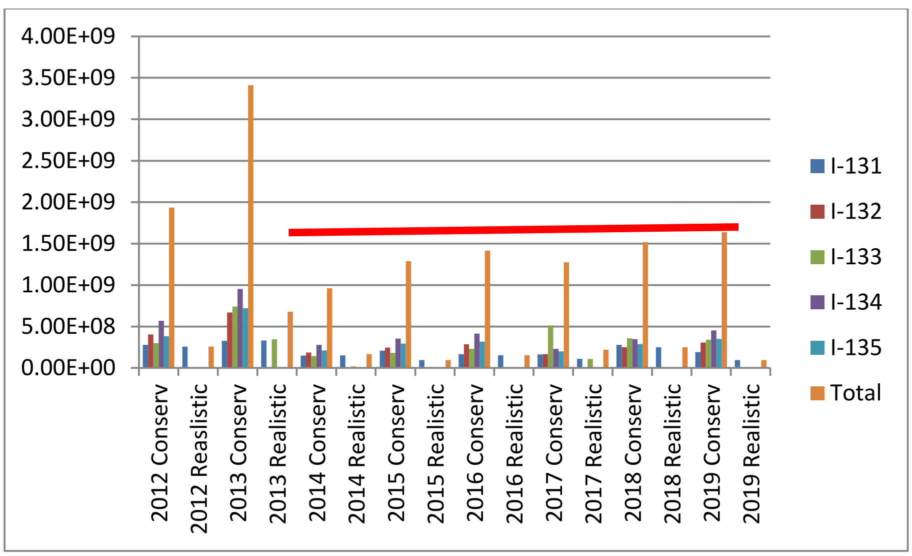

Figure D-2: Conservative vs realistic iodine estimation 2012 to 2019 (Bq)

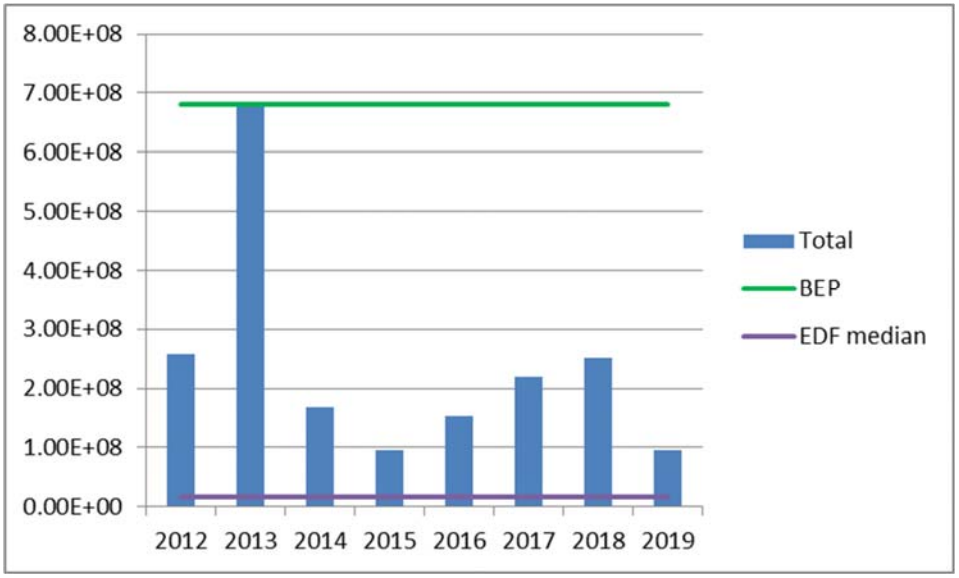

Figure D-3: Iodine discharge and BEP for 2012 to 2019 (Bq)

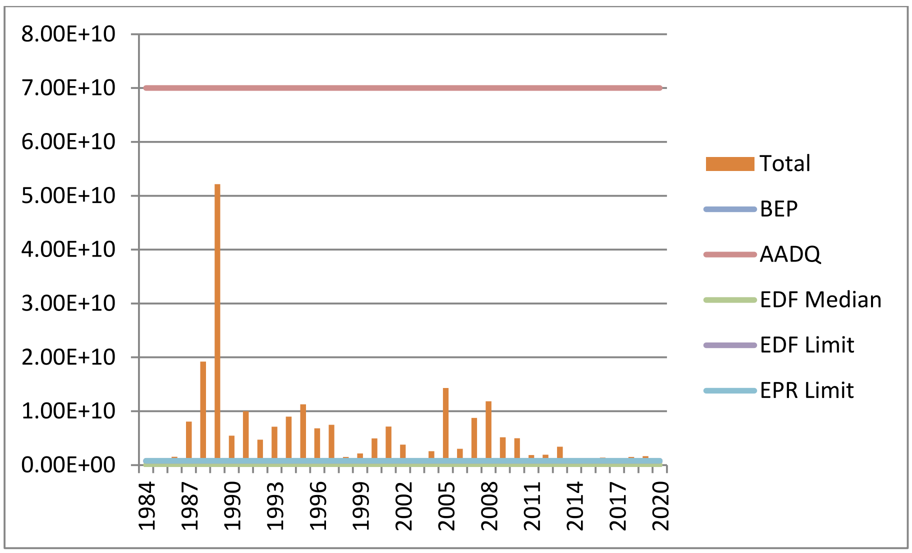

Figure D-4: Conservative discharge estimation with updated AADQ and benchmarks (Bq)

b) Headroom / Limit

The updated AADQ is about 100 times BEP (see Figure D-4) to cater for higher-than-normal fuel leaks, more frequent filter testing, and higher filter failure rate. The current AADQ only considered release from the activation and fission products found in the primary circuit and did not consider additional iodine releases from filter testing (albeit a small % (< 3%) of the current AADQ) but with large fuel leakers the iodines from the core will dominate the result from filter testing.

c) Updated gaseous iodine discharge estimation method

The current method tends to over-estimate the release of non-I-131 iodines. The I-131 measured in the DVN (or I-133 if no I-131) is used to derive the other iodines (I-132 to I-135) using the ratio of I-131 to the other iodines in the RCP. There are three issues with this approach.

Firstly, the current estimation method does not take credit decay in the TEG tank. The reason being that the ratios used to estimate I-132 to 135 uses the ratios in the primary circuit which has not decayed and not the ratios in the TEG tank which have decayed. Thus, for iodines discharged from the TEG tank into DVN, no credit is taken for the decay of short-lived iodines in TEG. It is proposed that this practice is changed as it may discourage operations staff from holding the TEG tank to decay iodine radionuclides given that no credit will be given for this. The extent of the significance of this over-estimation would be highly dependent on the scenario.

The second issue is that the iodine filters continue to release I-131 even after the filter test using I-131 as a source is completed. Typically I-131 is released for around 4 weeks following the filter test. This continuous but decaying release is not considered when estimating I-131 from the DVN versus from filter testing. In the weeks when filter testing is not performed, all I-131 measured is assumed to be from the primary circuit and continuous releases from filter testing is ignored. This overestimates the iodines by around 2 times which is significant.

The third issue is that the minimum detection concentrations are used for iodines not detected in the primary for I-132 to I-135. This overestimates the iodines by around 3 times which is significant.

Figure D-5 below shows the relatively high discharges of iodines in the years with large fuel leakers and the long-term operation with a fuel leaker in years 1988 and 1989. The proposed limit is about 2 times the highest release (1989) and was due to filter failures, so this enables adequate margin.

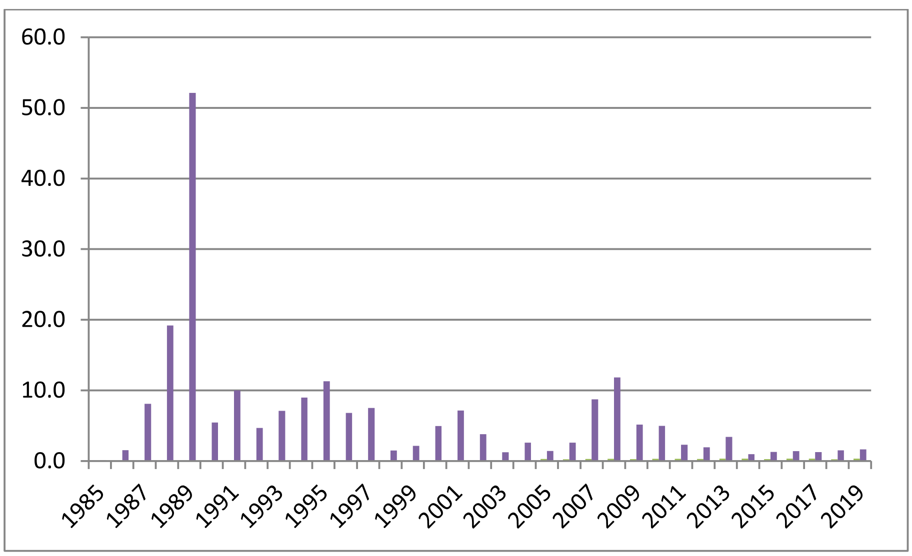

Figure D-5: Gaseous Iodine 1985 until 2019 (GBq)

The proposed approach is aligned to EDF which utilizes the actual measured I-133 and I-131 weekly composites in the DVN stack. I-131 is decay corrected to the beginning of the week since the filter testing (if any) might have occurred at any time during the week. I-133 is decay corrected back to the middle of the week assuming that the I-133 discharge is constant during the week. To consider batch releases, the release results from TEG and ETY is added. This is conservative since there may be some duplication of the batch release and the composite taken for the week but with this approach the short-lived isotopes are catered for.

Appendix E: Gaseous C-14

Proposed Limit

KNPS		**Basis Summary**
Best Expected Performance (BEP)	Limit (including headroom)	
360 GBq	1 400 GBq	The BEP of 2016 was selected as enveloping normal releases based on the C-14 formula used by EDF. A factor of 3,8 has been used to establish headroom for data uncertainty given there is limited data on the C-14 releases of Koeberg

Basis

a) Best expected Performance

Figure E-1 below shows the gaseous discharge trend for C-14 during the period 2005 to 2019. Given that KNPS does not yet have much actual plant data for C-14 releases even though the equipment was installed in 2014 for this, the same estimation formula that was used by EDF prior to 2016 was used at 197 GBq/GWe.y^{-1}. This is expected to be relatively conservative. As a benchmark, EDF OE for the 900MW fleet for the years 2016 and 2017 was obtained (EDF started actual measurement in 2016 for the 900 MWe fleet). The year 2016 is selected at 360 GBq as the BEP.

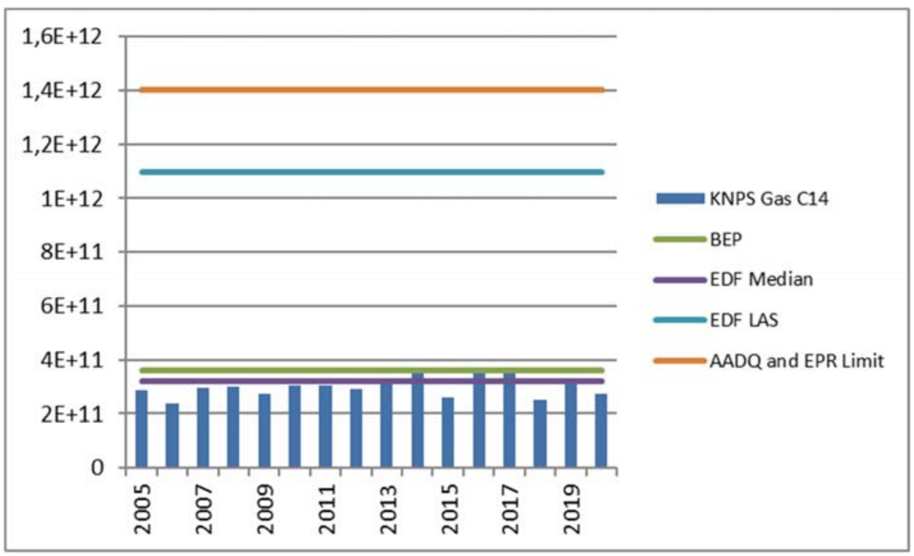

Figure E-1: C-14 gaseous releases from 2005 until 2019 with BEP, updated AADQ and benchmarks

b) Headroom / Limit

The updated AADQ at 4 times the BEP was determined to cater for uncertainties with the production of C-14 (see Figure E-1). The highest C-14 data measured by EDF during 2016 and 2017 was at Penly at 369 GBq/GWe.y. For two Koeberg units this would be around 700 GBq for one year. This has been increased by a factor of two for the headroom.

Appendix F: Other Gaseous Releases

Proposed Limit

KNPS		Basis Summary
Best Expected Performance (BEP)	Limit (including headroom)	
0,1 GBq	1 GBq	The BEP envelops historical performance except for the outlier result (high Tc-99m) due to filter failure issues. The updated AADQ has been established at 10 times the BEP to cater for filter failures and unexpected failures of airborne control during outages when systems are opened, and the reactor cavity is cleaned.

Basis

a) Best expected Performance

Figure F-1 below shows the trend of Other FP+AP (mainly particulate) gaseous discharges (non-logarithmic) and Figure F-2 (logarithmic scale). The year 2009 had known DVN filter bypass issues and 2019 is also suspected as having a bypass issue. As a result, the BEP excludes the 2009 event.

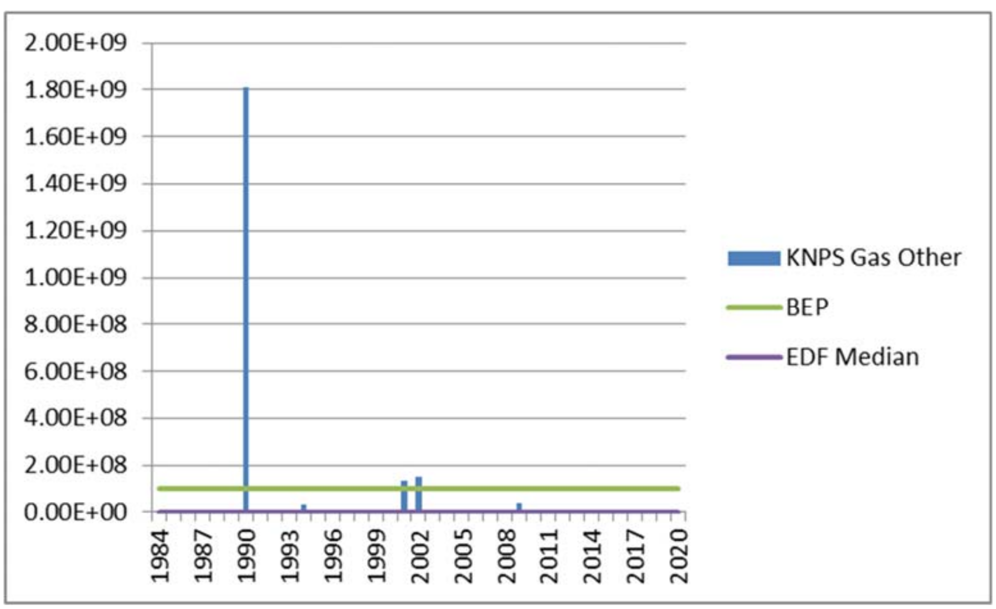

Figure F-1: Other Gaseous Releases from 2005 until 2019 (GBq)

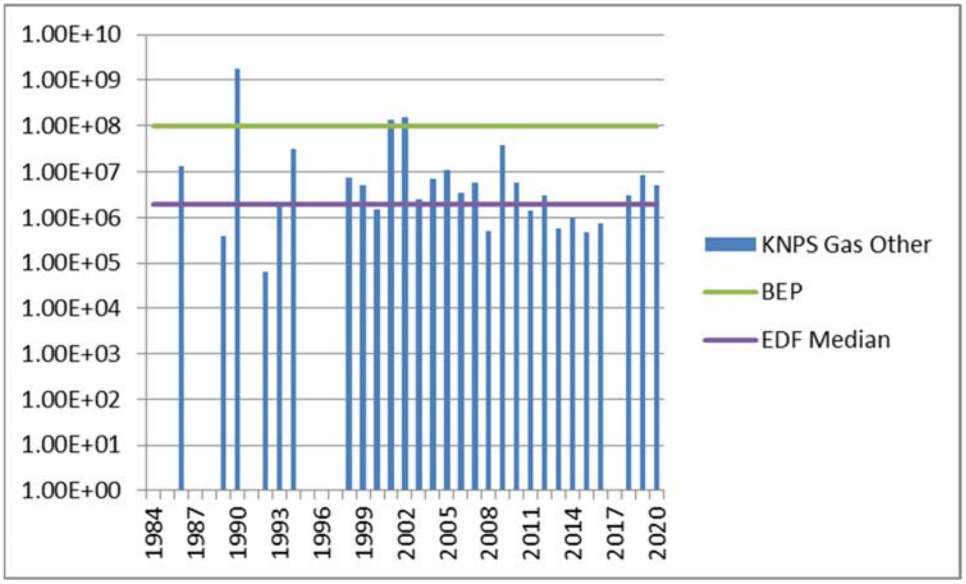

Figure F-2: Other Gaseous Releases from 2005 until 2019 (GBq)

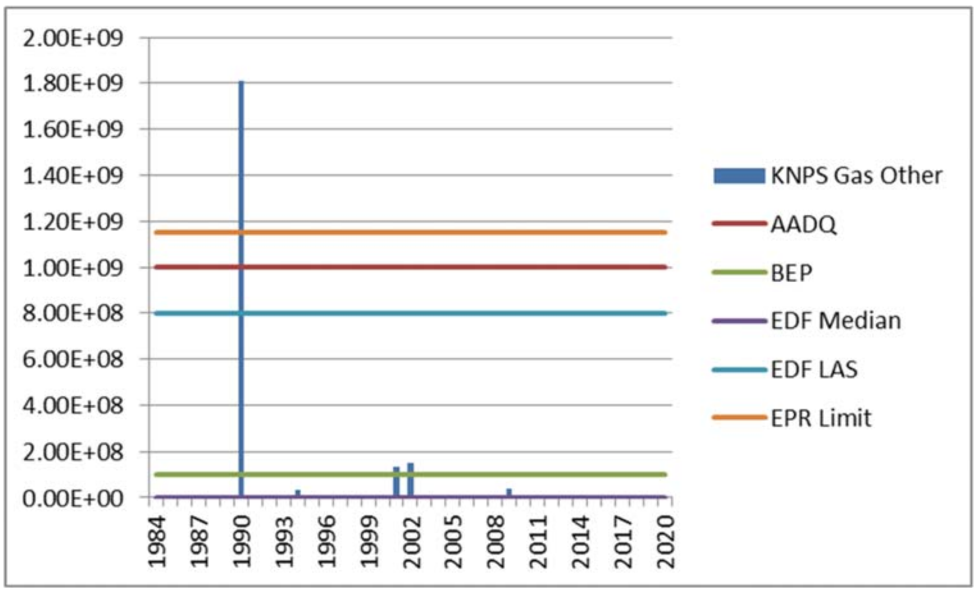

Figure F-3: Other Gaseous Releases from 2005 until 2019 (GBq)

b) Headroom / Limit

The updated AADQ (see Figure F-3) has been established by multiplying the BEP by a factor of 10 to cater for filter performance issues and radiation protection contamination control issues related to maintenance activities such as opening of systems and reactor cavity cleaning. The filter bypass issue that was experienced in year 1990 is not fully enveloped. The headroom is required to ensure sufficient margin to also cater for uncertainty. The KRT threshold 1 alarm is set at the lowest possible level of 37 Bq/m^3. A discharge just below this level for one month will result in 1,0 GBq which is in line with the updated AADQ. It would be important for the weekly composite samples to be flagged within one week if found to be at high levels.

Appendix G: Liquid tritium releases

Proposed Limit

KNPS		Basis Summary
Best Expected Performance (BEP)	Limit (including headroom)	
41 000 GBq	120 000 GBq	Tritium performance is relatively constant over time. The updated AADQ (for headroom) is 3 times BEP to cater for uncertainties.

Basis

a) Best expected performance

Figure G-1 below shows the tritium discharge trends for liquid. Tritium is generated mainly from the activation of boron and lithium found in the primary circuit. The boron concentration is reduced during the cycle and the amount of letdown to TEP increases during the cycle. The net result is two order of magnitude variability of tritium concentration in the coolant and together with the differences in power produced every year results in the variability shown in Figure G-1.

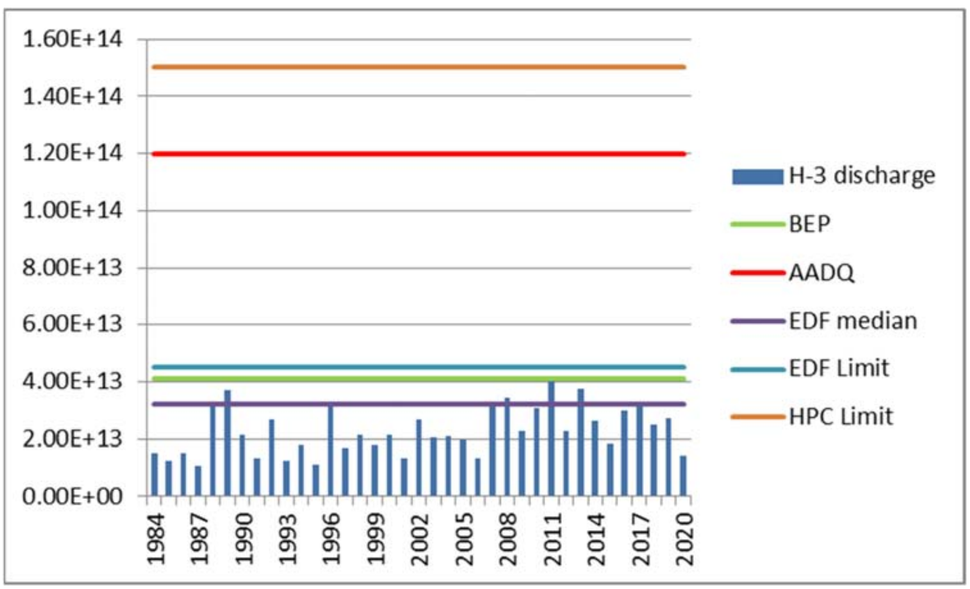

Figure G-1: Liquid Tritium Releases, updated AADQ and benchmark information (Bq)

b) Headroom / Limit

Headroom has been established by a factor of 3 above the BEP. This headroom is created to cater for further unexpected variability that may occur.

Appendix H: Liquid C-14 releases

Proposed Limit

KNPS		Basis Summary
Best Expected Performance (BEP)	Limit (including headroom)	
27 GBq	80 GBq	The C-14 values are estimated using the EDF formula based on MWh/yr. The 3 times BEP headroom will cater for uncertainties.

Basis

a) Best expected Performance

Figure H-1 below shows the performance of Liquid C-14 during the period 2005 to 2019. There is little measured data on the Koeberg C-14 discharge. As a result, the EDF adopted formula (from the IRSN) of 15 GBq/GWe.y was used to estimate C-14 discharges in the liquid pathway. The BEP that envelops normal operations is 2016.

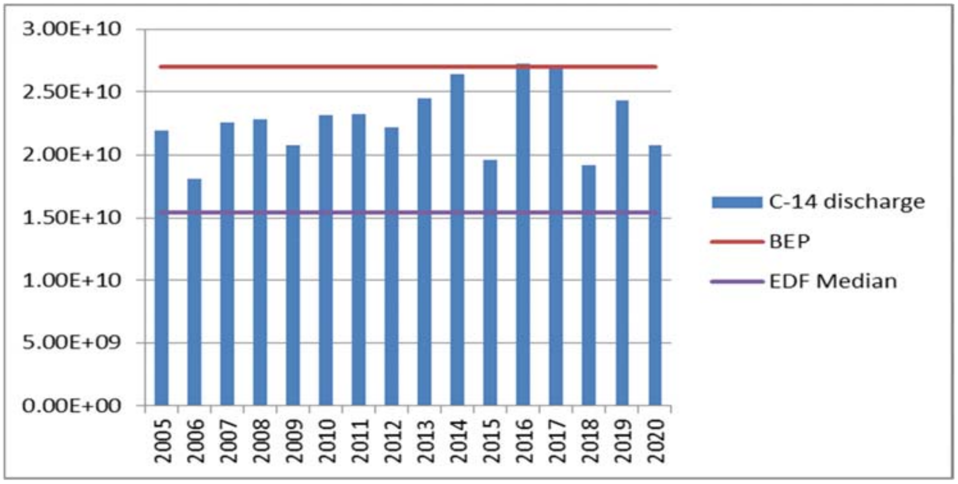

Figure H-1: Liquid C-14 Releases and BEP

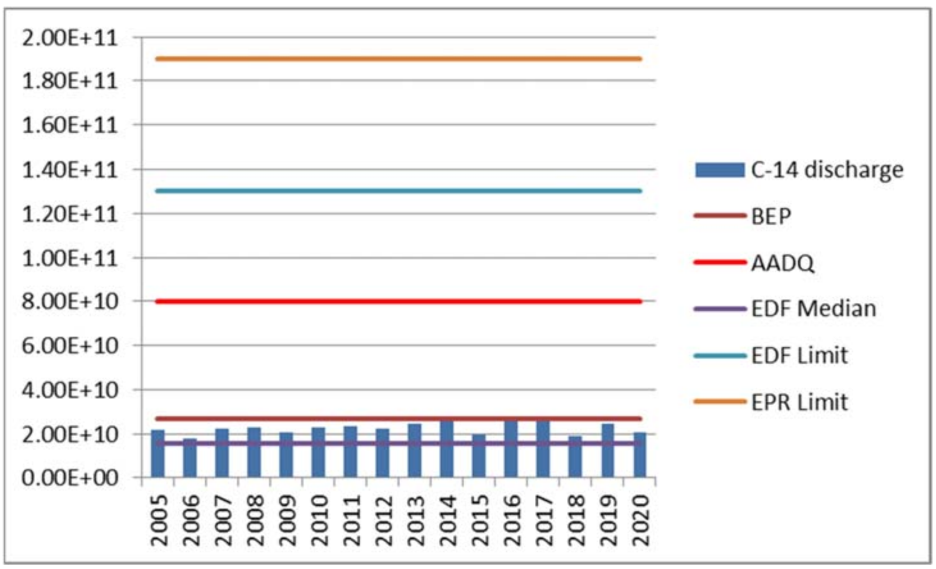

Figure H-2: Liquid C-14 Releases, updated AADQ and benchmarks

b) Headroom / Limit

The updated AADQ is 3 times BEP to consider uncertainties with the established C-14 discharge. It is noted that the highest recorded liquid C-14 discharge at an EDF station using 2016 and 2017 data was 50.2 GBq at Penly in 2017. Adjusted for two Koeberg units the value would be 35 GBq. This shows sufficient margin to 80 GBq as proposed above.

Appendix I: Liquid Iodine Releases

Proposed Limit

KNPS		Basis Summary
Best Expected Performance (BEP)	Limit (including headroom)	
0,2 GBq	10 GBq	The BEP envelopes historical performance and excludes some outlier events. The updated AADQ is 50 times BEP to allow of headroom to envelop fuel failures and filter failure events.

Basis

a) Best expected Performance

Figure I-1 below shows the trend of liquid iodine performance with BEP which envelope most releases apart from some outlier events. The high release in 2010 for example was due to a large fuel leak in combination with effluent that was not treated. Since the conductivity set point in the TEU evaporators was increased in 2014 the station has a better ability to deal with high activity waste. As such the release of 2010 and many of the outliers between 1993 and 2014 is not seen as BEP.

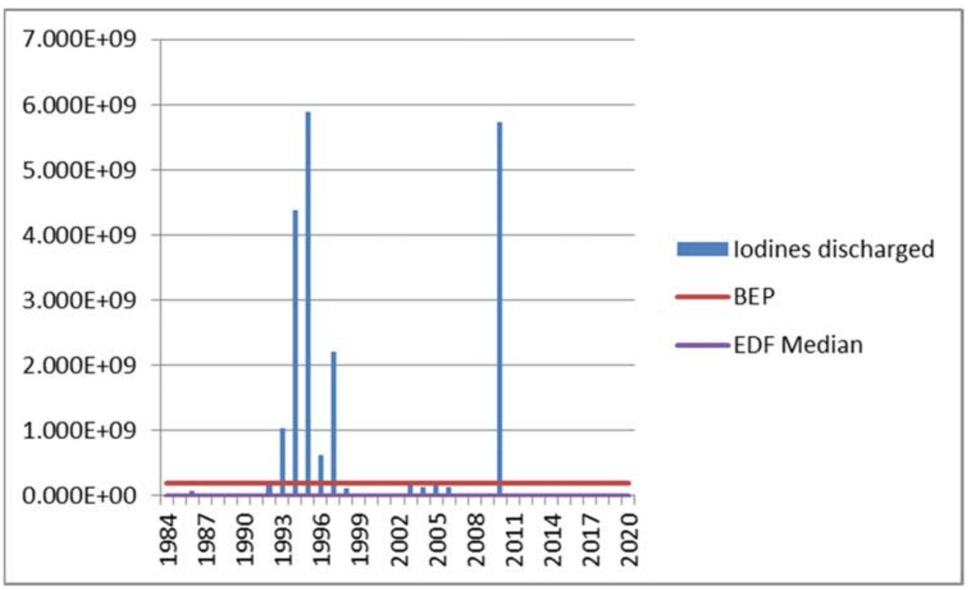

Figure I-1: Liquid Iodine Releases with BEP and EDF Median (2017)

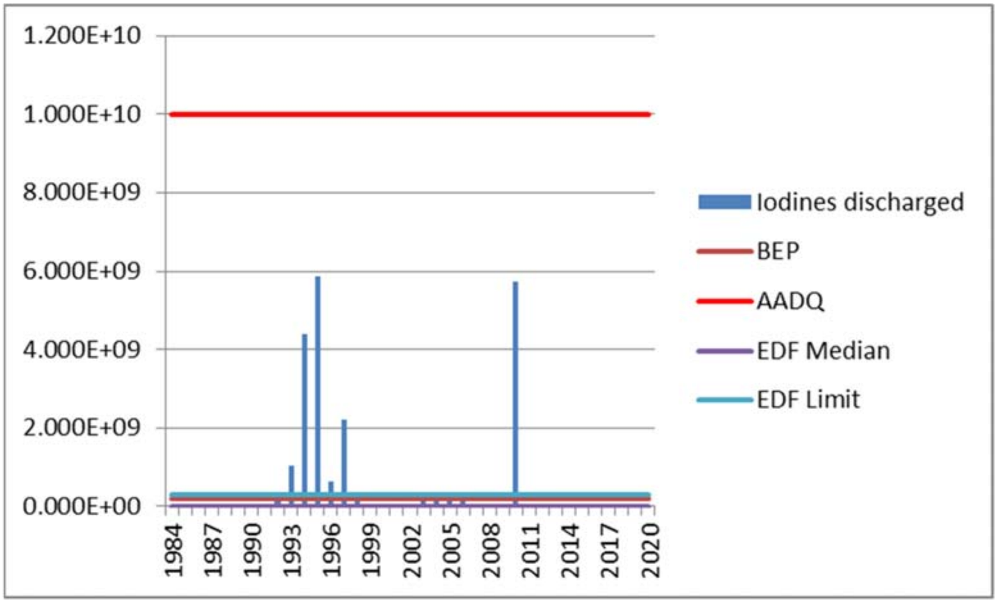

Figure I-2: Liquid Iodine Releases from 1989 until 2019 (GBq)

b) Headroom / Limit

Figure I-2 shows the updated AADQ at 50 times the BEP to cater for fuel leakers and the limited capability of the design for iodine decay in the TEG system.

Appendix J: Liquid cobalt, silver, caesium, iron, nickel and other fission product and activation product releases

Proposed Limits

	KNPS		Basis Summary
	Best Expected Performance (BEP) GBq	Updated AADQ (including headroom) GBq	
Ag-110m	0,25	2,5	The BEP is based on 2015 to 2020 release data (after TEU evaporator set point was changed. The updated AADQ is based on 10 times the BEP except for Cs-134/7 which is based on historical data with a 160- and 280-times BEP respectively.
Co-58	2,4	24	
Co-60	0,4	4	
Cs-134	0,092	15	
Cs-137	0,072	20	
Fe-55	1,1	11	
Ni-63	1,44	15	
Other	0,22	2,2	

Basis

a) Best expected Performance

Figure J-1 show the liquid FP and AP performance (excluding iodines, tritium, C-14, Ni-63 and Fe-55), BEP and updated AADQ. The performance prior to the TEU evaporator conductivity set point increase which allows better waste treatment is not seen as representative of BEP. Since 2011, the station has been able to continuously improve releases apart from 2018 which was a challenging year with respect to a high volume of waste generated in part due to the relatively high number of unplanned shutdowns. But it was determined that in general terms, 2013 was a good candidate year to envelope BEP.

Figures J-2, J-3, J-4, J-5, J-6, J-7, J-8 and J-9 show the BEP, updated AADQ and benchmarks for Ag-110m, Co-58, Co-60, Cs-134, Cs-137, Fe-55, Ni-63 and Other (FP+AP) respectively. Generally, the BEP and updated AADQs are higher than benchmarks due to the design limitations discussed in Section 3.

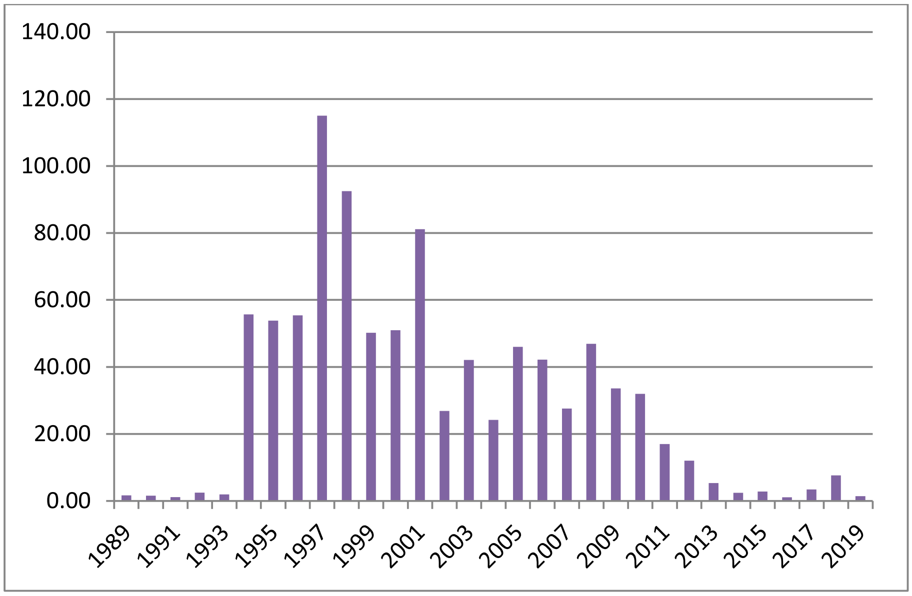

Figure J-1 Total liquid FP+AP (excl. H-3 / C-14) releases (GBq)

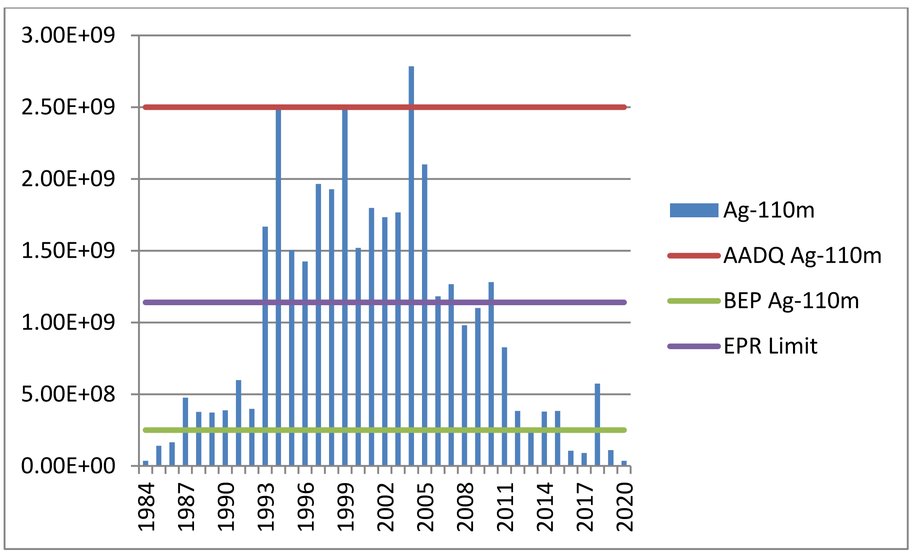

Figure J-2: Liquid Ag-110m releases BEP and updated AADQ (Bq)

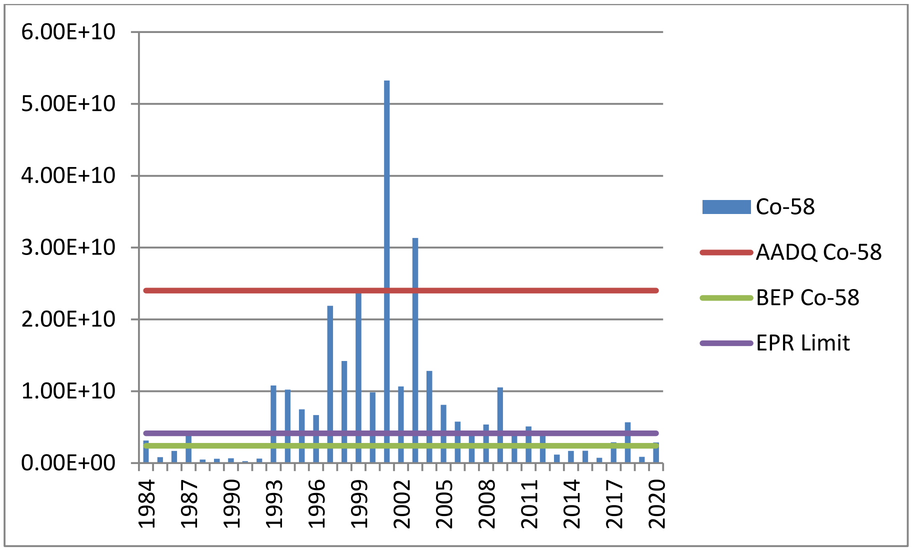

Figure J-3: Liquid Co-58 releases with updated AADQ and BEP (Bq)

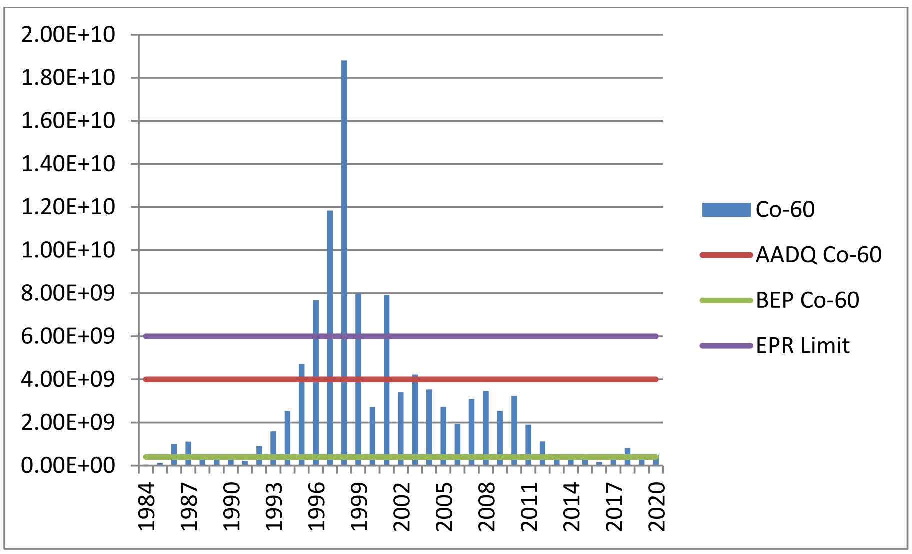

Figure J-4: Liquid Co-60 releases with BEP and updated AADQ (Bq)

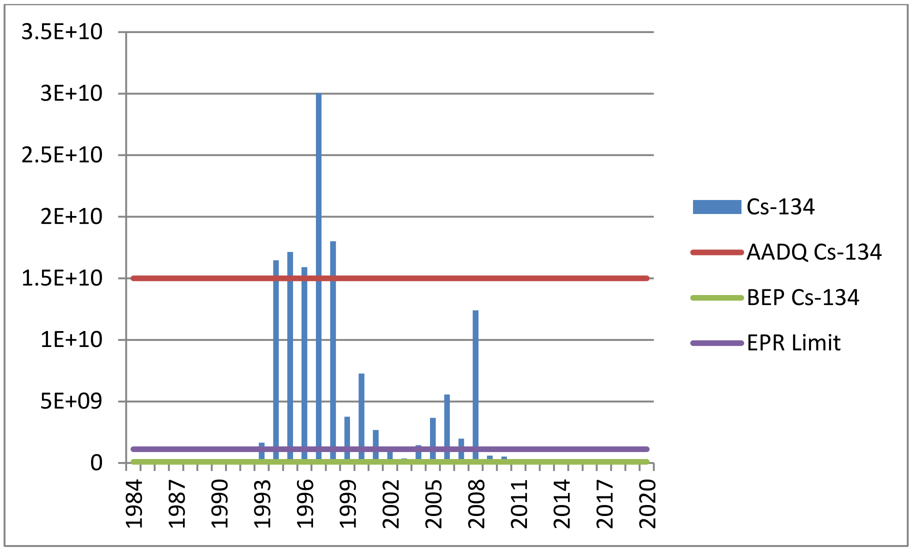

Figure J-5: Liquid Cs-134 releases with BEP and updated AADQ (Bq)

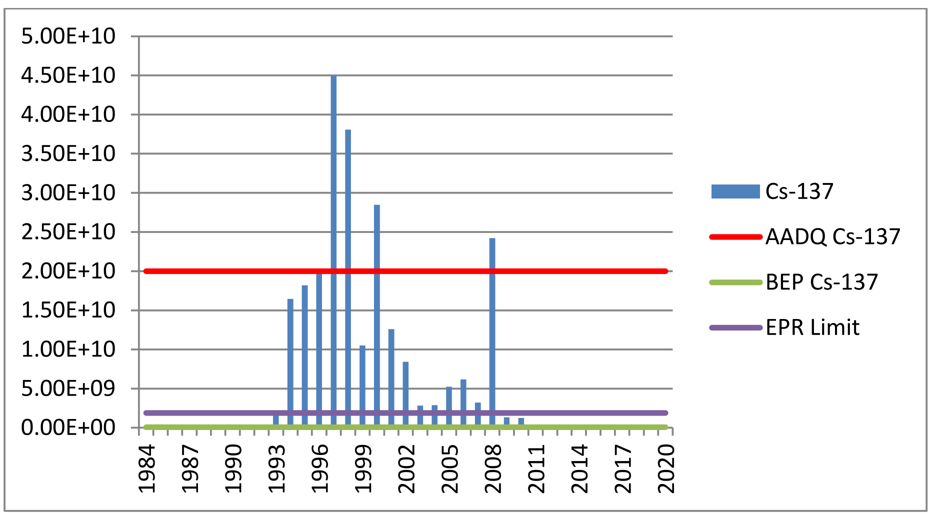

Figure J-6: Liquid Cs-137 releases with BEP and updated AADQ (Bq)

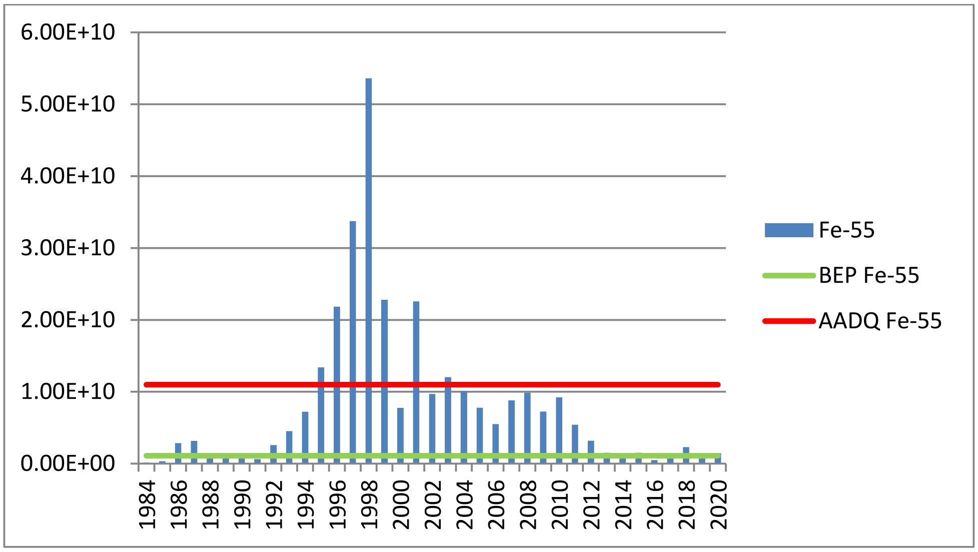

Figure J-7: Liquid Fe-55 releases with BEP and updated AADQ (Bq)

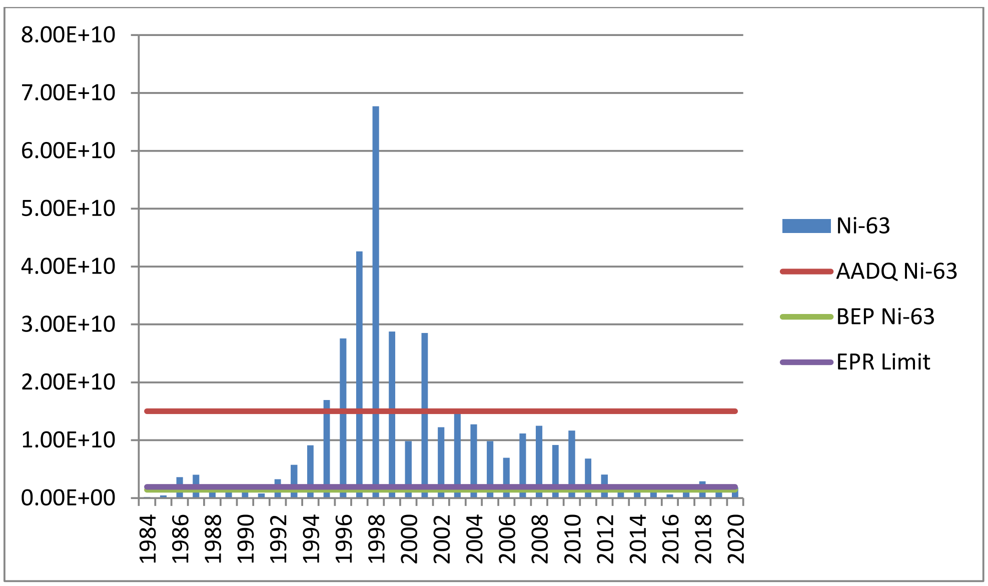

Figure J-8: Liquid Ni-63 releases with BEP and updated AADQ (Bq)

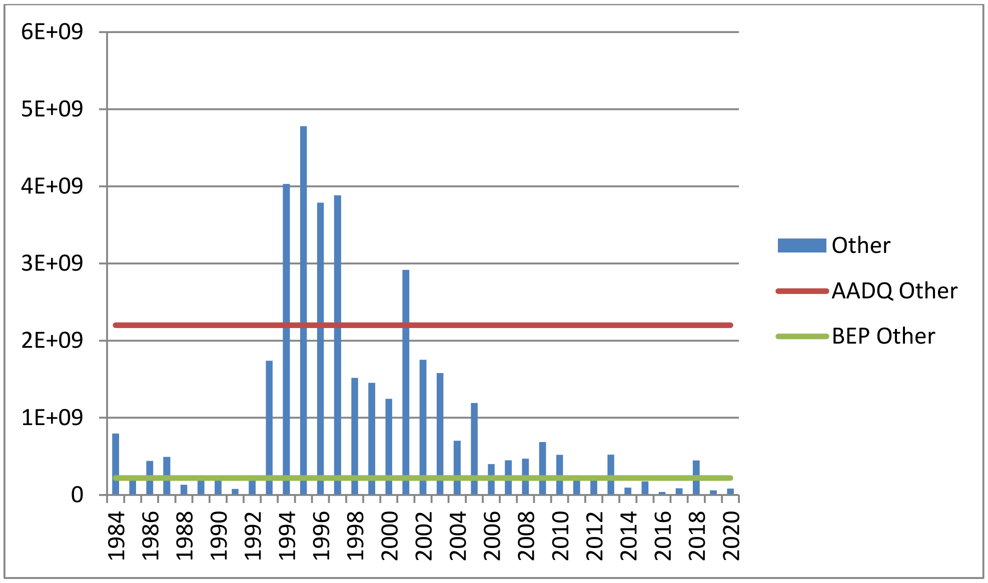

Figure J-9: Liquid Other FP+AP releases with BEP and updated AADQ (Bq)

b) Headroom / Limit

The updated AADQ is about 10 times BEP for all radionuclides apart from Cs-134/137 (about 160 times and 280 times respectively) to cater for contingencies. This headroom is required to cater for plant equipment failures, plant degradation, shortage of storage (not allowing sufficient decay) and human performance errors. Also, some headroom is required to deal with uncertainties of the SG replacement which may increase some radionuclides for a limited period. The main and biggest need for margin is for leaking fuel assemblies (Cs-134/137).

Appendix K: List of Radionuclides to include in 238-49

The list of radionuclides in Appendix 2 and 3 in [11] was used as the baseline list of radionuclides of interest. In addition the baseline list was compared to international sources such as 2004/2/Euratom and EDF effluent reports for 2017 to 2019 and 2012. Fourteen (14) radionuclides were added to the list as candidate additions, 4 from 2004/2/Euratom [15]: Fe-55, Ni-63, Te123m, C-14 and Xe-137 and five radionuclides from EDF: Xe-127, As-76, Hg-203, Se-75 and Sn-113, one measured at KNPS before: Nb-94, five radionuclides from the new build source term list in the Duynefontyn SSR: Ba139, I-129, Rh-106, Y90 and Y91 and nine (9) radionuclides from various other sources: Cu-64, Hf-181, Ni-59, Ru-105, Sn-123,Sb-126, Sb-127,Te-127m and U-237.

Three radionuclides of these 25 additional radionuclides are important enough to be added to the list of analysis in [11] in the liquid pathway: C-14, Fe-55 and Ni-63 and in the gaseous pathway: C-14 given these four radionuclides are considered principal radionuclides due to dose or activity contribution.

The radionuclides in Table K-1 below shows the radionuclides that contribute more than about (1) 1% dose, (2) 10% activity or (3) 1% activity and 0,1% dose in the various categories and is considered the list of principal radionuclides for monitoring. Radionuclides that are hard to measure are excluded if (1) the activity was less than 1% or the dose is less than 0,1%. For example, Fe-55, Ni-63 and I-129 are excluded from the gaseous pathway list of principal radionuclides given they were at about 0,01% dose, 0,002% dose and 0,2% activity respectively.

Given that Table K-1 is largely based on historical performance it will include releases from filter testing using a radioactive source (Te-99m and I-131).

Table K-1: List of updated principal radionuclides with % contribution of activity and dose

Category	Radionuclide	% activity per category	% dose	Comments
H-3 and C-14 in liquid pathway	H-3	100	0,1	
	C-14	100	30,7	Need to add to [11] in updated AADQ list and also to add LLD
Liquid pathway excl. H3 & C-14	Ag-110m	1,2	17,9	
	Co-58	11,3	1,5	
	Co-60	1,9	5,5	
	Cs-134	7,1	0,7	
	Cs-137	9,4	1,1	
	Fe-55	5,2	37,3	Need to add to [11] in updated AADQ list and also to add LLD
	Fe-59	0,1	2,5	
	I-131	48,0	0,9	
	Mn-54	0,8	0,2	

Category	Radionuclide	% activity per category	% dose	Comments
	Ni-63	7,1	0,1	Add to list of updated AADQs in [11]
	Sb-124	0,7	0,1	
	Zn-65	0,9	1,3	Consider adding to [11] in list for LLD
Gaseous Pathway H3 & C14	H-3	100	3,4	
	C-14	100	55,4	Need to add to [11] in AADQ list and add LLD
Noble gases	Ar-41	11,6	5,1	
	Kr-85m	1,7	0,1	
	Kr-87	1,7	0,4	
	Kr-88	2,8	2,4	
	Xe-133	69,8	1,3	
	Xe-135	4,3	0,5	
	Xe-138	2,3	1,1	
Particulates gaseous pathway	Ag-110m	0,9	0,1	
	Co-58	12,4	0,1	
	Co-60	12,4	2,0	
	Cs-134	6,2	0,5	
	Cs-137	12,4	1,5	Consider adding to list of LLDs in [11]
	Mn-54	5,3	0,1	
	Na-24	12,4	0,003	Consider adding to list of LLDs in [11]
	Sb-124	6,6	0,1	Consider adding to list of LLDs in [11]
	Tc-99m	12,4	0,0001	Consider adding to list of LLDs in [11]
Iodines in gaseous pathway	I-131	31,7	20,8	
	I-133	35,3	0,5	
	I-135	20,0	0,1	

Appendix L: Benchmarking with AMM

The updated AADQs have been benchmarked against the updated AMM as recommended by the IAEA that the results of the safety assessment shall be taken into account. The results of the safety assessment means that the dose of the updated AADQs shall be considered as well as the source term comparison used by the updated AMM.

Given that the updated AADQs include headroom to provide for operational flexibility and uncertainty, it is expected that in many cases the updated AADQs would be greater than the best estimate updated AMM but lower than the AMM-LTO.

1.0 Gaseous Discharges

Table L-1 below shows the comparison between updated AMM and updated AADQs for gaseous releases. Generally there is good alignment between the updated AADQ and the updated AMM (best estimate). The updated AADQ for noble gases is about 25 times lower than the AMM; 36 times lower for tritium; 1,5 times higher for iodines; 1,7 times higher for 'Other' and 3,9 times higher for C-14. The big differences being noble gases and tritium. The reason being that the AMM is more conservative for noble gases and tritium whereas the AADQs are slightly higher than the AMM for 'Other', iodines and C-14. Given that the updated AADQ is based on measured values there is sufficient confidence in the updated AADQ results albeit different to the updated AMM.

Table L-1: Comparison between updated AMM with the updated AADQs in Bq for gaseous releases

	Current AADQ	Updated AMM (LTO)	Updated AMM (BE)	Updated AADQ
Other	2,30E+13	7,30E+10	5,83E+08	1,00E+09
Tritium	5,72E+14	6,06E+14	5,75E+14	1,60E+13
C-14	n/a	3,63E+11	3,63E+11	1,40E+12
Iodines	6,82E+10	8,27E+10	4,59E+10	7,00E+10
Noble Gas	6,16E+15	1,58E+16	1,02E+16	4,14E14

2.0 Liquid Discharges

Table L-2 below shows the comparison between updated AMM and updated AADQs for liquid releases. Generally there is good alignment between the updated AADQ and the AMM (best estimate). The updated tritium AADQ is 4,8 times lower than the AMM (BE); 2,9 times higher for C-14; 15,3 times lower for iodines and 4,7 times lower for 'Other'. In summary, the AMM is more conservative except for C-14 mainly due to the relatively large headroom added to cater for uncertainties given that C-14 has not been adequately measured at KNPS historically.

Table L-2: Comparison between updated AMM with the updated AADQs in Bq for liquid releases

	Current AADQ	Updated AMM LTO	Updated AMM Best Estimate	Updated AADQ
Tritium	5,73E+14	5,32E+14	5,72E+14	1,20E+14
C-14	0,00E+00	2,73E+10	2,73E+10	8,00E+10
Iodines	1,72E+12	1,79E+10	1,53E+10	1,00E+10
Other	3,12E+12	2,37E12	4,43E+11	9,37E+10

Appendix M: Dose assessment of the impact of updated AADQs on Non-Human Biota

Table M-1 and M-2 show the dose to non-human biota due to liquid and gaseous discharges respectively. The non-human biota assessment from the PRIPE chapter was used but adjusted taking into account the different updated AADQ source term.

Table M-1: Non-human biota dose impact from liquid discharges at updated AADQ discharge levels

	Total Dose Rate (µGy h-1)
Benthic fish	0,06
Bird	0,02
Crustacean	0,07
Macroalgae	0,05
Mammal	0,04
Mollusc - bivalve	0,07
Pelagic fish	0,03
Phytoplankton	0,01
Polychaete worm	0,08
Reptile	0,04
Sea anemones & True coral	0,07
Vascular plant	0,04
Zooplankton	0,02

Table M-2: Non-human biota dose impact from gaseous discharges at updated AADQ discharge levels

	Total Dose Rate (µGy h-1)
Amphibian	29,1
Bird	12,5
Mollusc - gastropod	11,4
Reptile	27,1
Annelid	29,2
Arthropod - detritivorous	29,3
Flying insects	10,7
Grasses & Herbs	11,7
Lichen & Bryophytes	11,1
Mammal - large	15,0
Mammal - small-burrowing	29,4
Shrub	11,2
Tree	10,2

Appendix N: Environmental Reporting Levels and LLDs

The current environmental reporting levels (ERLs) are based on the updated AADQs. There is currently no LLDs which is not in line with international practice and hence LLDs will be introduced.

1.0 Liquid ERL and LLD

The ERLs have been developed taking into account the dose from various radionuclides and in various dose pathways. The main objective is to only establish ERLs and LLDs for dominant radionuclides in dominant pathways but augment this if required. Table N-1 below shows that the contribution in the liquid pathway is dominated by crustaceans (47,8%), fish (26,2%) and molluscs (19,7%). As such ERLs and LLDs will only be established for these three media in the liquid pathway and only for Ag-110m. C-14 has been excluded since it is a hard to measure radionuclide and the biota also contains a significant amount of C-14 from natural sources making the measurement less valuable than for Ag-110 (Table N-2 shows the predicted C-14 from natural sources and from KNPS). Fe-55 has also been excluded since it is a hard to measure radionuclide.

Table N-1: Dose per pathway from liquid releases at updated AADQ levels

Media / Pathway	Dose uSv	% contribution	Dominant (dose) Radionuclides
Crustaceans	3,7	47,1	Fe-55 (49%) Ag-110m (30%) C-14 (16%)
Fish	2,0	25,9	C-14 (74%) Fe-55 (13%) Ag-110m (7%)
Mollusc	1,5	19,5	Fe-55 (59%) C-14 (20%) Ag-110m (11%)
Beach exposure	0,5	7,5	Co-58 (47%) Co-60 (48%)
Other	0,1	0,1	

Table N-2: Predicted C-14 at updated AADQ vs naturally occurring C-14

	Predicted C-14 from KNPS at updated AADQ (Bq/kg)	Estimated C-14 from natural uptake (Bq/kg)
Crustaceans	16,3	24
Fish	9,7	21
Cow Milk	17,7	16
Cow Meat	105,3	38
Sheep Meat	81,7	47

The methodology used to establish ERLs and LLDs takes into account measured data where available. The measured values correspond to a selected year and the average (for the quarter) and maximum values are adjusted based on the ratio of the discharge of that particular year and the updated AADQ values. The ERL is set at about 3 times the predicted concentration using the PC-CREAM code or measured values at updated AADQ discharge levels. In line with NUREG 1301 [20], the ERL will only apply to the average of all positive results from all environmental samples for the quarter and will not apply to individual (one-off results).

The LLD value is set at about ten times the minimum measured value historically (if available) to provide the necessary confidence that the LLD is achievable. Table N-3 below summarises the ERL and LLD values.

The environmental LLDs will still need to be confirmed by the Chemistry Department who need to test the capability of detectors at Koeberg to ensure these LLDs can be met. Currently there are no LLDs in place for the analysis of environmental samples so this exercise will be required.

Table N-3: Updated ERL and LLD for pathways from liquid releases

Mussels (Bq/kg)									
	Predicted	Measured*				Current ERL	Updated		
		Ave	Max	Year	Min		LLD	ERL	uSv at ERL
Ag-110m	5,3	10,3	16,9	2005	0,15	221	1,0	31	1,0
Fish (Bq/kg)									
	Predicted	Measured*				Current ERL	Updated		
		Ave	Max	Year	Min		LLD	ERL	uSv at ERL
Ag-110m	0,89					11	0,3	3,0	0,5
Crustaceans (Bq/kg)									
	Predicted	Measured*				Current ERL	Updated		
		Average	Max	Year	Min		LLD	ERL	uSv at ERL
Ag-110m	17,8	1,44	1,46	1999	0,05	221	2	20,00	1,25

2.0 Gaseous ERL and LLD

Table N-4 below shows the dose contribution of the various dose pathways from gaseous discharges. The dominant dose pathways include the ingestion of cow milk, cow meat, grain and the inhalation of mainly C-14 and tritium. It is only necessary to include ERLs and LLDs for I-131 in cow's milk and inhalation since C-14 is excluded as a hard to measure radionuclide and since C-14 is also found naturally. It is proposed that Co-60 is included with an ERL and LLD for the inhalation pathway since this is the most dose significant particulate form a dose perspective and similarly the addition of Cs-137 as the most dose significant particulate in milk. The ERLs and LLDs are summarised in Table N-5 below.

Table N-4: Dose contribution of media related to gaseous discharges at updated AADQ discharge levels

Media / Pathway	Dose uSv	% contribution	Dominant (dose) Radionuclides
Cow Milk	2,1	19	I-131 (59%) C-14 (35%)
Cow Meat	2,0	18	C-14 (81%) I-131 (15%)
Grain	1,4	13	C-14 (99%)
Inhalation	1,3	12	C-14 (80%) H-3 (11%) I-131 (6%) Co-60 (0,3%)
Plume shine	0,9	8	Ar-41 (68%) Xe-133 (23%)
Sheep's Meat	0,8	7	C-14 (82%) I-131 (14%)
Other	1,6	15	

Table N-5: ERL and LLDs for media related to gaseous discharges

Inhalation (Bq/m^3)											
	Predicted at updated AADQ	**Measured***				**Current ERL**	**Updated**		**uSv at ERL**	**NUREG 1301**	
		Ave	**Max**	**Year**	**Min**		**LLD**	**ERL**		**LLD**	**ERL**
I-131	7,9E-04	0,001	0,001	1987	0,001	0,125	0,005	0,05	5,3	0,003	0,03
Co-60	4,60E-05					11,8	0,01	0,1	8,4		
Milk (Bq/L)											
	Predicted at updated AADQ	**Measured***				**Current ERL**	**Updated**		**uSv at ERL**	**NUREG 1301**	
		Ave	**Max**	**Year**	**Min**		**LLD**	**ERL**		**LLD**	**ERL**
I-131	0,46					1,61	0,1	3,0	0,003	0,04	0,11
Cs-137	0,01	0,5	0,7	1988	0,05	6,44	0,50	1,00	0,5	0,67	2,60

Appendix O: Quarterly Discharge Notification Levels

As stated in Section 5.2 currently there is no quarterly reporting limits in 238-49. Nevertheless, quarterly discharge administrative limits have been included in EffMan at 50% of annual discharge limits. This practice has been reviewed.

Quarterly discharge data from 2010 to 2016 in the various discharge categories is shown in Table O-1 below:

Table O-1: Quarterly discharge percentage of annual for 2010 to 2016

	Maximum	**Minimum**
Liquid tritium	57,0	3,1
Liquid Iodine	100,0	0,0
Liquid Other	56,5	3,5
Noble Gas	97,5	0,4
Other gases	88,9	0,0
Gaseous Tritium	35,7	7,1
Gaseous Iodine	61,5	0,9

As shown above, there is a relatively high degree of variability between quarters as a percentage of annual discharge. In all cases except gaseous tritium, the maximum percentage of any quarter of annual discharge is more than 50%. From the data above it is perhaps inappropriate to introduce quarterly limits and given that arrangements are already in place to submit the quarterly reports to NNR, there is no need for quarterly notification thresholds to be established.

It is useful that the quarterly reports continue to report the quarterly discharge as a % of 50% of annual discharge AADQs but the term 'quarterly limit' should be amended to a 'quarterly target' since there are no limits for quarterly discharges in 238-49.