CHAPTER 7: POTENTIAL RADIOLOGICAL IMPACT ON THE PUBLIC AND THE ENVIRONMENT		
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AMENDMENT RECORD			
Rev	**Draft**	**Date**	**Amendments**
0	2	31/03/2014	Changes to address Eskom comments following submission of TSSR Chapter 7.
1		21 July 2022	DSSR Chapter 7 update to address NNR comments on the TSSR and to include response and changes following Eskom comments. The main changes are: • Eskom KNPS LTO final source term included and the prospective dose calculated, and • the cumulative new NPS and KNPS source term information used in the ERICA Tool version 2 to calculate the non-human biota dose.
1a		15 March 2024	DSSR Chapter 7 update to address NNR comments on the DSSR.

Executive Summary

This Site Safety Report (SSR) tests and demonstrates the safety of the site by enveloping for the following scenarios:

1) KNPS remains the only nuclear power station to be hosted on the site, but has been modified through, among others, the steam generator replacement and the thermal power uprate projects to generate 2 200 MWe (6 130 MWth).
2) A new nuclear power station (NNPS) with a generating capacity of up to 2 500 MWe is added to the KNPS, which would increase on-site generating capacity to 4 700 MWe.
3) A NNPS with a generating capacity of 4 000 MWe is added to the KNPS, which translates to a maximum total on-site generating capacity of 6 200 MWe. It is further assumed that KNPS will continue to operate until 2044, after which a 20-year decommissioning period will follow, during which time spent fuel will be retained on-site (i.e., up to 2064) in a Transient Interim Storage Facility (TISF). The TISF will store not more than 160 casks up to about 10 years after the end of the commercial operation of KNPS. It is further assumed that a new nuclear installation will become operational from 2030, will operate for 60 years and could be extended to 80 years (i.e., up to 2110).

The prospective radiological impact on the public and the environment (PRIPE) discussed in this document was performed for the nuclear facilities described in scenario 3. Normal operational discharges of airborne and liquid radioactivity, and direct external radiation from nuclear installation structures are assessed.

As no vendor has yet been appointed, detailed design and power generation of the NNPS remain undefined except that PWR GEN III technology will be selected by Eskom. NNPS design certification information of four representative GEN III technologies provided source terms for normal operational discharges to the environment and which were used for PRIPE. Once a specific NNPS is selected, a detailed description of all systems of the NNPS and its location at the site will be presented and re-assessed in a safety analysis report (SAR) required for the next licensing stage. Conservative assumptions are made for this SSR in respect of the airborne and liquid radioactive discharges to the environment.

PRIPE for this SSR was carried out based on the conservative assumption that public exposure is experienced from all three nuclear facilities, KNPS, NNPS and TISF, operating simultaneously during a period of 60 years. It is

unlikely that KNPS and NNPS operations will overlap for more than 20 years.

The total effective dose of the representative person is compared to the KNPS dose constraints of 250 µSv/y:

- *Total annual dose*
  = 94.0 µSv/y (KNPS) + 36.4 µSv/y (NNPS) + 4.46E-03 µSv/y (TISF)
  = 130.4 µSv/y.

A screening dose rate assessment was done for non-human biota. It is concluded that the liquid and airborne discharges from a NNPS and KNPS are unlikely to pose a radiological risk.

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7.1 Purpose and Scope

The purpose of this chapter is to demonstrate that the annual effective dose defined for the public in national safety standards and associated dose constraints can be met by all the nuclear installations on the Duynefontyn site (Department of Minerals and Energy, 2006). The methodology for deriving the site Dose Conversion Factors (DCFs), where each DCF is the dose per unit radionuclide discharged and which is used in this report to calculate the dose to the representative person, is described in (Eskom, 2021). It is essential that the reader is familiar with the revised methodology to assess the dose for members of the public from normal operation at the Duynefontyn site in (Eskom, 2021).

The prospective radiological impact on the public and the environment (PRIPE) from the site is evaluated for the following scenarios (see ***Chapter 3***):

- Koeberg Nuclear Power Station (KNPS) remains the only nuclear power station to be hosted on the site, but has been modified through, among others, the steam generator replacement and the thermal power uprate projects to generate 2 200 MWe and 6 130 MWth (Eskom). A nuclear power station(s) with a generating capacity of 4 000 MWe is added to the KNPS, which translates to a maximum total on-site generating capacity of 6 200 MWe.
- Transient Interim Storage Facility (TISF) for the temporary storage of used nuclear fuel to accommodate the storage of not more than 160 casks up to about 10 years after the end of the commercial operation of KNPS.

The total effective dose of the representative person is compared to the KNPS dose constraint of 250 µSv/y. However, separate dose constraint values for each nuclear installation will in future be proposed by Eskom and to be approved by the NNR.

A screening radiological risk assessment was carried out for non-human biota assuming simultaneous operational discharges from the NNPS and KNPS.

7.2 Regulatory Framework

The description of the existing and planned activities on the site was developed based on the current national legal and regulatory framework presented in Chapter 2 (Legal and Regulatory Basis) and more specifically:

- the National Nuclear Regulator Act, 1999 (Act No. 47 of 1999 (Republic of South Africa, 1999), Reference 3.1, Section 2 (1)(a)) of the Act applies to the siting, design, construction, operation, decontamination, decommissioning and closure of any nuclear installation.
- R.927: The Regulations on Licensing of Sites for New Nuclear Installations (Department of Energy, 2011). Regulation 5(2)) requires:
- ‘A statement as to the proposed use of the site in terms of the range of technologies and plant designs being considered for the nuclear installation(s) and use on the site, including where appropriate the maximum thermal power, general design characteristics such as the engineered safety features of the nuclear installation(s) included as safety measures against the hazardous consequences of postulated events, and the layout on the site.’
- R.388: Regulations in Terms of Section 36, Read with Section 47 of the Act (Department of Minerals and Energy, 2006), Sections 2.4 Licensing and 3.3 Prior Safety Assessment.

The above Act and regulations are supported by the following requirements and guidelines documents that have relevance to PRIPE:

- RD-0022, Radiation Dose Limitation at Koeberg Nuclear Power Station (National Nuclear Regulator, 2008a);
- RD-0024, Requirements on Risk Assessment and Compliance with Principal Safety Criteria for Nuclear Installations (National Nuclear Regulator, 2008b);
- RD-0034, Quality and Safety Management Requirements for Nuclear Installations (National Nuclear Regulator, 2008c);
- RG-0011, Interim Guidance on the Siting of Nuclear Facilities (National Nuclear Regulator, 2016a);
- RG-0016, Guidance on the Verification and Validation of Evaluation and Calculation Models used in Safety and Design Analyses (National Nuclear Regulator, 2016b);
- RG-0019, Guidance on the Safety Assessments of Nuclear Facilities (National Nuclear Regulator, 2018).

- RG-0027, Interim Regulatory Guide: Ageing Management and Long Term Operations of Nuclear Power Plants (NNR, 2019).
- RG-0028, Interim Regulatory Guide: Periodic Safety Review of Nuclear Power Plants. Centurion: National Nuclear Regulator (NNR, 2019).

7.3 Dose Assessment Methodology

7.3.1 Regulatory Dose Criteria

Regulations (in (Department of Minerals and Energy, 2006)) specify an effective dose limit from all authorised actions of 1 mSv. For the purposes of this prospective dose assessment, the effective dose to the representative person from all nuclear facilities on the site is compared to the current KNPS dose constraint of 250 µSv/y. Separate dose constraint values for each nuclear installation on the Duynefontyn site will in future be proposed by Eskom and to be approved by the NNR.

7.3.2 Sources of ionising radiation

PRIPE is assessed for sources:

- KNPS and NNPS airborne radioactive discharges;
- KNPS and NNPS liquid radioactive discharges;
- external radiation from the TISF and the containment structures of KNPS and NNPS.

Liquid and airborne source terms for normal and continuous NNPS operational discharges were derived from data of new nuclear power stations (NPSs) representative of GEN III NPS technologies. The radionuclide composition of each reactor type's source term was considered. Enveloping airborne and liquid source terms were constructed by selecting the maximum radionuclide specific source term when comparing the four different NPSs technologies. The source terms were adjusted to 4 000 MWe. The NPS technologies considered and the methodology to calculate an enveloping source is described in ***Appendix 7.A***.

The source terms for KNPS Long Term Operation (LTO) are provided by the revised Activity Migration Model (Eskom, 2022). The source terms are included in ***Appendix 7.C***.

Dose assessments were carried out with the code PC-CREAM 08 (Smith, 2015) to derive site DCFs for each radionuclide in the airborne and liquid source terms. The DCFs were derived based on the methodology developed for KNPS (Eskom, 2021). The DCFs are applied to the source terms for KNPS LTO and the NNPS to estimate the annual dose to the representative person selected from members of the public for the site.

The dispersion factors for liquid discharges to the sea and the atmosphere included in the DCFs are specific to KNPS. The application of the KNPS DCFs to the NNPS when considering the difference in locations of the NNPS discharges when compared to those of KNPS were assessed to confirm the validity of their use for the NNPS. The assessment is discussed in Section 7.3.3 below.

7.3.3 Dispersion of NNPS Normal Operational Discharges

The site specific atmospheric and marine dispersion and transfer data in environmental media (soil, biota and foodstuff) used to calculate site DCFs for the representative person for KNPS are bounding in respect of the NNPS (Eskom, 2021). The site specific DCFs can therefore be applied to the NNPS source terms for liquid and airborne discharges. This can be concluded when comparing the relative locations of discharges to the environment and the representative person as illustrated in ***Figure 7.1*** and ***Figure 7.2*** (see ***Chapter 3*** for preliminary layout of NNPS).

The DORIS marine compartment selected in PC-CREAM 08 model for KNPS to derive DCFs includes the proposed location of the NNPS liquid discharge to the sea and is shown in ***Figure 7.1***. The dispersion of NNPS liquid discharges is therefore equivalent to that of KNPS for purposes of calculating the dose (Eskom, 2021). It is, however, expected that the dilution for NNPS discharges will be much higher than for KNPS. KNPS liquid discharges are into the surf zone and result in poorer dilution and higher radioactivity concentrations when compared to the NNPS discharge that is proposed to be further into the sea and well beyond the surf zone.

The atmospheric dispersion of NNPS discharges from a future stack approximately 1.5 km NNE of KNPS was assessed to confirm that the airborne concentrations for the same source term assumed for KNPS, when discharged from NNPS, are not higher than those of KNPS. The DCFs when applied to the NNPS discharges will therefore not underestimate the dose to the representative person.

Source terms representative of KNPS reported annual discharges (Eskom, 2021) and the resulting dose to the representative person from three critical nuclides, C-14, H-3 and I-131, were modelled for the two different stack locations representing KNPS and NNPS. A summary of the results in ***Table*** 7.1 shows the dose from NNPS discharges to be less than the dose from the same discharge quantities when applied to KNPS. The detailed results are included in ***Appendix 7.D***. The airborne dose for the KNPS DCFs is therefore conservative in respect of the NNPS airborne dose.

Table 7.1: A comparison of the dose to the representative person from airborne discharges from the different KNPS and NNPS stack locations

Stack: KNPS	**Source Term;** Bq/y	**Dose; µSv/y**
C-14	1.06E+11	7.30E-01
H-3	7.90E+12	2.20E-01
I-131	1.38E+08	3.28E-02
	Total =	**9.83E-01**
Stack: NNPS (1.5 km NE of KNPS)	**Source Term;** Bq/y	**Dose; µSv/y**
C-14	1.06E+11	3.02E-01
H-3	7.90E+12	9.11E-02
I-131	1.38E+08	1.12E-02
	Total =	**4.05E-01**

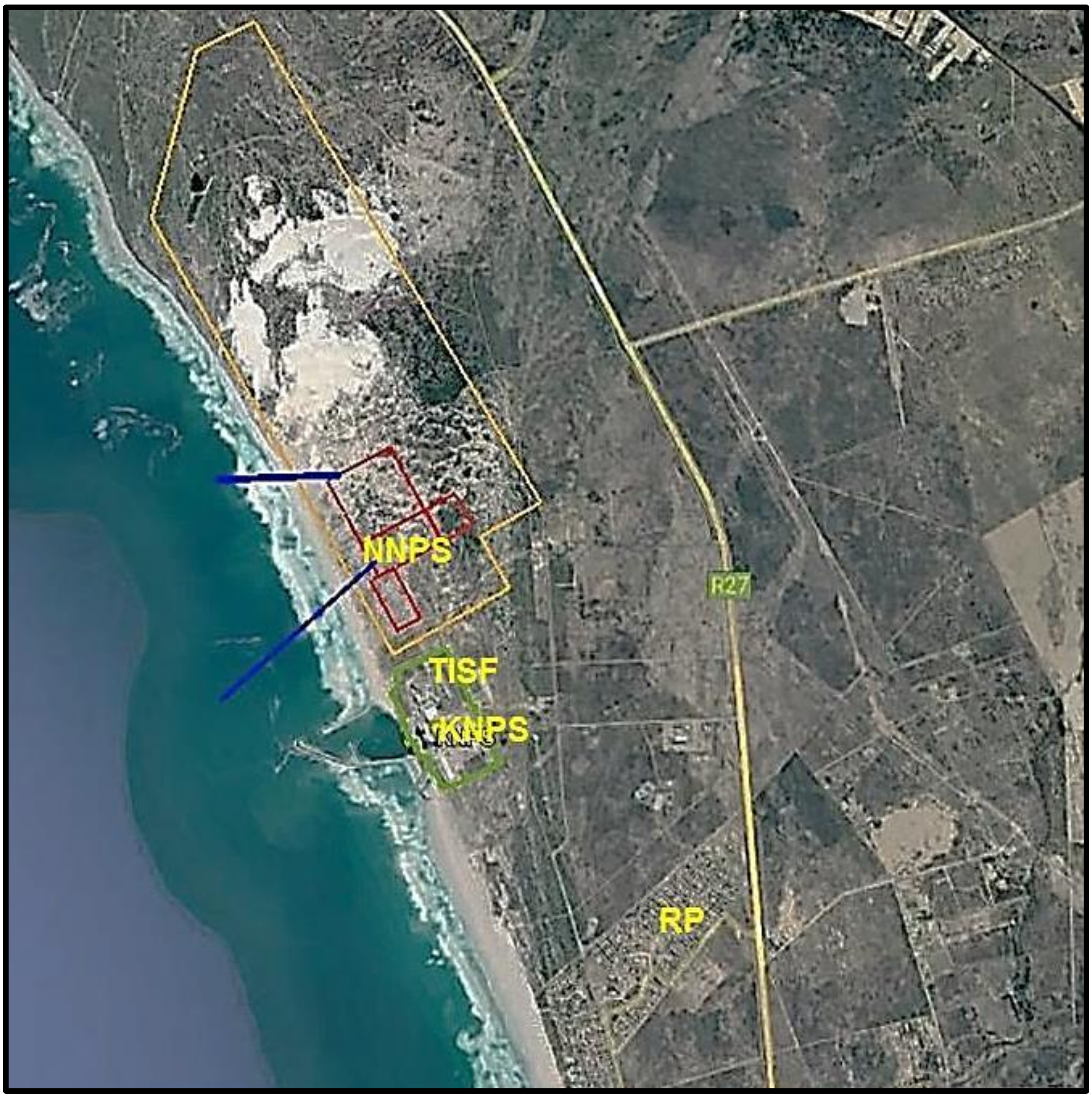

Figure 7.1: Relative Positions of KNPS, NNPS and Representative Person (RP)

Figure 7.2: Discharge to the Sea from KNPS and NNPS

7.3.4 Direct External Radiation Exposure from Structures Containing Irradiated and Spent Nuclear Fuel

Direct radiation from the nuclear installation(s) can potentially contribute to the public dose. In the case of KNPS and a NNPS the main sources are constituted by the facilities contained in the reactor building. The predominant source is the neutron flux from the reactor core. The KNPS safety evaluation of dose to an individual at the most exposed points at the boundary of the Owner-Controlled Area (OCA[1]), for example, showed that

[1] Owner Controlled Area: The owner-controlled area is an area outside of a restricted area, but inside the site boundary, to which the licensee can limit access for any reason. The boundary of the site, the limit of the Owner Controlled Area.

the thickness of the reactor building walls that has been set considering the required mechanical strength under the reference accident conditions, is a thickness that is in excess of what is required for the radiological protection of the environment (Eskom).

Monitoring results of the Koeberg Environmental Surveillance Laboratory (ESL) surveillance programme show that some areas in the public domain show higher dose values when compared to monitoring results inside the OCA. This is because of variations in terrestrial radiation associated with naturally occurring radioactivity in the underlying geological strata. Exposure and public dose due to direct external radiation from the nuclear installations and measured at the OCA boundary should continue to indicate negligible dose in the future.

Eskom proposes to construct a TISF for the temporary storage of dry casks at KNPS to accommodate used nuclear fuel from the reactors for the operational life of the power station, thereby ensuring the continued safe operation of KNPS (Eskom, 2020). The TISF will be constructed on a portion of vacant land within the KNPS protected area. The TISF will comprise of concrete pads within a site footprint of approximately 12 800 square metres. It will be constructed to accommodate up to 160 dry storage casks, which will be placed on the pads in a modular manner over time. The dry storage casks will be either metal or concrete. The casks that are to be used at KNPS must be designed to provide adequate intrinsic radiological shielding of both gamma and neutron radiation. These casks are sealed and allow for zero leakage of gasses or solid material.

Direct radiation is discussed further in ***Section 7.5.3***.

7.4 The Representative Person

The exposure pathways and habits data upon which the definition of the site representative person is based are described in the dose assessment methodology (Eskom, 2021). The methodology was also used to derive the site DCFs.

The most restrictive DCFs, and therefore the most conservative dose, is for an urban resident and in the age category ‘child’. It is designated as representative IRP01 in the PRIPE Methodology. IRP01 was selected from two sets of critical groups and three age groups (infant, child and adult) which are defined as follows:

- IRP01: An urban resident living in proximity of the beachfront and site boundary, thus experiencing a combined exposure to liquid and airborne discharge exposure pathways. The types of houses provide a high shielding factor because of their construction and limit exposure pathways that involve inhalation and plume exposure. Terrestrial foodstuff consumption grown locally is limited, consisting mainly of fruit and broadleaf vegetables from garden patches, as well as chicken and eggs. Seafood consumption consisting of locally caught fish could be high as well as the time spent on the beach and intertidal zone.

- IRP02: A resident in an informal settlement who could be more exposed to pathways from airborne discharges than the urban resident in IRP01. IRP02 may be more self-reliant on food production compared to IRP01. Exposures to liquid discharge pathways are expected to be less when compared to IRP01.

The DCFs are included in ***Appendix 7.C***.

7.5 Source Terms and Annual Dose Assessment Results

7.5.1 KNPS Dose from Airborne and Liquid Discharges

The normal operations source term for the KNPS LTO prospective dose assessment was provided by the KNPS Nuclear Engineering: Nuclear Analysis and Siting (Eskom, 2022). ***Appendix 7.C*** includes the source terms and the doses per nuclide. The results for the representative person are summarised in ***Table 7.2***.

Table 7.2: KNPS Dose from airborne and liquid discharges

Discharge pathway	KNPS LTO dose, µSv/y
Liquid	61.4
Airborne	32.6
Total	94.0

7.5.2 NNPS Dose from Airborne and Liquid Discharges

A methodology to develop enveloping source terms using design data of operational discharges from four PWR GEN III type reactors is described in ***Appendix 7.A***.

The representative person age group for which the highest dose is calculated in ***Appendix 7.B*** is for the age group '*infant*'. The age group is different to that of KNPS because of the difference in sets of nuclides comprising the source term as reported for each technology. The range of DCFs for each technology is therefore different.

Table 7.3: NNPS Dose from airborne and liquid discharges

Representative Person	Airborne, µSv/y	Liquid, µSv/y	Total Dose, µSv/y
IRP01 - Adult	34,2	11.3	45.5
IRP01 - Child	27.1	9.3	36.4
IRP01 - Infant	39.6	6.8	46.4
Note: All three age groups are reported whereas for KNPS the age group represented by 'Child' results in the maximum dose for IRP01.			

7.5.3 Direct External Radiation

Direct external radiation (gamma and neutron radiation) from the different nuclear installations can potentially contribute to the public dose. The current KNPS direct radiation makes a negligible contribution to annual dose based on monitoring carried out by the ESL surveillance programme.

Two sets of thermoluminescent dosimeters (TLDs) are employed at KNPS for direct radiation monitoring. Twenty-nine (29) TLDs which are replaced every month are located in three roughly concentric rings as follows:

- the inner perimeter fence: 0.6 km to 1 km;
- the public exclusion boundary: 1.5 km to 2.9 km;
- rural areas: 3.3 km to 10.5 km from Koeberg.

Most of these TLDs are strategically located such that there is at least one in each of the 16 geographical sectors. Nineteen (19) TLDs are located further afield and are replaced every three months at the following localities:

- urban areas such as Mamre, Atlantis, Table View, Milnerton, Durbanville, Epping, Pinelands, Woodstock, Sea Point, and Robben Island;
- TLDs are located on farms.

The direct external radiation from the current nuclear installations (KNPS and CSB) is not distinguishable from the natural background radiation at the OCA boundary. Some areas in the public domain and at a greater distance than the OCA boundary show higher values. This is a result of variations in terrestrial radiation associated with naturally occurring radioactivity in the underlying geological strata as reported earlier. It is expected that a similar situation will apply should an NNPS be added to the site.

It is not clear, however, if the TISF may contribute to the representative person dose. A screening assessment of the TISF direct radiation was carried out as follows:

- The external radiation dose for the representative person was estimated based on a safety study carried out for the GNS and HI-STAR-100 spent fuel casks (Eskom, 2018).
- The dose results from direct radiation for a single cask were extrapolated to represent dose accrued for a full year (8766 h) at the various distances from a total of 160 casks containing spent fuel.
- The representative person was located in the nearest residential area which is approximately 2 000 m away to the SE.
- The results are included in ***Table 7.4*** and illustrated in ***Figure 7.3***.

Table 7.4: TISF External radiation dose as a function of distance

Distance, m	Single cask, mSv/h	No. of casks	µSv/y
500	1.40E-03	160	1.96E+03
1000	1.84E-05	160	2.58E+01
1500	2.42E-07	160	3.39E-01
2000	3.18E-12	160	4.46E-03

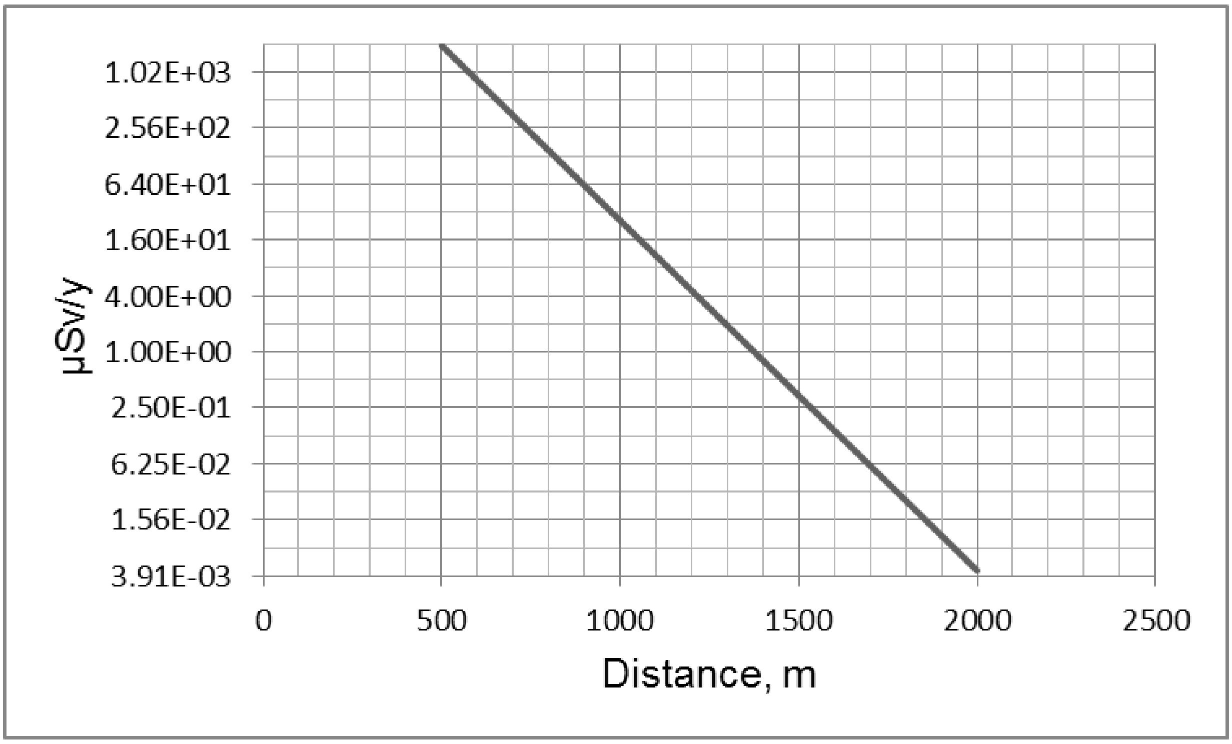

Figure 7.3: TISF External radiation dose as a function of distance

It can be concluded that the TISF dose contribution to the representative person will be negligible.

The KNPS old steam generators will be stored in a specially constructed building adjacent to the TISF. Dose rates on the external surfaces of the building were assessed in (Necsa, 2020). It is concluded that the TISF external radiation envelopes the OSG results.

7.5.4 Representative Person Total Annual Dose

The dose calculated for the NNPS is less than for KNPS. The probable reason for this is that different vendors include different design data and specifically data representing improved GEN III waste management systems compared to that of KNPS.

The total dose is reported for the age group 'child', the age group with highest dose for KNPS, although the 'infant' age group is estimated to receive the highest dose from an NNPS. The total dose (age group Child) for the three types of nuclear installations, KNPS, NNPS and TISF respectively, is estimated to be:

94.0 µSv/y + 36.4 µSv/y + 4.46E-03 µSv/y = 130.4 µSv/y.

7.6 Radiological Impact on Non-Human Biota

The latest version of the ERICA Assessment Tool (version 2.0.185) was used to estimate the ionising radiation dose to non-human biota at the site (Beresford, 2007). Dose rate screening values can be selected as follows:

- ERICA's default incremental screening dose rate value of 10 µGy/h for all ecosystems, or
- 40 µGy/h for terrestrial animals or 400 µGy/h for terrestrial plants. For aquatic species a value of 40 µGy/h is applied to mammals, reptiles, amphibians and birds or 400 µGy/h for all other species. These numbers are derived from the IAEA and UNSCEAR (United Nations Special Committee on the Effects of Atomic Radiation) reports and are really benchmarks below which populations are unlikely to be significantly harmed based on reviews of the scientific literature. These also correspond to the US DoE (US Department of Energy) dose limit of 10 mGy/d (approximately 400 µGy/h) for native aquatic animals and benchmarks of 400 and 40 µGy/h for terrestrial plants and terrestrial animals, respectively used in the US DoE's graded approach.

The default screening value of 10 µGy/h used for all ecosystems and organisms is a proposed generic screening value that below which 95% of all species should be protected from ionising radiation. The 10 µGy/h criterion is a screening value which should be used to screen out sites of low concern. It is not intended that this screening value be used as a dose rate limit. There is consensus that dose rates below 40 µGy/h, indicate that there will be no adverse effects.

ERICA assessments can be carried out at three levels:

- Tier 1 is simple and conservative; it requires a minimal amount of input data, the user can select radionuclides from a default list, and the results are for the most sensitive combination of reference organisms.
- Tier 2 is more specific and less conservative; the user can enter input data such as radionuclides that are not on the default list and edit transfer parameters. The results are calculated for each reference organism individually.
- The situations requiring a Tier 3 assessment are likely to be complex

and unique. Tier 3 is a probabilistic risk assessment in which uncertainties within the results may be determined using sensitivity analysis. A Tier 3 assessment requires consideration of biological effects data

ERICA Tier 2 risk assessments were carried out for marine and terrestrial reference organisms using site specific data and listed in ***Appendix 7.E***.

The estimated total (internal and external summed) dose rates for each reference organism included in the assessment are compared with the dose rate screening values. A risk quotient, RQ, for each specific radionuclide selected for inclusion in the assessment is calculated as follows:

- $RQ_{ro} = (DR^{ro}_{Tot}) \div (SDR)$
- RQ_{ro} = Risk quotient for reference organism 'ro';
- DR^{ro}_{Tot} = total (weighted or unweighted) absorbed dose-rate (µGy/h) for each reference organism 'ro', and
- SDR = the screening dose rate (µGy/h) selected

If the RQs are below 1 for all organisms then the assessment has not exceeded the screening level. An uncertainty factor of 3 or 5 (or higher) was used and therefore there is a low probability that the estimated dose rate to any organism exceeds the incremental screening dose rate if RQs are below 1. The resulting risk to non-human biota can then be considered to be trivial.

If the expected value RQ (and by implication the conservative RQ) is above 1 for any organism then the assessment has exceeded the screening value at Tier 2 and the ERICA Tool will recommend that further assessment be conducted

7.6.1 Marine organisms

Two important element specific input parameters that are required are:

- KD distribution coefficients that defines the partitioning of the nuclides between the dissolved and solid phases, and
- CR values of nuclide concentrations in organisms relative to the environmental media.

Default values are available in ERICA for the nuclides included in the site assessment except for iron (Fe) and molybdenum (Mo). KD and CR coefficients are required to calculate the biota dose resulting from Fe-55, Fe-59 and Mo-99. KD data was obtained from PC=CREAM 08 software default values and the CR values for Fe and Mo were selected to be chromium (Cr) and tin (Sn). These elements resemble Fe and Mo the closest. The selections were done following the recommendations in ERICA in the absence of empirical data:

- Use an available CR value for an organism of similar taxonomy within that ecosystem for the radionuclide under assessment (a preferred option) – for example, a value for marine pelagic fish was assumed to be applicable to marine benthic fish.
- Use an available CR value for a similar reference organism (a preferred approach) – for example, available CR values for one vertebrate reference organism were applied to other vertebrate reference organisms.
- Use CR values recommended in previous reviews or derive them from previously published reviews (a preferred approach) - in some instances, it was necessary to use broad reviews of stable element concentrations in media and biota to derive CR values or adopt previously recommended values without being able to go back to the source reference to confirm these.
- Use specific activity models for H-3 and C-14 (a preferred approach) - specific activity models were used to derive H-3 and C-14 CR values for all reference organisms in terrestrial ecosystems (no values were based on observed data).
- Use an available CR value for the given reference organism for an element of similar biogeochemistry; for instance, available CR values for transuranic and lanthanide elements were used if CRs were not available for another member of these series.
- Use an available CR value for biogeochemically similar elements for organisms of similar taxonomy; for instance, actinide element CRs for marine reptiles were assumed to be the same value as for marine birds.
- Use an available CR value for biogeochemically similar elements available for a similar reference organism - for instance, Nb CRs for marine vertebrates were derived from available Zr values.
- Use allometric relationships, or other modelling approaches, to derive appropriate CRs - for instance, CRs for wild bird eggs were derived from available CRs for wild birds and published relationships between radionuclide concentrations in eggs and meat of domestic poultry. Assume the highest available CR (a least preferred option) - this option was used on a few occasions only to provide Po and Tc

CR values for terrestrial invertebrate reference organisms and a small number of Ru and C CRs for freshwater reference organisms.

- For aquatic ecosystems use (if justified) an appropriate CR value for the reference organism in a different ecosystem (a least preferred option); in the ERICA freshwater database, CR values for the same reference organism in the marine ecosystem (from the ERICA marine database) were assumed for a limited number of freshwater CR values.

The procedure that was followed to prepare site specific input data for ERICA (marine biota) was as follows:

- Select unfiltered seawater and sediment concentrations per unit nuclide activity from DORIS marine dispersion results used in the PRIPE Method Document (Eskom, 2021). The 60-year integrated values are used.
- The NNP and KNPS liquid source terms are summed and the total nuclide specific unfiltered seawater and sediment concentrations are calculated.
- Select the principal nuclides from the site liquid source term and use their unfiltered seawater and sediment concentrations as input data to ERICA Tier 2. The principal nuclides are selected by assessing the nuclide importance in respect of its Environmental Media Concentration Limits (EMCL Bq/l) provided in ERICA Tier 1 and the total liquid source term per nuclide.

The data used in the procedure are included in ***Appendix 7.E***, ***Table 7.E.1*** to ***Table 7.E.4***.

The results of the risk assessment for marine reference organisms are shown in ***Table 7.5***. It is concluded that the liquid discharges from NNPS and KNPS are unlikely to pose a risk.

Table 7.5: ERICA marine organisms - screening value equal to 10 µGy/h

Organism	Total Dose Rate per organism (µGy/h)	Screening Value (µGy/h)	Risk Quotient (expected value) (unitless)	Risk Quotient (conservative value) (unitless)
Benthic fish	5.73E-01	1.00E+01	5.73E-02	1.72E-01
Bird	2.09E-01	1.00E+01	2.09E-02	6.27E-02
Crustacean	5.99E-01	1.00E+01	5.99E-02	1.80E-01
Macroalgae	4.33E-01	1.00E+01	4.33E-02	1.30E-01
Mammal	6.00E-01	1.00E+01	6.00E-02	1.80E-01
Mollusc - bivalve	5.20E-01	1.00E+01	5.20E-02	1.56E-01
Pelagic fish	2.64E-01	1.00E+01	2.64E-02	7.92E-02
Phytoplankton	9.25E-02	1.00E+01	9.25E-03	2.78E-02
Polychaete worm	9.01E-01	1.00E+01	9.01E-02	2.70E-01
Reptile	5.92E-01	1.00E+01	5.92E-02	1.78E-01
Sea anemones & True coral	4.07E-01	1.00E+01	4.07E-02	1.22E-01
Vascular plant	4.11E-01	1.00E+01	4.11E-02	1.23E-01
Zooplankton	1.12E-01	1.00E+01	1.12E-02	3.37E-02

7.6.2 Terrestrial organisms

The procedure that was followed to prepare site specific input data for ERICA (terrestrial biota) was as follows:

- The relative importance of the nuclides in the airborne source term was determined by calculating the ratio of the product of the nuclide's source term and its EMCL value to the product of the C-14 source term and EMCL value.

C-14 has the lowest EMCL value, i.e. the highest dose per unit activity. Nuclides that have a value less than 1E-06 were screened out because of its negligible dose contribution.

- The soil activity of each nuclide following build-up over 60 years continuous discharge, is calculated using the results of PLUME and GRANIS in the PC-CREAM 08 code system that was used to calculate the DCFs. The input data are included in ***Appendix 7.E***, ***Table 7.E.5*** to ***Table 7.E.8***.

The results of the dose assessments for terrestrial reference organisms exceed the default ERICA screening value of 10 µGy/h. However, when the dose rates per organism is screened against 40 µGy/h the RQ ‘expected’ values (as opposed to the conservative RQ values) are less than 1. The conservative RQ values exceed 1 for most organisms. These conservative results must be interpreted by considering the very conservative NNPS and KNPS airborne source terms and the most conservative PLUME atmospheric concentrations. Deposition data was selected from PLUME output at 500 m, the distance of maximum deposition, from a 10 m high discharge point in an SSE wind sector. This is the sector where highest deposition occurs.

Table 7.6: ERICA terrestrial organisms - screening value equal to 40 µGy/h

Organism	Total Dose Rate per organism (µGy/h)	Screening Value (µGy/h)	Risk Quotient (expected value) (unitless)	Risk Quotient (conservative value) (unitless)
Amphibian	3.63E+01	4.00E+01	9.07E-01	2.72E+00
Bird	1.75E+01	4.00E+01	4.37E-01	1.31E+00
Mollusc - gastropod	1.51E+01	4.00E+01	3.78E-01	1.13E+00
Reptile	3.38E+01	4.00E+01	8.44E-01	2.53E+00
Annelid	3.48E+01	4.00E+01	8.71E-01	2.61E+00
Arthropod - detritivorous	3.50E+01	4.00E+01	8.74E-01	2.62E+00
Flying insects	1.45E+01	4.00E+01	3.62E-01	1.09E+00
Grasses & Herbs	1.64E+01	4.00E+02	4.11E-02	1.23E-01
Lichen & Bryophytes	1.54E+01	4.00E+02	3.84E-02	1.15E-01
Mammal - large	1.57E+01	4.00E+01	3.92E-01	1.18E+00
Mammal - small-burrowing	3.55E+01	4.00E+01	8.87E-01	2.66E+00
Shrub	1.43E+01	4.00E+02	3.57E-02	1.07E-01
Tree	1.46E+01	4.00E+02	3.65E-02	1.09E-01

7.7 Verification & Validation

The Commercial-Off-The-Shelf (COTS) software, PC-CREAM 08, was used to assess public dose resulting from the normal operational radioactive discharges of NPSs included in the scope of Eskom SSRs.

The freely available COTS software ERICA Tool (ET) was used for non-human biota radiological risk from normal discharges defined for PC-CREAM 08 and used in the SSRs.

The verification and validation aspects of the PC-CREAM 08 software and the associated ERICA tool are described in (Eskom, 2023).

7.8 Monitoring

Monitoring of environmental radioactivity by the KNPS ESL on the Duynefontyn site and region and analysis of actual levels of radioactivity in environmental media and food commodities is on-going. It will be expanded to include the NNPS.

Periodic surveys are carried out of land and marine use, demographical changes and include reviews of the data used for the characterisation of the representative person.

7.9 Management System

The PRIPE investigations performed in this SSR entailed the following:

- application of the revised methodology to assess the ionising radiation dose for members of the public from normal operation at the Duynefontyn site;
- derivation of a bounding source term for annual atmospheric and liquid discharges based on the selection of the reference reactor technologies.

The following documents were compiled by the consultant and accepted by Eskom to assist in quality assurance and to present a clear and auditable trail showing how key decisions were made and conclusions reached:

- SRK's Integrated Quality Management System and associated Work Instructions;
- the project-specific Project Quality Plan;
- Methodology Document;

- Quality Control Plan;
- Project Process Chart.

Input data to PRIPE also relies on the KNPS quality management system. This conforms to the overall management system for this SSR (***Chapter 10***, Management System), national regulations, international guidelines as outlined in documents of national authorities and relevant Eskom classification procedures.

Table 7.7 lists the activities carried out, the links to other SSR sections/chapters and the relevant quality control requirements.

Table 7.7: Summary of Activities, Links and Quality Requirements

Activity	Links		Quality Requirements
	Inputs	Outputs	
Request KNPS source term data and site methodology for dose assessment	KNPS Activity Migration Model and PRIPE Methodology	Representative dose	Eskom review,
Demonstrate compliance with regulatory requirements	***Chapter 2*** (Legal and Regulatory Basis).	***Chapter 7*** (Potential Radiological Impact on the Public and the Environment). Dose compliance assessment.	Independent review.
Obtain demography related information	***Chapter 5.4*** (Demography).	***Chapter 7*** (Potential Radiological Impact on the Public and the Environment). Dose compliance assessment	Eskom review.

A regulatory compliance table is presented in ***Table 7.8*** to indicate the relevant issues that have been dealt with in this section.

Table 7.8: Regulatory Compliance Matrix

Act/Regulation	Section/Regulation	Issue	Section Where Covered
Regulations on Siting of New Nuclear Installations	Regulation 5 (6)	Assessment of potential impact of operations on public exposure. Demonstrate compliance with regulatory dose criteria	7.3
Regulation R. 388	Regulation 5(5)	Annual effective dose limit to members of the public	7.3
Regulation R. 388	Regulation 1(2)(xvii)	Dose constraints	7.5
Regulation R. 388	Regulation 1(2)(xiv)	Source terms and discharges	7.5
Requirements Document RD-0034	Section 7	Management systems	7.9

7.10 Conclusions

PRIPE was assessed for three nuclear facilities, KNPS, NNPS and TISF, assuming simultaneous operation during a period of 60 y. The dose to members of the public, calculated in terms of a representative person (age group 'child'), is as follows:

- Total annual dose = 94.0 µSv/y (KNPS) + 36.4 µSv/y (NNPS) + 4.46E-03 µSv/y (TISF) = 130.4 µSv/y.

The dose is less than the NNR dose limit as well as the current KNPS dose constraint of 250 µSv/y.

A screening dose rate assessment was done for non-human biota. It is concluded that the liquid and airborne discharges from a NNPS and KNPS are unlikely to pose a radiological risk.

7.11 References

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Appendix 7.A: NNPS Source Terms

A bounding NNPS source term is calculated for the site that represents 4 000 MWe energy generated by typical GEN III technology NNPS. The source term is derived as follows:

The annual operational discharges, liquid and airborne, of four reference GEN III NNPS are selected. The NNPS are:

a) AP1000 – U.S.A. (Westinghouse, 2007)
b) EPR – France (AREVA, 2007)
c) AP1400 – Korea (KEPCO, 2018)
d) HPR1000 - China (GNS, 2020)

It is important to note that the different vendors report different sets of nuclides for normal operational discharges (also referred to as radionuclide vectors) and which do not necessarily overlap, i.e., different nuclide vectors per reactor type. Empty spaces in ***Table 7.A.2*** to ***Table 7.A.5*** indicate no values reported for the specific NNPS in the vendor reference documents.

A reactor thermal power that equates to 4 000 MWe is calculated for each of the NNPS reactor type as is shown in ***Table 7.A.1***.

Table 7.A.1: Equivalent Reactor Thermal Power for Representative NNPS

Parameter	AP1000	EPR	APR1400	HPR1000
MWe per reactor unit	1117	1710	1400	1180
MWth per reactor unit	3415	4500	3983	3500
MWe / MWth per reactor unit	0.33	0.38	0.35	0.34
Reactor MWth / 4000 MWe	12229	10526	11380	11864

The annual radionuclide specific discharges for liquid and airborne are listed and converted to nuclide specific source term per unit reactor thermal power, MWth, for each reactor types; please refer to ***Table 7.A.2*** and ***Table 7.A.3.***

The total source term for each radionuclide discharged as liquid or airborne when generating 4 000 MWe by either of the reactor types is calculated and the maximum value is selected and used in PRIPE; refer to ***Table 7.A.4*** and ***Table 7.A.5***.

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Appendix 7.E: Non-human Biota Dose – ERICA Assessment Tool Input Data

Table 7.E.1: Sediment and unfiltered seawater radioactivity per unit liquid nuclide discharge calculated with DORIS

Radionuclide **Note: Nuclides identified by an asterisk (*) are progeny of a preceding nuclide.**	**Seabed sediment (Bq/kg)**	**Unfiltered seawater (Bq/L)**
Ag-110m	2.28E-10	4.61E-13
As-76	1.43E-14	3.53E-14
Ba-139	6.62E-17	1.98E-15
Ba-140	1.72E-12	2.34E-13
La-140*	7.59E-12	2.05E-13
Be-7	1.19E-11	3.91E-13
Br-82	2.52E-14	4.63E-14
Br-84	6.25E-18	7.65E-16
C-14	4.02E-10	4.99E-13
Ce-141	1.67E-10	3.00E-13
Ce-144	1.83E-09	3.95E-13
Co-57	1.46E-09	4.07E-13
Co-58	3.54E-10	3.61E-13
Co-60	8.30E-09	4.38E-13
Cr-51	5.90E-11	3.10E-13
Cs-134	2.98E-10	4.85E-13
Cs-136	3.05E-12	2.37E-13

Radionuclide **Note: Nuclides identified by an asterisk (*) are progeny of a preceding nuclide.**	**Seabed sediment (Bq/kg)**	**Unfiltered seawater (Bq/L)**
Cs-137	1.31E-09	4.97E-13
Cs-138	1.71E-17	7.74E-16
Cu-64	1.96E-14	1.77E-14
Fe-55	2.55E-09	4.59E-13
Fe-59	1.08E-10	3.54E-13
H-3	3.59E-12	4.98E-13
Hf-181	2.23E-10	3.22E-13
Hg-203	1.36E-10	3.53E-13
I-129	3.12E-11	5.00E-13
I-130	1.50E-15	1.72E-14
I-131	2.37E-13	1.79E-13
Xe-131m	3.00E-13	9.79E-14
I-132	5.36E-17	3.30E-15
I-133	4.15E-15	2.83E-14
Xe-133	1.79E-14	2.08E-14
I-134	7.82E-18	1.26E-15
I-135	4.37E-16	9.37E-15
Xe-135*	9.58E-16	9.13E-15
Cs-135*	5.45E-19	1.56E-22

Radionuclide **Note: Nuclides identified by an asterisk (*) are progeny of a preceding nuclide.**	**Seabed sediment (Bq/kg)**	**Unfiltered seawater (Bq/L)**
La-140	1.46E-12	5.09E-14
Mn-54	1.99E-09	3.98E-13
Mn-56	6.78E-15	3.69E-15
Mo-99	1.50E-12	7.89E-14
Tc-99m*	1.50E-12	7.76E-14
Tc-99*	1.04E-17	1.46E-20
Na-24	1.96E-15	2.08E-14
Nb-94	3.37E-08	4.85E-13
Nb-95	1.74E-10	3.08E-13
Nd-147	2.81E-11	2.02E-13
Pm-147*	5.80E-11	2.57E-15
Sm-147*	7.62E-21	1.69E-26
Ni-59	7.55E-09	4.97E-13
Ni-63	6.77E-09	4.94E-13
Np-239	6.11E-14	7.02E-14
Pu-239*	4.84E-15	1.13E-19
U-235*	3.97E-23	1.87E-28
Pa-231*	1.38E-26	2.92E-32
Ac-227*	4.31E-27	9.15E-33
Ra-223*	4.30E-27	1.07E-32

Radionuclide Note: Nuclides identified by an asterisk (*) are progeny of a preceding nuclide.	Seabed sediment (Bq/kg)	Unfiltered seawater (Bq/L)
Pb-211*	4.30E-27	1.07E-32
Bi-211*	4.30E-27	1.07E-32
Tl-207*	4.30E-27	1.07E-32
P-32	6.04E-13	2.49E-13
Pr-143	5.16E-11	2.18E-13
Pr-144	8.73E-17	4.16E-16
Rb-88	5.23E-18	4.28E-16
Rb-89	3.81E-18	3.66E-16
Sr-89*	3.56E-16	8.12E-17
Rh-105	1.50E-14	4.63E-14
Rh-106	9.11E-22	1.20E-17
Ru-103	8.08E-11	3.46E-13
Ru-105	7.02E-15	6.33E-15
Rh-105*	8.86E-15	5.74E-15
Ru-106	9.16E-10	4.49E-13
Sb-122	7.86E-14	7.88E-14
Sb-124	8.71E-12	4.02E-13
Sb-125	1.25E-10	4.91E-13

Radionuclide **Note: Nuclides identified by an asterisk (*) are progeny of a preceding nuclide.**	**Seabed sediment (Bq/kg)**	**Unfiltered seawater (Bq/L)**
Te-125m*	1.24E-10	9.79E-14
Sb-126	1.05E-12	2.31E-13
Sb-127	1.50E-13	1.05E-13
Te-127*	1.65E-13	1.02E-13
Se-75	1.87E-11	4.44E-13
Sn-113	7.26E-10	3.71E-13
Sn-123	8.21E-10	3.75E-13
Sr-89	1.69E-12	3.88E-13
Sr-90	6.73E-12	4.99E-13
Sr-91	8.19E-16	1.34E-14
Y-91m*	8.33E-15	1.33E-14
Y-91*	2.13E-12	2.25E-15
Sr-92	6.83E-17	3.88E-15
Y-92*	9.31E-15	3.84E-15
Tc-99m	3.77E-16	8.55E-15
Tc-99*	1.34E-19	1.59E-21
Te-123m	1.86E-11	4.44E-13
Te-123*	1.26E-23	1.80E-27
Te-127m	1.69E-11	4.40E-13

Radionuclide **Note: Nuclides identified by an asterisk (*) are progeny of a preceding nuclide.**	**Seabed sediment (Bq/kg)**	**Unfiltered seawater (Bq/L)**
U-237	3.96E-13	1.59E-13
Np-237*	3.47E-18	2.94E-21
U-233*	1.35E-22	1.34E-27
Th-229*	2.25E-25	4.83E-31
Ac-225*	2.25E-25	4.80E-31
Bi-213*	2.25E-25	4.81E-31
Pb-209*	2.25E-25	4.81E-31
W-187	1.58E-13	3.22E-14
Re-187*	1.48E-23	2.55E-26
Xe-127	9.16E-13	3.58E-13
Xe-137	3.80E-20	9.24E-17
Y-90	3.29E-12	7.55E-14
Y-91	3.23E-10	3.43E-13
Y-92	1.22E-14	5.05E-15
Zn-65	8.30E-10	4.30E-13
Zr-95	3.61E-10	3.48E-13
Nb-95*	4.09E-10	8.86E-14
Zr-97	2.67E-13	2.30E-14
Nb-97	2.86E-13	2.30E-14

DORIS Reference Files:

CREAM Table CSV file	CREAM Table CSV file
PC-CREAM version: 1.5.1.92	PC-CREAM version: 1.5.1.92
Database version: 2.0.0 update version	Database version: 2.0.0 update version
Assessment Name: DORIS_Dcf_2020_Final	Assessment Name: DORIS_Dcf_2020_Final
Description: Doc 238-49 nuclides_plus_Nov2020_VER=2E+09 m3/y_TRS422_7 paras	Description: Doc 238-49 nuclides_plus_Nov2020_VER=2E+09 m3/y_TRS422_7 paras
Last updated: 11/11/2020 21:38	Last updated: 11/11/2020 21:38

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Table 7.E.3: ERICA Environmental Media Concentration Limits (EMCL) and reference marine organisms

Radionuclide	EMCL Bq/L	Limiting organism
Ac-228	2.13E-03	Polychaete worm
Ag-110m	6.21E-02	Polychaete worm
Am-241	5.35E-04	Phytoplankton
At-218	5.32E+01	Polychaete worm
Ba-137m	1.57E+00	Polychaete worm
Ba-140	3.65E-01	Polychaete worm
Bi-210	1.60E+00	Polychaete worm
Bi-212	4.15E-02	Polychaete worm
Bi-214	3.73E-02	Polychaete worm
C-14	1.52E+01	Bird
Ca-45	4.31E+02	Phytoplankton
Cd-109	3.41E-01	Sea anemones & True coral
Ce-141	7.58E-03	Polychaete worm
Ce-144	1.71E-03	Polychaete worm
Cf-252	2.22E-04	Phytoplankton
Cl-36	1.59E+04	Vascular plant
Cm-242	4.39E-04	Phytoplankton

Radionuclide	EMCL Bq/L	Limiting organism
Cm-243	4.37E-04	Phytoplankton
Cm-244	4.39E-04	Phytoplankton
Co-57	4.76E-02	Polychaete worm
Co-58	5.92E-03	Polychaete worm
Co-60	2.30E-03	Polychaete worm
Cr-51	1.10E+00	Polychaete worm
Cs-134	2.86E-01	Polychaete worm
Cs-135	1.36E+02	Reptile
Cs-136	2.10E-01	Polychaete worm
Cs-137	7.75E-01	Polychaete worm
Eu-152	7.35E-04	Polychaete worm
Eu-154	6.85E-04	Polychaete worm
H-3	4.26E+05	Crustacean
I-125	1.99E+01	Macroalgae
I-129	9.43E+00	Macroalgae
I-131	9.09E+00	Macroalgae
I-132	1.13E+01	Polychaete worm
I-133	1.72E+01	Macroalgae
Ir-192	2.28E-02	Polychaete worm
La-140	2.51E-04	Polychaete worm

Radionuclide	EMCL Bq/L	Limiting organism
Mn-54	1.10E-03	Polychaete worm
Nb-94	1.36E-03	Polychaete worm
Nb-95	2.78E-03	Polychaete worm
Ni-59	1.17E+02	Polychaete worm
Ni-63	1.05E+02	Polychaete worm
Np-237	1.05E-02	Vascular plant
P-32	1.36E-01	Crustacean
P-33	8.40E-01	Crustacean
Pa-231	1.52E-04	Phytoplankton
Pa-234m	2.15E-03	Polychaete worm
Pb-210	4.00E-04	Phytoplankton
Pb-212	3.38E-03	Phytoplankton
Pb-214	9.09E-03	Polychaete worm
Po-210	4.42E-04	Polychaete worm
Po-212	2.97E+09	Polychaete worm
Po-214	7.04E-02	Polychaete worm
Po-216	5.52E-05	Polychaete worm
Po-218	4.69E-05	Polychaete worm
Pu-238	8.33E-04	Phytoplankton
Pu-239	8.85E-04	Phytoplankton

Radionuclide	EMCL Bq/L	Limiting organism
Pu-240	8.85E-04	Phytoplankton
Pu-241	7.94E-01	Phytoplankton
Ra-224	1.07E-01	Phytoplankton
Ra-226	3.21E-02	Phytoplankton
Ra-228	1.49E-01	Phytoplankton
Rh-106	3.25E-02	Polychaete worm
Ru-103	8.55E-02	Polychaete worm
Ru-106	6.94E-02	Polychaete worm
S-35	4.63E+04	Vascular plant
Sb-124	4.74E-01	Polychaete worm
Sb-125	2.04E+00	Polychaete worm
Se-75	1.54E+00	Polychaete worm
Se-79	2.42E+01	Mammal
Sr-89	8.00E+01	Mammal
Sr-90	2.64E+01	Mammal
Tc-99	9.90E-01	Macroalgae
Te-129m	3.17E+00	Phytoplankton
Te-132	7.14E-01	Polychaete worm
Th-227	3.83E-05	Phytoplankton
Th-228	2.58E-05	Phytoplankton

Radionuclide	EMCL Bq/L	Limiting organism
Th-230	1.72E-04	Phytoplankton
Th-231	3.14E-02	Polychaete worm
Th-232	1.92E-04	Phytoplankton
Th-234	3.39E-03	Polychaete worm
Tl-208	8.47E-02	Polychaete worm
U-234	2.06E-01	Polychaete worm
U-235	2.20E-01	Polychaete worm
U-237	1.32E+01	Polychaete worm
U-238	2.29E-01	Polychaete worm
Y-90	3.48E-02	Polychaete worm
Zn-65	4.22E-02	Polychaete worm
Zr-95	5.99E-04	Polychaete worm

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Table 7.E.8: Nuclide soil activity calculated with GRANIS as integrated activity concentrations in soil layers (Bq d/m^2) for deposition rate over one year of 1 Bq/m^2/s

Radionuclide and soil depth	Time (y)			
	1	**40**	**60**	**80**
Ag-110m				
0m - 0.01m	3.95E+09	9.17E+09	9.17E+09	9.17E+09
0.01m - 0.05m	2.69E+08	2.07E+09	2.07E+09	2.07E+09
0.05m - 0.15m	3.82E+06	1.24E+08	1.24E+08	1.24E+08
0.15m - 0.3m	2.80E+04	4.70E+06	4.70E+06	4.70E+06
0.3m - 1m	6.20E+01	6.46E+04	6.46E+04	6.46E+04
		Bq/m^3 =	**1.14E+10**	
Co-58				
0m - 0.01m	2.24E+09	3.02E+09	3.02E+09	3.02E+09
0.01m - 0.05m	1.01E+08	2.02E+08	2.02E+08	2.02E+08
0.05m - 0.15m	1.06E+06	3.50E+06	3.50E+06	3.50E+06
0.15m - 0.3m	6.26E+03	3.81E+04	3.81E+04	3.81E+04
0.3m - 1m	1.18E+01	1.48E+02	1.48E+02	1.48E+02
		Bq/m^3 =	**3.23E+09**	
Co-60				
0m - 0.01m	5.10E+09	3.07E+10	3.07E+10	3.07E+10
0.01m - 0.05m	4.06E+08	3.84E+10	3.85E+10	3.85E+10
0.05m - 0.15m	6.32E+06	1.40E+10	1.42E+10	1.42E+10

Radionuclide and soil depth	Time (y)			
	1	**40**	**60**	**80**
0.15m - 0.3m	4.94E+04	3.55E+09	3.75E+09	3.77E+09
0.3m - 1m	1.15E+02	3.28E+08	3.89E+08	3.98E+08
		Bq/m^3 =	**8.75E+10**	
Cs-134				
0m - 0.01m	4.79E+09	1.99E+10	1.99E+10	1.99E+10
0.01m - 0.05m	3.68E+08	1.21E+10	1.21E+10	1.21E+10
0.05m - 0.15m	5.61E+06	2.03E+09	2.03E+09	2.03E+09
0.15m - 0.3m	4.32E+04	2.25E+08	2.25E+08	2.25E+08
0.3m - 1m	9.92E+01	9.31E+06	9.32E+06	9.32E+06
		Bq/m^3 =	**3.43E+10**	
I-131				
0m - 0.01m	3.52E+08	3.63E+08	3.63E+08	3.63E+08
0.01m - 0.05m	2.62E+06	2.80E+06	2.80E+06	2.80E+06
0.05m - 0.15m	5.05E+03	5.58E+03	5.58E+03	5.58E+03
0.15m - 0.3m	6.04E+00	6.92E+00	6.92E+00	6.92E+00
0.3m - 1m	2.57E-03	3.06E-03	3.06E-03	3.06E-03
		Bq/m^3 =	**3.66E+08**	
I-132				
0m - 0.01m	4.36E+06	4.36E+06	4.36E+06	4.36E+06
0.01m - 0.05m	4.01E+02	4.01E+02	4.01E+02	4.01E+02

Radionuclide and soil depth	**Time (y)**			
	1	**40**	**60**	**80**
0.05m - 0.15m	9.54E-03	9.54E-03	9.54E-03	9.54E-03
0.15m - 0.3m	1.41E-07	1.41E-07	1.41E-07	1.41E-07
0.3m - 1m	7.42E-13	7.44E-13	7.44E-13	7.44E-13
		Bq/m³ =	**4.36E+06**	
I-133				
0m - 0.01m	3.93E+07	3.94E+07	3.94E+07	3.94E+07
0.01m - 0.05m	3.26E+04	3.28E+04	3.28E+04	3.28E+04
0.05m - 0.15m	6.98E+00	7.05E+00	7.05E+00	7.05E+00
0.15m - 0.3m	9.31E-04	9.44E-04	9.44E-04	9.44E-04
0.3m - 1m	4.42E-08	4.49E-08	4.49E-08	4.49E-08
		Bq/m³ =	**3.94E+07**	
Sb-124				
0m - 0.01m	2.01E+09	2.59E+09	2.59E+09	2.59E+09
0.01m - 0.05m	8.26E+07	1.48E+08	1.48E+08	1.48E+08
0.05m - 0.15m	8.08E+05	2.19E+06	2.19E+06	2.19E+06
0.15m - 0.3m	4.50E+03	2.03E+04	2.03E+04	2.03E+04
0.3m - 1m	8.13E+00	6.70E+01	6.70E+01	6.70E+01
		Bq/m³ =	**2.74E+09**	
Sr-89				
0m - 0.01m	1.72E+09	2.10E+09	2.10E+09	2.10E+09

Radionuclide and soil depth	Time (y)			
	1	40	60	80
0.01m - 0.05m	1.21E+08	1.92E+08	1.92E+08	1.92E+08
0.05m - 0.15m	1.08E+06	2.39E+06	2.39E+06	2.39E+06
0.15m - 0.3m	5.58E+03	1.86E+04	1.86E+04	1.86E+04
0.3m - 1m	9.52E+00	5.15E+01	5.15E+01	5.15E+01
		Bq/m^3 =	**2.29E+09**	