

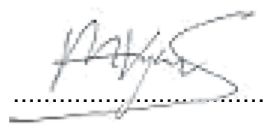
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CHAPTER 8: EMERGENCY PLANNING

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Author declaration:

I declare that appropriate diligence and quality assurance was applied in the compilation of this report. As such I am confident in the results here described and the conclusions drawn.



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AMENDMENT RECORD			
Rev	Draft	Date	Description
0		January 2017	New section. Thyspunt Site Safety Report compiled in support of Eskom's Nuclear Installation Site Licence for the Thyspunt site and submitted to the NNR.
0a		September 2025	Section updated to incorporate PSA section
0b		March 2026	Chapter updated to include executive summary and address NNR comments.

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EXECUTIVE SUMMARY

For the Thyspunt site to be considered and issued a nuclear installation site license, it must be shown in the Site Safety Report (SSR) that the site meets the emergency planning requirements which are laid down in the regulations for siting new nuclear installations (R 927).

The SSR must include an assessment of any external events that could hinder the establishment of emergency arrangements that have to be in place for a new nuclear power station. This chapter of the TSSR provides information on the feasibility of developing and implementing an emergency plan for Thyspunt. In demonstrating the feasibility of a nuclear emergency plan many related factors must be considered, some of them are:

- Radiological Risk
- Emergency Planning Zones
- Site Specific Characteristics and Emergency Plan Feasibility
- Special Population Groups
- Economic Impacts

The importance of these site related factors is dependent on the nuclear hazard posed by a nuclear power station. No vendor has yet been appointed and the new nuclear power station technology to be sited and constructed at Thyspunt is not known. However, Eskom has specified the use of the PPE approach for assessing the feasibility of the site which is based on PWR GEN III design reactors which includes advanced safety characteristics when compared to existing operating nuclear reactors in the world today.

The safety objectives of these reactors include a significantly lower probability of accidents that may require off-site emergency response and, should off-site emergency response be required it will be very limited. These objectives are defined in the European Utility Requirements (EUR) objectives for Emergency Planning as follows:

- minimal emergency protection action beyond 800 m from the reactor during releases from the containment, i.e. actions involving public evacuation, based on projected doses up to 7 days, which may be implemented during the emergency phase of an accident, e.g. during the period in which significant releases may occur - This period is generally shorter than 7 days.
- no delayed action at any time beyond about 3 km from the reactor, i.e. actions involving public temporary relocation, based on projected doses up to 30 days caused by groundshine and aerosol resuspension, which may be implemented after the practical end of the releases phase of an accident.
- no long-term action at any distance beyond 800 m from the reactor, actions involving public permanent resettlement, based on projected doses up to 50 years caused by groundshine and aerosol resuspension. Doses due to ingestion are not considered in this definition.

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The key findings and recommendations of this emergency response study can be summarised as follows. A limited Thyspunt Level 3 PSA study which includes an external hazard bounding analysis PSA was performed to determine if the safety criteria set by the NNR for risks to members of the public and site personnel arising from accidental releases from six proposed EPR or eight AP1000 reactors located at the Thyspunt site will be respected. The conclusions from this study are:

- The annual expected station risks due to reactor accidents for the population within a 50 km radius around the site was deemed to be well-within the NNR risk limits.
- The annual expected station risks due to external hazard induced reactor accidents for the population within a 50 km radius around the site was also deemed to be within the NNR risk limits, considering that the external hazards induced reactor accidents are based on conservative assumptions.
- The safety criteria as well as the bias against larger accidents has been satisfied for the limited scope of the Thyspunt Level 3 PSA.

A deterministic radiological consequence assessment of postulated reference accidents shows that the need for off-site short-term emergency interventions like sheltering, evacuation or iodine prophylaxis is unlikely. Protective actions related to food may be required for a limited period, up to distances of 40 km. The emergency plan will therefore include protective measures such as the following:

- An immediate ban on the consumption of locally grown food in an area affected by the accident.
- The protection of local food and water supplies, for example, covering open wells and sheltering animals and animal feed; and
- Long-term sampling and control of locally grown food and feed. Control of milk production and distributors is generally considered particularly important because it is a significant part of children's diets.

An effective emergency plan for Thyspunt, is feasible subject to a degree of infrastructure upgrade. Although the proposed facilities met the requirement for no evacuation outside the exclusion zone as per the NNR requirements, an important aspect of infrastructure upgrade will involve improvement of the off-site access roads that will service the sites, especially during the construction phase but also in case there is a need to extend the emergency planning activities in the unlikely event of the nuclear accident.

Further, the emergency plan feasibility must be assessed frequently until such time that the next licensing phase of a new nuclear power station is entered, will see potentially major changes in the region in respect of the following population and emergency planning considerations:

- population density and distribution within the emergency planning zones, with particular focus on existing and projected population densities and distributions in

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the region, including resident populations and transient populations - These data are kept up to date over the lifetime of the nuclear power station.

- present and future use of land and resources.
- physical site characteristics that could impede the development and implementation of emergency plans.
- populations in the vicinity of the nuclear power station that are difficult to evacuate or shelter (for example, schools, prisons, hospitals).
- ability to maintain population and land-use activities in the protective zone at levels that will not impede implementation of the emergency plans.

The final and detailed emergency plan for Thyspunt site will be developed in the later licensing stage once the design of the installation has been finalised.

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8 EMERGENCY PLANNING

8.1 Introduction

The fundamental safety objective in the development of a nuclear installation consisting of nuclear power plants is to protect people and the environment from the harmful effects of ionising radiation. One of the safety principles which form the basis of this objective is to ensure sufficient arrangements and emergency preparedness for effective and adequate response (International Atomic Energy Agency, 2006) in the case of a nuclear accident. The scope and extent of arrangements for emergency preparedness and response have to reflect:

- A *source term* analysis (that is representative of the overall potential hazards taking posed to the public and the environment owing to the *new nuclear installation(s)*).
- Probabilistic Risk Assessment (PRA) using the site characteristics and the source terms to demonstrate compliance with the probabilistic risk limits.
- the characteristics of the radiation risks associated with these accidents;
- The identification and determination of emergency planning zones using the characteristics of the site, source term analysis and PRA

Arrangements include criteria set in advance for use in determining when to take different protective actions and the capability to take actions to protect and inform personnel at the scene, and if necessary, the public, during an emergency. These arrangements are based on emergency planning zones (EPZs) which represent the areas in which planning for given protective actions are based on estimated health risks. Traditionally three zones were defined (National Nuclear Regulator, 2005), viz.:

- The inner emergency planning zone (also referred to as the Precautionary Action Zone, PAZ) is a designated area where specific urgent protective actions are implemented immediately upon the declaration of a general emergency. The goal is to substantially reduce the risk of deterministic effects by implementing protective actions before a release.
- The intermediate emergency planning zone (also referred to as the Urgent Protective Action Zone, UPZ) is a pre-designated area where preparations are made to promptly shelter people in-situ, perform environmental monitoring and implement urgent protective actions based on the results of monitoring within a few hours following a release.

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- The outer emergency planning zone (also referred to as the Longer-Term Protective Action Zone, LPZ) is a pre-designated area around the nuclear installation where preparations are made to effect implementation of contingency plans based on documented late-phase emergency plans.

The UPZ for nuclear power plants consists of an area of about 16 km in radius and the LPZ consists of an area of about 80 km in radius.

Significant advancement in research and knowledge of potential nuclear accident scenarios (Electric Power Research Institute, 2007) as well as new safety features of modern nuclear power reactors, have allowed a re-evaluation of the traditional EP requirements. Advanced light water reactors such as the EPR and AP1000 (the two reference reactor technologies that provide the plant parameter envelope for the Site Safety Report (SSR) have safety characteristics that result in an extremely low likelihood for core damage accident sequences which could result in a loss of the containment retention function. These reactor designs are provided with the capability to respond to severe accident containment challenges (Westinghouse, 2004) and (Areva, 2006). These advances in modern reactor safety technology have allowed Eskom Holdings (hereinafter referred to as Eskom) to adopt the position that for any new nuclear installation to be sited in South Africa there will be no need for a short-term off-site emergency plan (Eskom, 2009). It must be demonstrated that for any nuclear installation on the site it is extremely unlikely that quantities of radioactivity will be released to the environment during an accident and therefore will not cause any of the National Nuclear Regulator (NNR) intervention levels being exceeded for:

- sheltering, evacuation and iodine prophylaxis at the UPZ boundary;
- food-banning, temporary relocation and permanent resettlement at the corresponding LPZ boundaries.

Further discussion of this position is included in **Subsection 8.3.3**.

8.2 Purpose and Scope

This chapter of this SSR presents an assessment of two reactor technologies in respect of emergency plan requirements for licensing the site. It presents information on the extent of EPZs, emergency plan viability and demonstrates compliance with NNR risk limits (Department of Energy, 2011).

For the purpose of this SSR, it must be emphasised that the focus of the emergency planning is on the suitability of the site to have a viable emergency plan. This means that the SSR must identify any physical characteristics unique to the site that could pose a significant impediment to

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the development and implementation of an emergency plan. These aims are aligned with the internationally agreed safety requirements and guides provided in **Appendix A-8.A**. The external zone for a proposed site shall be established with account taken of the potential for radiological consequences for people and the feasibility of implementing emergency plans, and of any external events or phenomena that may hinder their implementation. Before construction of the nuclear installation is started, it shall be confirmed that there will be no insurmountable difficulties in establishing and implementing an emergency plan for the external zone (Republic of South Africa, 1999).

This chapter builds on the available site specific data presented in **Sections 5.4** (Demography), **5.5** (Land and Water Use), **5.7** (Nearby Transportation, Industrial and Military Facilities), **5.8** (Meteorology) and **Chapter 6** (Evaluation of External Events) (Eskom, 2025b).

8.3 Safety Requirements and Criteria

8.3.1 Regulatory Framework

The national legal and regulatory framework related to nuclear emergency planning of nuclear installations is comprehensive and the main safety requirements and criteria are summarised below.

The Department of Minerals and Energy through the National Nuclear Regulator Act (1999), (Republic of South Africa, 1999), requires that, where the possibility exists that a nuclear accident affecting the public may occur, the NNR must direct the relevant holder of a nuclear authorisation, other than a holder of a certificate of exemption, to:

- enter into an agreement with the relevant municipalities and provincial authorities to establish an emergency plan within a period determined by the Regulator;
- cover the costs for the establishment, implementation and management of such emergency plan insofar as it relates to the relevant nuclear installation or any action contemplated in Section 2(1)(c) of the act;
- submit such emergency plan for its approval.

The Act (Republic of South Africa, 1999) requires an effective emergency plan for the protection of persons should a nuclear accident occur. Full compliance with these requirements will have to be demonstrated prior to receiving nuclear fuel on site.

The principal requirements for the licensing of the site and which have to be demonstrated in the SSR, are stated in the NNR regulations on licensing of sites for new nuclear installations (Department of Energy, 2011). The specific requirements in respect of emergency planning are as follows:

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“(4) A *source term* analysis that is representative of the overall potential hazards posed to the public and the environment owing to the *new nuclear installation(s)*. A representative scope of internal and *external events* enveloping the *new nuclear installation(s)* must be taken into consideration”.

“(5) A Probabilistic Risk Assessment (PRA) using the site characteristics referred to in Regulation 5(3) and the *source terms* referred to in Regulation 5(4) to demonstrate compliance with the *probabilistic risk limits*. This analysis must include the impact of all nuclear installations and actions on the site, existing and proposed, for which authorizations have been granted by the Regulator”.

“(7) The identification and determination of *emergency planning zones* using the characteristics of the site, *source term* analysis and PRA established in accordance with Regulations 5(3), 5(4) and 5(5) respectively. In determining the *emergency planning zones* due account must be taken of physical boundaries such as rivers, dams, mountain ranges, as well as municipal boundaries. The *emergency planning zones* must include the following:

- An exclusion zone which is a radius determined for the purposes of evacuating persons in the event of a nuclear accident.
- Within the boundaries of that zone or within any erven intersecting with that zone there must be no members of the public resident, no uncontrolled recreational activities, no commercial activities, or institutions which are not directly linked to the operation of nuclear installations situated within this zone, or for which an authorization has not been granted;
- An overall *Emergency Planning Zone* (EPZ) of such size that emergency or remedial measures must be considered where the potential exists that any members of the public may receive more than an annual effective dose of 1 mSv due to the *source term*;
- A Long Term Protective Action Planning Zone (LPZ), where preparations for effective implementation of protective actions to reduce the risk of *stochastic health effects* from long term exposure to deposition and ingestion must be developed in advance consistent with international standards.

(8) An analysis to demonstrate the viability of an emergency plan taking into account relevant data established in accordance with Regulations 5(3), 5(4) and 5(5), including *disaster management infrastructure*. It must be shown that risks to the public, as well as the financial consequences caused by damage and radioactive contamination, are “as low as reasonably achievable.”

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8.3.2 Related National Acts and International Conventions

Other international conventions and national acts for which compliance has to be demonstrated in subsequent licensing phases are the following:

- The Convention on Nuclear Safety that requires, for any new nuclear installation, emergency plans to be prepared and tested before the facility commences operation above a low power level and to be agreed by the regulatory body (Art. 16) (International Atomic Energy Agency, 1994).
- The Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management that also requires each contracting party to ensure that before and during operation of a spent fuel or radioactive waste management facility there are appropriate on-site and, if necessary, off-site emergency plans. Such emergency plans should also be tested at an appropriate frequency (Art. 25) (International Atomic Energy Agency, 1997).
- The Convention on Early Notification of a Nuclear Accident (International Atomic Energy Agency, 1986a) that also requires that in the event of an accident South Africa shall (i) notify, directly or through the International Atomic Energy Agency (IAEA), those states that are or may be physically affected and the IAEA of the nuclear accident, its nature, the time of its occurrence and its exact location where appropriate; and (ii) promptly provide the states referred to above (i) directly or through the IAEA, and (ii) the IAEA with such available information relevant to minimising the radiological consequences in those states.
- The Convention on Assistance in the Case of a Nuclear or Radiological Accident (International Atomic Energy Agency, 1986b) that requires the contracting parties to cooperate with other contracting parties and with the IAEA in accordance with the provisions of this convention to facilitate prompt assistance in the event of a nuclear accident or radiological emergency to minimise its consequences and to protect life, property and the environment from the effects of radioactive releases. This includes the preparation of emergency plans.
- The Disaster Management Act (2002) that requires the Minister to prescribe a national disaster management framework. The framework must reflect a proportionate emphasis on disasters of different kind, severity and magnitude that occur or may occur in South Africa, Section 7.1 of (Republic of South Africa, 2002).

In addition, it is required (Department of Minerals and Energy, 2004a) that the relevant provincial and/or municipal authorities must:

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- develop and implement processes, including associated acceptance criteria, for the conduct of periodic assessment of current and planned population distribution, disaster management infrastructure and new development, to ensure that the emergency plan, as contemplated in Section 38 of the National Nuclear Regulator Act (1999), can be implemented effectively at all times (Republic of South Africa, 1999);
- document the processes contemplated in subsection 4(a) in procedures acceptable to the regulator;
- report to the NNR on the implementation and the results of the monitoring processes at intervals acceptable to the regulator.

The NNR (National Nuclear Regulator, 2005) also requires that:

- emergency plans are coordinated with the plans for non-radiological emergencies, both on and off-site, and agreements be established with the local and provincial authorities;
- EPZs are defined for the site;
- adequate supplies, equipment, communication systems and emergency facilities are in place to allow intervening organisations to fulfil their responsibilities and must be identified and kept available for use during emergencies;
- emergency facilities are suitably located to minimise the exposure of emergency workers;
- a laboratory be identified that is able to perform the analysis of radioactive samples.

It is also required that specific provisions are in place for keeping of a record of all persons in a nuclear accident defined area (Department of Minerals and Energy, 2006) and that a public safety information forum is established by the holder of a nuclear installation licence (Department of Minerals and Energy, 2004b).

8.3.3 Eskom's Position on Emergency Planning Requirements for Thyspunt and Other Future Sites

Eskom established a guiding principle for siting for a proposed nuclear installation (Eskom, 2013). It has to be demonstrated that no off-site short-term emergency interventions such as sheltering, evacuation or iodine prophylaxis are required. The principle is stated as follows:

“For any new nuclear installation to be sited in South Africa without the need for a short-term off-site emergency plan, it must be

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demonstrated that the site will not result in any of the NNR intervention levels for:

1. sheltering, evacuation and iodine prophylaxis at the UPZ boundary, and
2. food-banning, temporary relocation and permanent resettlement at the LPZ boundary being exceeded more frequently than $1\text{E-}06/\text{y}$.

The EPZ radii for future sites are:

- PAZ = 0 km;
- UPZ = EZ = 0.8 km;
- LPZ = 40 km for food-banning/replacement measures, but no temporary relocation beyond 3 km or permanent resettlement beyond 800 m;
- EPZ = 40 km.

In sites containing multiple reactors, these radii are taken as the distance from the boundary to the reactor nearest to it.”

For the purpose of this SSR, the level and extent of emergency preparedness required for the development of a nuclear installation were derived from these requirements (Eskom, 2009) and (Eskom, 2013).

8.4 Generic Intervention Levels

Eskom has adopted the use of generic intervention levels adopted by the NNR (National Nuclear Regulator, 2005) as developed by the IAEA. These levels are listed in **Table 8.1**, **Table 8.2** and **Table 8.3**.

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Table 8.1: Generic Intervention Levels for Urgent Protective Actions

Protective Action	Generic Intervention Level ^{1,2}
Sheltering	10 mSv ³
Evacuation	50 mSv ⁴
Iodine Prophylaxis	100 mGy ⁵

Table 8.2: Generic Intervention Levels for Temporary Relocation and Permanent Resettlement

Period	Intervention Level	Definition
1st month	30 mSv	Temporary relocation
Subsequent month	10 mSv	Temporary relocation
Lifetime (50 years)	1000 mSv	Permanent resettlement

Table 8.3: Generic Action Level for Foodstuffs

Radionuclides in Foods Destined for General Consumption	(kBq/kg)
Cs-134, Cs-137, Ru-103, Ru-106, Sr-89, I-131	1
Sr-90	0.1
Radionuclides in Milk, Drinking water and Infant Foods	
Cs-134, Cs-137, Ru-103, Ru-106, Sr-89	1
I-131, Sr-90	0.1
Am-241, Pu-238, Pu-239, Pu-240, Pu-242	0.001

¹These levels are of avertable dose, i.e. the action should be taken if the dose that can be averted by the action, taking into account the loss of effectiveness due to any delays or for other practical reasons, is greater than the generic intervention level given.

² The levels in all cases refer to the average over suitably chosen samples of the population not to the most exposed individuals. However, projected doses to groups of individuals with higher exposures should be kept below the thresholds for deterministic effects.

³ Sheltering is not recommended for longer than two days. Authorities may wish to recommend sheltering at lower intervention levels for shorter periods or so as to facilitate further protective actions, e.g. evacuation.

⁴ Evacuation is not recommended for a period of longer than one week (7 days). Authorities may wish to initiate evacuation at lower intervention levels for shorter periods and also where evacuation can be carried out quickly and easily, e.g. for small groups of people. Higher intervention levels may be appropriate in situations in which evacuation would be difficult, e.g. for large population groups or with inadequate transport.

⁵ Avertable committed absorbed dose to the thyroid due to radioiodine (for practical reasons. one intervention level is recommended for all age groups).

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The guiding principle adopted by Eskom for the site in respect of the PAZ is that the nuclear installation must not be capable of giving rise to deterministic effects anywhere more frequently than 1E-06/y (Eskom, 2013). If this is not achievable for a certain technology, a PAZ shall be defined but inside the EZ. In this case action levels of dose for acute exposure by organ or tissue at which intervention is expected to be undertaken under any circumstances are listed in **Table 8.4** (International Atomic Energy Agency, 2003). Intervention is expected to be undertaken under any circumstances to prevent 25 Gy absorbed dose to the lung delivered over one year from inhalation of high linear energy transfer linear energy transfer (LET) radiation⁶.

More recent criteria (International Atomic Energy Agency, 2011) and (National Nuclear Regulator, 2012) in respect of deterministic effects have been used to perform an assessment of the PAZ and are listed in **Appendix A-8.C**.

Table 8.4: Action Level of Dose for Acute Exposure to Low LET Radiation

Organ or Tissue	Projected Absorbed Dose to the Organ or Tissue in Less Than Two Days
	(Gy)
Whole body (bone marrow)	1.0
Lung	6.0
Skin	3.0
Thyroid	5.0
Lens of the eye	2.0
Gonads	3.0
Foetus	0.1

8.5 Radiological Risk

In order to understand the risk associated with locating a new nuclear power plant on the Thyspunt site, a Probabilistic Safety Assessment (PSA) was performed using source term information of a typical PWR as well as site specific characteristics. This study was aimed at providing an indicative

⁶ This exception is derived for inhalation of high LET emitters (e.g. alpha emitters); it is an estimate of the threshold for development of severe deterministic health effects.

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Level 3 PSA that can be used in the current licensing stage and will be supplemented by a full PSA in the subsequent licensing stages once a decision on the design is finalised.

The Westinghouse AP1000 and the Framatome's EPR reactors were used as reference designs for the proposed for the Thyspunt site since the design of the proposed new nuclear installation has not yet been selected. To ensure that the results are a conservative representation of the on- and off-site radiological consequences resulting from an accidental release, the following assumptions were considered:

- No credit was taken for on-site mitigative actions which will be documented in severe accident management guidelines.
- No emergency plan countermeasures (sheltering, evacuation, and iodine prophylaxis), other than a food ban, have been assumed.
- People were assumed to stay at the same location for the duration of the exposure period.
- The calculations were performed for "cold" releases at ambient temperature conditions.
- The height and width of the reactor building were set to 56 m and 37 m respectively to include build wake effect.

This study includes a preliminary siting Level 3 PSA for the EPR and AP1000 reactor technologies to determine the risks to the public and workers on the site resulting from a potential release of a severe accident. The Level 3 PSA uses release frequencies, release fractions and source terms from the generic Level 1 and 2 PSA studies which are outlined in the AP1000 Probabilistic Safety Analysis Report (Westinghouse, 2004) and in the Standard EPR Probabilistic Safety Analysis Edition (Areva, 2006). It combines these inputs with site specific input data (for example meteorological and population data) to estimate the overall public and worker risk.

To perform the Level 3 PSA calculations, a source term is calculated for each Release Category (RC). MAAP4 software was used in both the AP1000 and EPR to calculate the source terms (release fractions calculated with MAPP4 applied to the initial radionuclide inventories) to the environment for the 8 AP1000 RCs and 6 EPR RCs considered in the Level 2 PSA studies.

The Level 3 PSA analysis included the following endpoints:

- Number of early fatalities
- Number of latent cancer (late) fatalities
- Short-term individual doses.
- Long-term individual doses
- Individual risk of early health effects

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- Individual risk of late health effects

The scope of the initiating events studied in the Level 1 and Level 2 EPR PSA (Areva, 2006) include internal events and hazards. The assessment was performed for all plant operational states (i.e. full power, low power, and shutdown). Consideration of the risk associated with external hazards is discussed in Section 5 (Eskom, 2025a).

The AP1000 PSA calculates the Large Release Frequency for internal events at power. Consideration of the risk associated with external hazards is discussed in Section 5 (Eskom, 2025a).

The aim of the Level 3 results is to assess the peak and average public and site worker risks due to accidental release of radioactive materials into the atmosphere from the proposed nuclear installation at the Thyspunt site and to compare those risks to the criteria of the NNR in RD-0024 (National Nuclear Regulator, 2008) (refer to **Table 8.5**).

Table 8.5: NNR Safety Criteria for Accident Conditions

NNR Criteria	
Peak Public Risk	5.00E-6 fatalities per year
Average Peak Public Risk	1.00E-8 fatalities per person per year
Peak Site Personnel Risk	5.00E-5 fatalities per year
Average Site Personnel Risk	1.00E-5 Fatalities per person per year.

An additional criterion specified in RD-0024 (National Nuclear Regulator, 2008) is the basis against larger accidents. The requirement entails that the annual frequency $f(N)$ of accidents affecting more than N fatalities be less than AN^{-1} , where A is a constant derived from the national population. A is derived by limiting the mean fatality probability per person per annum to $1E-08$, in the range of 1 to N_p , where N_p is an acceptable projection of the national population.

8.5.1 Assessment of Peak and Average Public Risks

8.5.1.1 Peak Public Risk

Peak individual risk refers to the highest risk that a member of the public may be subjected to because of a nuclear accident. The risk will be greatest closest to the plant. The point closest to the site at which the public may be found is the site boundary. The population data started from 2.0 km (Eskom, 2025a). This distance was not an option available in the PC Cosyma

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software, therefore the peak public risk was calculated at a distance of 2.25 km from the plant, which is the closest available option.

Thus the risk at 2.25 km is given as the annual fatalities at 2.25km divided by the number of people in that distance band.

Mathematically it is expressed as:

$$\text{Peak public risk} = \sum_{i=1}^n \frac{(D_{I(2,25km)}) \times f_i}{P_{(2,25km)}} \quad (1)$$

Where $D_i(2.25 \text{ km})$ is the total mean number of fatalities a 2.25 km due to Release Category RC_i , f_i is the frequency of the RC_i and $P(2.25 \text{ km})$ is the total population at 2.25 km (Eskom, 2025a).

The limit for peak public risk is 5.0E-06 fatalities per year because of an accident at a nuclear installation.

8.5.1.2 Average Public Risk

Average Public Risk to an individual in the national population is defined as the number of annual fatalities divided by the total national population and is expressed as:

$$\text{Average Public Risk} = \sum_{i=1}^8 \frac{D_i \times f_i}{\text{Total National Population}} \quad (2)$$

Where D_i is again the total mean number of fatalities summed over all distances due to Release Category RC and f_i is the frequency of the RC . The average public fatalities limit is 1.0E-08 fatalities per person per year.

8.5.1.3 Methodology for Peak and Average Public Risks

A similar approach used in the Koeberg Level 3 PSA study, using the relevant input information for the Thyspunt site and the AP1000 and EPR nuclear reactors was followed to calculate the peak and average public risks associated with the proposed new reactors. First, a set of RCs with associated source terms and frequencies were obtained from the AP1000 PSA Report (Westinghouse, 2004), while those of the EPR were obtained from the Standard EPR PSA Edition 2006 (Areva, 2006).

For each RC:

- The appropriate PC Cosyma input files were selected representing the radiological inventory, meteorological and population data.
- Site-specific information such as:
 - Spatial distribution data.
 - Dispersion characteristics.

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- Deposition characteristics of the various nuclides.
- Meteorological conditions.
- Countermeasures; and
- Shielding parameters.
- Probabilistic PC Cosyma calculations were performed to estimate the early and late fatalities per distance band for each RC.
- Thereafter the early and late fatalities were summed to determine the total fatalities per distance band.
- The total fatalities per distance band were then multiplied with the associated RC's frequency, summed up for all distance bands of all the RCs and divided by the national population to obtain the average public risk.
- The peak public risk is obtained by multiplying the total number of fatalities at 2.25 km for each RC by the associated release frequency and dividing the sum over all RCs by the population at the site boundary.
- The total risk for a multi-unit reactor site is estimated by multiplying the results with the number of units.

8.5.2 Assessment of Peak and Average Worker Risks

The peak and average worker risks are defined as the risks affecting on-site workers due to an accidental release, since all workers are exposed to this risk, it corresponds to the peak and average worker risks.

The limit for peak and average worker fatalities is 5.0E-05 per year and 1.0E-05 per person per year respectively.

The following section describes the methodology to estimate the peak and average worker risks associated with the AP1000 and EPR reactor designs were used as reference reactors for the Thyspunt site.

8.5.2.1 Methodology for Peak and Average Worker Risks

The individual risk is defined as the maximum risk inside the 2.0 km radius (Eskom, 2025a). Since all the personnel are exposed to this risk, this corresponds to the peak and average site personnel risks due to reactor accidents. The peak and average worker risks are estimated from the sum of the conditional individual mortality at 2 km for each RC multiplied by the relevant RC frequency.

As stated in the current Koeberg Level 3 PSA study (Eskom, 2025a), using PC Cosyma to estimate doses on site (e.g. close to the site of the accident) can lead to considerable uncertainty. Therefore, the peak and average risks to site personnel from accidents related to releases from core damage were adjusted/scaled by a factor of 10 as recommended in the "Comparison of PC Cosyma and ARCON2 Near-Field Atmospheric Dispersion Factors",

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Number: PSA-R-T18-03, Revision 2 (Eskom, 2025a).

The Koeberg Site Personnel Risk Assessment, PSA-R-T18-01 (Eskom, 2025a), demonstrates that the peak and average site personnel risk resulting from fuel handling accidents in the containment building and in the spent fuel building is substantial in the Koeberg design. The fuel handling system and fuel management strategy information to calculate the contribution of fuel handling accidents to the peak and average site personnel risk for this study is not available, this must be noted as a limitation in the scope of this study.

8.5.3 External Hazards-Bounding Analysis

The contribution to the overall risk that were considered in this assessment from the following site-specific external hazards, namely:

- Seismic
- Tornadoes
- Strong winds.

External floods (including intense local precipitation, tsunami and storm surge) were omitted since the plant platform level and the design of its volumetric protection measures are not known. Therefore, it is assumed that the plant will be designed to eliminate the risk resulting from an external flooding event, i.e. terrace level will be above the probable maximum tsunami level.

In the bounding analysis, the external hazard CDF is the product of the external hazard occurrence frequency and the representative induced initiating event's Conditional Core Damage Probability (CCDP). The CDF contribution of the external hazard are presented in (Eskom, 2025a).

8.5.4 PC Cosyma Code Description

In this study the radiological consequences are evaluated using PC Cosyma Version 2.02. The overall methodology of PC Cosyma has been described in detail in the PC Cosyma package report. A summary of the PC Cosyma code is captured in the current Koeberg Level 3 PSA. The quality assurance of Version 2.02 of the PC Cosyma code is documented in (Eskom, 2025a) as well as the RCs that corresponds to the AP1000 and EPR.

8.5.5 Population Distribution data

The PC Cosyma population data file used represents the 2022 projected population. The 2022 projected population was based on the 2011 national

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census data which provides the baseline data for the population distribution within the site region.

This data however was supplemented with the Ideal Dataset for 2022 and can be construed to represent the most recent and detailed representation of population data within the site region. While Census 2022 was undertaken by StatsSA, the results small area layer level of resolution was not available at the time that this study was conducted.

Further, the population data includes the tourist / transient population within 50 km of the site, i.e. it represents the 2022 cumulative population (sum of the permanent resident and tourist populations).

The process described in the Update of PC Cosyma Population Data File to 2026 Baseline for Koeberg Nuclear Power Station, PSA-Q-T16-11 was followed to derive the PC Cosyma population input file from the 2022 demographic data obtained from the Thyspunt site (Eskom, 2025a).

8.5.6 Meteorological Data and Sampling

The meteorological information used in the PC Cosyma MET file consist of one year's hourly recordings of wind direction, wind speed, stability class (Pasquill categories A to F), the depth of the mixing layer and rainfall rate. The one year of hourly meteorological data amounts to 8 760 weather sequences. The meteorological data for Thyspunt was recorded by a 10-meter-high on-site meteorological monitoring station.

The process described in PC Cosyma Weather Data was used to derive the meteorological data input file using meteorological data from the Thyspunt site gathered from 2017 – 2018.

When using hourly source meteorology, the preferred method is stratified or importance sampling, so as to minimise the chance of omitting significant but infrequent weather sequences. In stratified sampling the meteorological sequences that have similar pattern of hourly weather changes are grouped into a number of categories. The objectives of the categorization are, first, to group those meteorological conditions which would lead to comparable radiological consequences for a given release, and second, to select categories such that adequate resolution is provided over the whole spectrum of consequences that result from the distribution of meteorological conditions (Eskom, 2025a).

Furthermore, PC Cosyma requires that the meteorological hourly data file be present and does not allow missing data. During instances where missing data were present the procedures outline in PSA-Q-T16-08 were adopted (Eskom, 2025a)

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8.5.7 Dispersion and Deposition Parameters

Default dispersion parameters were used, to ensure alignment with the Cosyma methodology detailed of which are contained in (Eskom, 2025a).

8.5.8 Exposure Pathways

The following pathways cloud-shine, ground-shine, inhalation, and resuspension were used in the dose calculations. However, the ingestion pathway was not considered since the calculations assume a food ban.

8.5.9 Probabilistic Risk Results

PC Cosyma was used to calculate the potential risk associated with locating nuclear power plants at the Thyspunt site using either 8 AP1000 or 6 EPR reactors to demonstrate compliance to risk limits. The dose results, the number of fatalities and the consequences related to the operation of such assessed against the NNR safety criteria as outlined in RD-0024 (National Nuclear Regulator, 2008). The AP1000 results for internal events show that the “Containment Bypass Failure” (BP) release category are the highest contributor to public risk, and therefore it was used to assess the mean individual 30-day effective dose. The effective dose for the RC-Bypass was calculated at 5.46E-01 whilst the EPR effective dose was estimated at 9.4E-02 (see details in (Eskom, 2025a)) for mean short term individual dose. The mean long-term individual doses to various organs as well as the effective doses calculated for a 50-year period after the accident shows the effective dose of 1.01E+00 for AP1000 and 1.99E-01 for EPR (Eskom, 2025a).

The risk of fatalities and the consequences related to the operation of such a facility were then compared with the NNR safety criteria as outlined in RD-0024 (National Nuclear Regulator, 2008).

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Table 8.6: Annual Risk Assessment for the Thyspunt site due to Newly Proposed Nuclear Power Plant

Risk Measure	AP 1000			EPR			NNR Criteria
	Annual Risk Per Unit	Annual Risk (per Station)	% of NNR Criteria	Annual Risk Per Unit	Annual Risk (per Station)	% of NNR Criteria	
Peak Public Risk	4.67 E-08	3.74E-07	7.5%	1.77E-08	1.06E-07	2.12%	5.00E-06
Average Public Risk	5.38E-12	4.28E-11	0.4%	4.43E-12	2.66E-11	0.27%	1.00E-08
Peak Site Personnel risk	9.10E-07	7.28E-06	14.6%	5.50E-07	3.3E-06	6.59%	5.00E-05
Average Site Personnel Risk	9.10E-07	7.28E-06	72.8%	5.5E-07	3.3E-06	32.97%	1.00E-05

The results shows that the annual expected station risks due to reactor accidents for the population within a 50 km radius around the site are deemed to be well-within the NNR risk limits. The annual expected station risks due to external hazard induced reactor accidents for the population within a 50 km radius around the site was also deemed to be within the NNR risk limits. The safety criteria as well as the bias against larger accidents has been satisfied for the limited scope of the Thyspunt Level 3 PSA.

8.6 Emergency Planning Zones

Radiological consequences were assessed for severe accidents that are beyond the design basis to determine compliance with NNR regulations and Eskom requirements for EPZs. A brief overview of the selected accidents and the detail of the associated source terms are included in **Appendix A.8-B**. The accidents were selected following the Eskom requirements on emergency planning summarised in **Subsection 8.3.2**. These requirements define EPZs of fixed sizes and vendors will be required to demonstrate that emergency planning actions will not be necessary outside these defined zones. EPZs are therefore not designed to a particular reference accident. The approach is to consider the frequencies and consequences of severe accidents and then to set a frequency limit of 1E-06/y. Emergency actions outside the pre-defined EPZs shall not be required more frequently than this limit. The frequency and consequence of every accident is considered and

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compared to the relevant reference levels (in terms of frequency and consequence) for each EPZ. This approach envelopes the reference-accident approach of the NNR (National Nuclear Regulator, 2012). Therefore, it is considered that the intent, with respect to reference accident selection is met (Eskom, 2013).

8.6.1 PAZ

Eskom proposed a PAZ of 0 km. The feasibility of having no precautionary⁷ actions to avoid severe deterministic health effects was investigated by performing assessments of acute exposures described in **Appendix A-8.C**. The results are summarised in **Table 8.7**. In the case of inhalation or ingestion of radioactive material, a value of the 30 day committed relative biological effectiveness (RBE) weighted absorbed dose is used to specify the threshold for the possible onset of severe deterministic effects in the organ concerned (International Atomic Energy Agency, 2011).

⁷ Table 8.7 shows the absorbed doses to various organs due to an acute exposure from radiations over 30 days, without interventions. Fig 8.1 to Fig. 8.4 shows the projected effective dose with intervention considered. Table 8.7, Fig 8.1 and Fig 8.4 are related since they trends dose exposure, although in different units. The primary difference between millisieverts (mSv) and gray (Gy) units is in their focus on the radiation's biological effect. Gy measures the absorbed dose, which is the amount of energy deposited by radiation in a substance, typically human tissue. While mSv, on the other hand, measures the equivalent dose, which considers the type of radiation and the sensitivity of the tissues being exposed. The conversion between these two units is, 1 Gy is being equivalent to 1 Sv, which is then converted to mSv. Further, sheltering dose was estimated over period of 2 days, evacuation dose was estimated over period of 7 days while thyroid dose was estimated over period of 7 days.

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Table 8.7: Dose for Acute Exposure to Radiation

Deterministic dose	External Cloud Dose, Sv/h	Thyroid Dose - 30 days, Gy	Red Marrow - 30 days Dose, Gy	Lung Dose - 30 days, Gy	Alveolar-Interstitial Dose - 30 days, Gy
Dispersion coefficient 2.4E-04 at 200 m	2.94E-02	1.39E-01	2.44E-03	5.47E-02	2.80E-02
Dispersion coefficient 1E-02	1.22E+00	5.79E+00	1.02E-01	2.28E+00	1.17E+00
Generic criteria for Acute Doses for which Protective Actions and other response actions are expected to be taken under any circumstances to avoid or minimise Severe Deterministic Effects		Thyroid: 2 Gy	Red Marrow: 2 Gy	Lung and Alveolar-Interstitial: 30 Gy	

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The PAZ requirement of 0 km is not met based on the assessment presented in this chapter.

A PAZ of 200 m and therefore inside the exclusion zone, can be demonstrated based on results of screening dose assessments. However, it is recommended that a PAZ = UPZ = 0.8 km be adopted because of the following reasons. Large uncertainties exist in calculations for airborne concentrations at short distances because of the complex behaviour of gaseous releases inside and close to the building structures. It is also unlikely that during an actual severe accident, precautionary evacuation from the site to avoid potential deterministic effects will not be taken for nuclear installation personnel not directly involved in emergency actions.

8.6.2 UPZ and LPZ

The projected radiation doses for the EPZs applicable to the public were calculated using the software programmes PC COSYMA (PC Cosyma Users Manual, 1995) and ECOSYS (Conrad, 2011). These programmes are internationally used for nuclear accident consequence analysis. The methodologies and input data used in these programmes are discussed in **Appendix A-8.C**. The projected dose results for comparison to generic intervention levels are summarised in **Table 8.8** and **Table 8.9** and illustrated in **Figure 8.1** to **Figure 8.4**. It should be noted that the potential contamination of drinking water following an accident is not considered. Contamination of water resources will contribute to the radiation dose but not significantly when compared to other pathways. Some of the findings on water resources following the Chernobyl accident support this assumption (International Atomic Energy Agency, 2006). Activity concentrations of soluble radionuclides measured in drinking water showed that their contribution to internal dose was usually negligible compared with that associated with the intake of food. Drinking water contributed approximately 1 per cent to the dose of critical groups in some of the worst affected areas compared to external radiation from soil (50 per cent) and food ingestion (24 per cent). Short-lived radionuclides do not affect groundwater supplies, because groundwater residence times are much longer than their physical decay time. In most of the studied area the activity concentration in groundwater was significantly lower than in most river and lake systems. Radionuclides in irrigation water did not add significant to radioactivity in crops in comparison with that which had been initially deposited in atmospheric fallout and subsequently taken up *in situ* from the soil (International Atomic Energy Agency, 2006).

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Table 8.8: Dose Estimates for Severe Accidents and a Comparison to UPZ and LPZ Intervention Level Requirements

Protective Action	Generic Intervention Level	Exposure duration	EPZ requirement, km	Projected Dose Estimates for the AP1000 and EPR Reactor Technologies		
				Reactor Technology	Projected Total Dose estimated; mSv	Eskom EPZ requirement met?
Sheltering	10 mSv (RD-0014)	2 days	0.8	EPR	2.384	Yes
	100 mSv (PP-0015)	7days		AP1000	22.803	No – Although the requirement is not met at a distance of 0.8 km, it is met at 2 km where the projected dose is<10 mSv (6.715 mSv)
Evacuation	50 mSv	7 days	0.8	EPR	2.550	Yes
	100mSv (PP-0015)			AP1000	24.956	Yes
Iodine prophylaxis	100 mGy (RD-0014)	— 7 days	0.8	EPR	5.847 (Committed absorbed dose)	Yes
	50mSv (PP-015)			AP1000	45.68 (Committed absorbed dose)	Yes
Temporary relocation	30 mSv during initial 30 days and 10 mSv in subsequent 30 days		3	EPR	0.098 (first 30 days) and 0.014 (subsequent 30	Yes

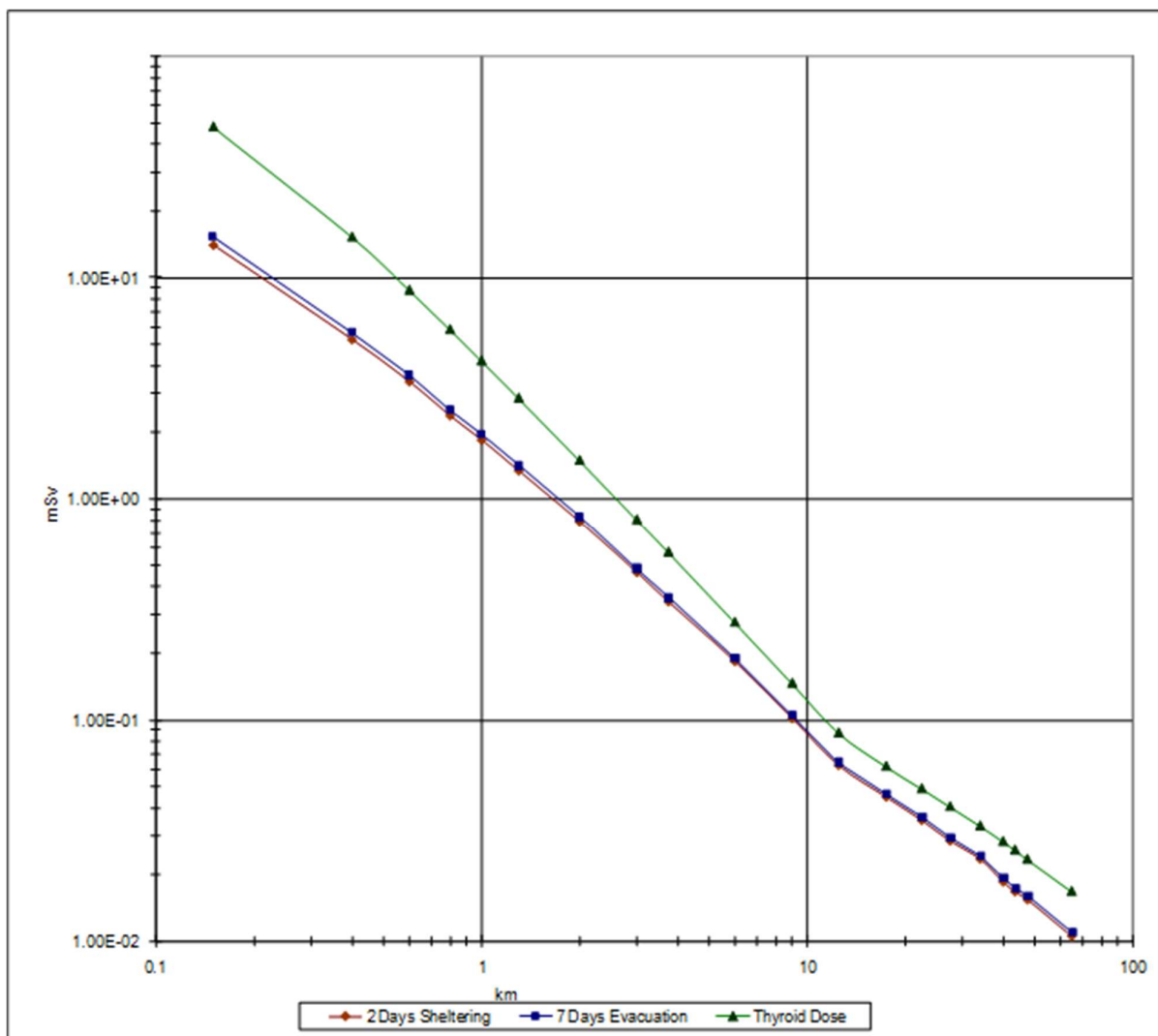
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Protective Action	Generic Intervention Level	Exposure duration	EPZ requirement, km	Projected Dose Estimates for the AP1000 and EPR Reactor Technologies		
				Reactor Technology	Projected Total Dose estimated; mSv	Eskom EPZ requirement met?
	100 mSv/a (PP-0015)				days)	
				AP1000	1.185 (first 30 days) and 0.214 (subsequent 30 days)	Yes
Permanent resettlement	1 000 mSv	Lifetime	0.8	EPR	1.969	Yes
				AP1000	24.02	Yes
Food banning/replacement			40	EPR	Projected dose decreases to approximately 1 mSv at 40 km in first year following an accident; no food banning or replacement considered. Food banning and replacement will be required for distances < 40km.	
				AP1000		

Note: Effective dose: cloudshine, groundshine, resuspension and deposition on skin and clothing as applicable to intervention scenario; Committed Effective Dose - Inhalation (50y).

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Figure 8.1: EPR Projected Dose - Sheltering, Evacuation and Thyroid Dose



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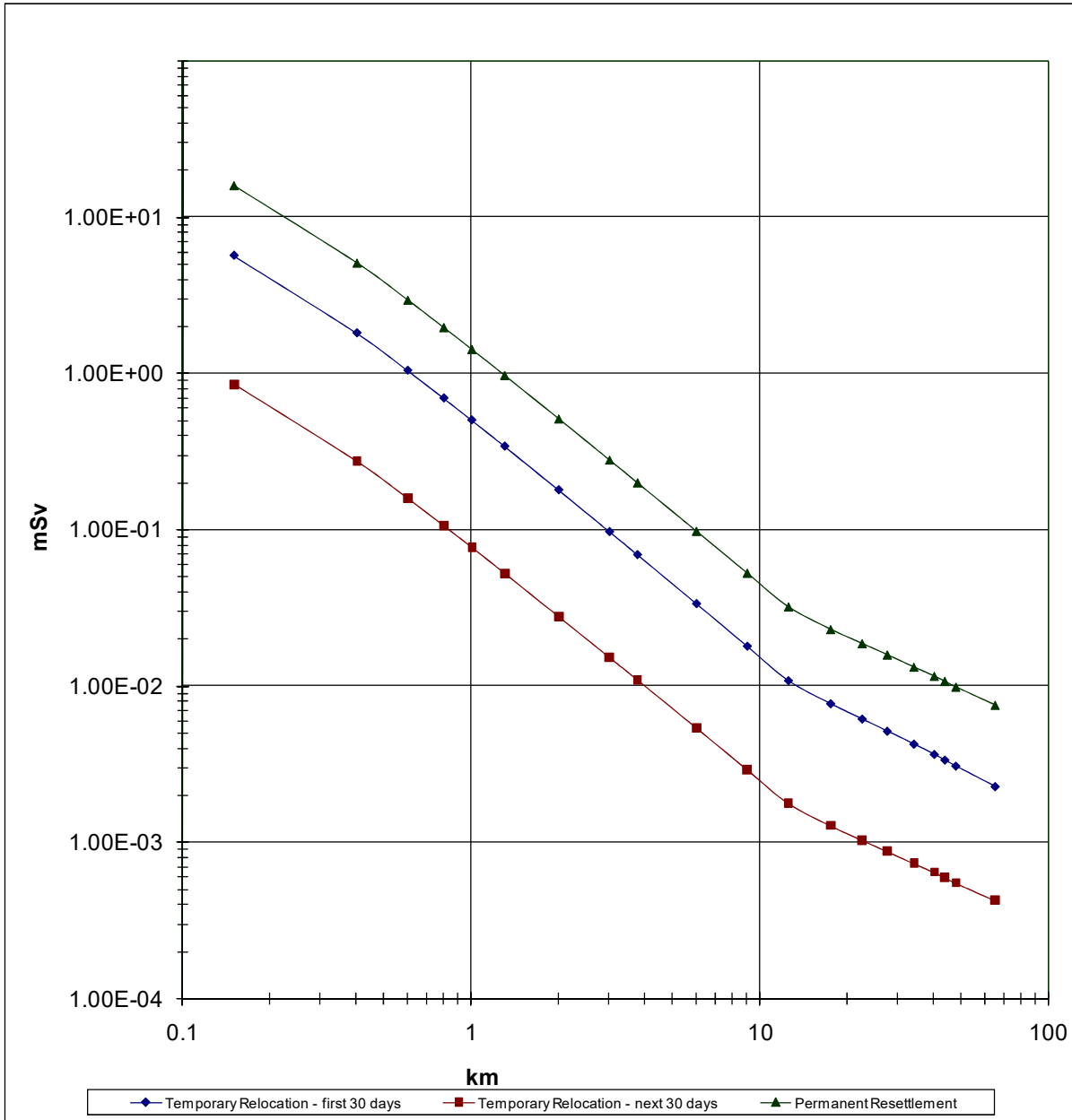


Figure 8.2: EPR Projected Dose - Temporary Evacuation and Permanent Resettlement

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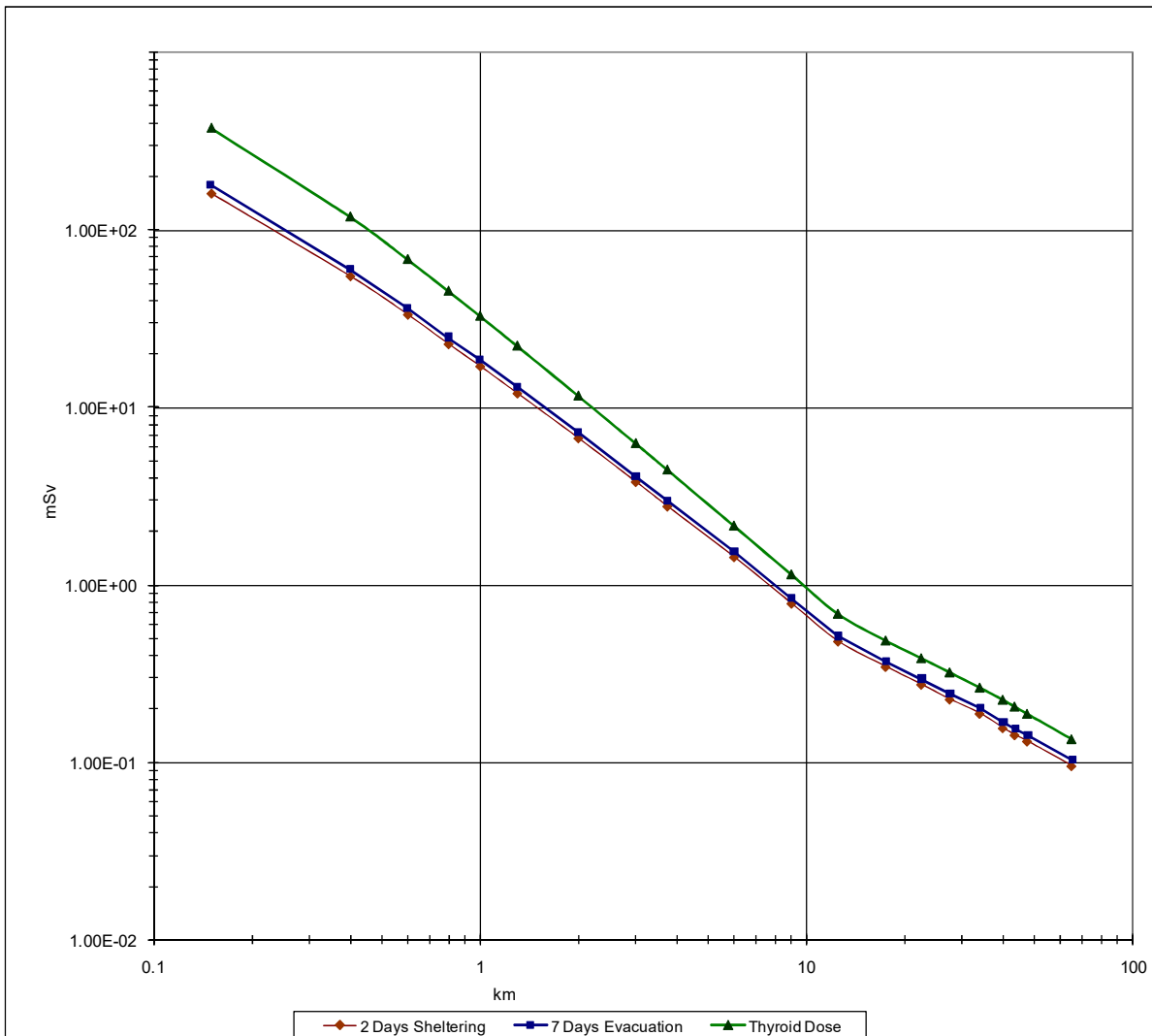


Figure 8.3: AP1000 Projected Dose - Sheltering, Evacuation and Thyroid Dose

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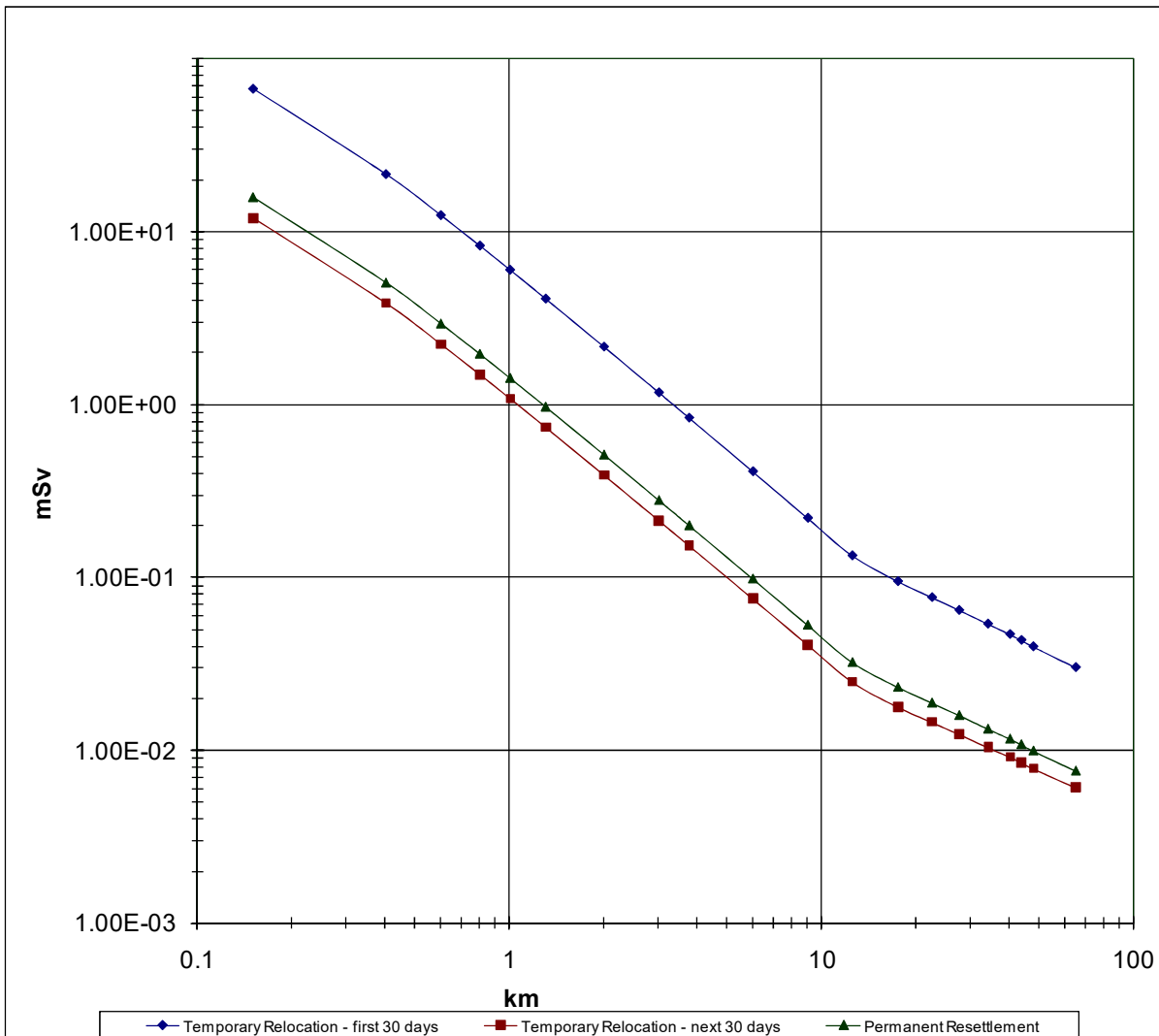


Figure 8.4: AP1000 Projected Dose - Temporary Evacuation and Permanent Resettlement

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Apart from the dose assessments to compare results to intervention levels, an assessment of the total projected dose was done for all exposure components to assess the potential dose at very short distance from the nuclear installation. A distance equal to 2.5 km was selected for this purpose. The integrated airborne radioactivity calculated for the AP1000 source term was used since it envelops the EPR source term. Rainfall of 10mm was assumed in order to simulate significant deposition of airborne radioactivity at this short distance and to arrive at a conservative result. The results are listed in **Table 8.9** and illustrated in **Figure 8.5**. It shows the importance of the ingestion pathway but also that temporary relocation (with food banning in place) and permanent resettlement will not be necessary.

Table 8.9: Projected Time Dependent Effective Dose from all Exposure Pathways at 2.5 km (AP1000)

Time	Total, mSv	Ingestion, mSv	Inhalation ,mSv	Cloud Shine,mSv	Ground Shine,mSv	Skin/clothes, mSv
1day	7.5E+00	3.8E+00	1.6E+00	8.7E-01	1.1E+00	1.8E-01
1 week	2.8E+01	2.3E+01	1.6E+00	8.7E-01	2.9E+00	1.8E-01
2 weeks	4.3E+01	3.6E+01	1.6E+00	8.7E-01	4.1E+00	1.8E-01
1 month	6.0E+01	5.1E+01	1.6E+00	8.7E-01	6.1E+00	1.8E-01
6 months	9.2E+01	7.5E+01	1.6E+00	8.7E-01	1.4E+01	1.8E-01
1 year	1.1E+02	9.2E+01	1.6E+00	8.7E-01	2.0E+01	1.8E-01
2 years	1.3E+02	9.7E+01	1.6E+00	8.7E-01	2.7E+01	1.8E-01
5 years	1.4E+02	1.0E+02	1.6E+00	8.7E-01	3.7E+01	1.8E-01
10 years	1.6E+02	1.1E+02	1.6E+00	8.7E-01	4.5E+01	1.8E-01
50 years	1.8E+02	1.1E+02	1.6E+00	8.7E-01	6.4E+01	1.8E-01
70 years	1.8E+02	1.1E+02	1.6E+00	8.7E-01	6.7E+01	1.8E-01

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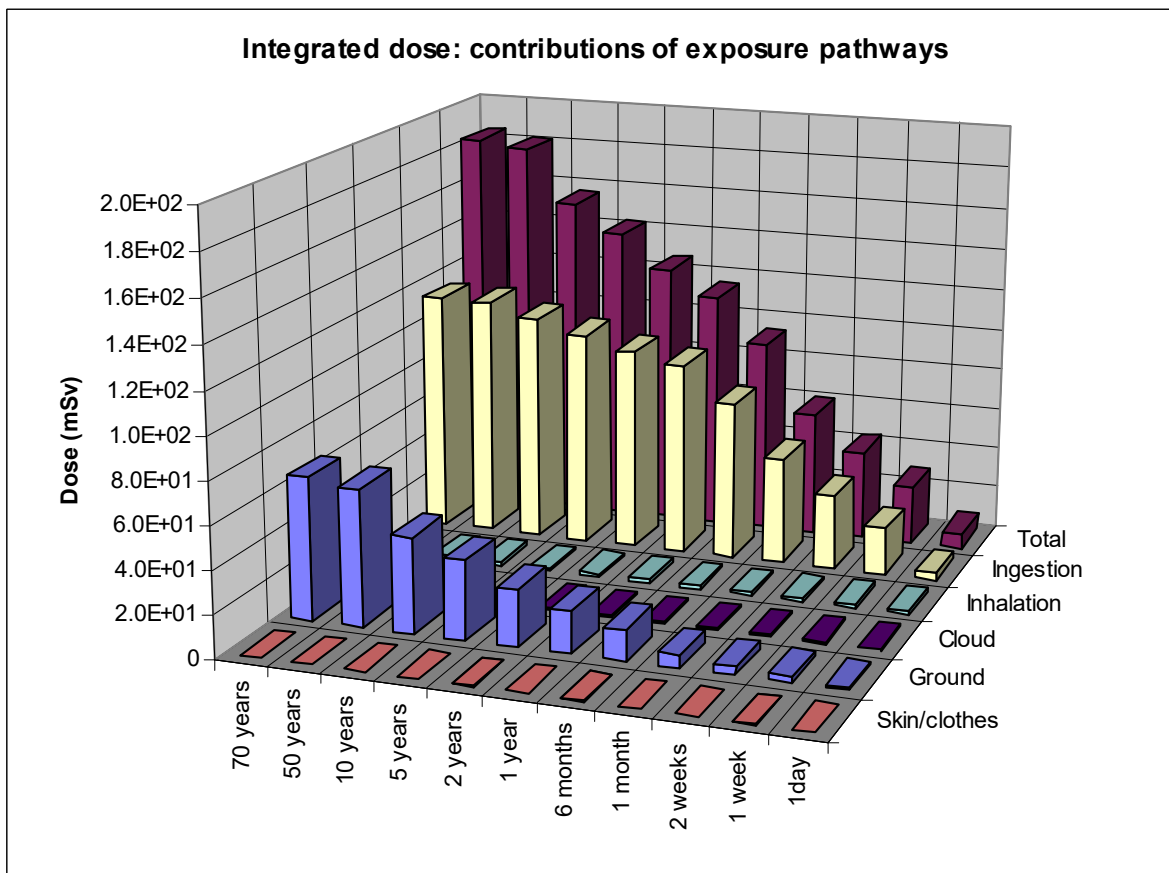


Figure 8.5: Projected Time Dependent Dose from all Exposure Pathways at 2.5 km (AP1000)

8.6.3 Food Banning and Replacement

The projected concentrations at the 40 km radius for the main types of foodstuff produced in the area of the nuclear installation up to that distance were calculated based on the methodology described in [Appendix A-8.E](#). Information on agricultural produce is provided in [Section 5.5](#) (Eskom, 2025b) and relevant foodstuffs were considered for estimating radioactivity concentrations. The main activity is dairy farming. The area around Humansdorp is the largest milk producer in South Africa. The radioactive iodine concentration in milk is therefore of particular interest.

The radioactivity concentrations in foodstuffs were determined assuming an accident occurred at the time of year when agricultural activities result in the maximum concentrations, i.e. the period February to April. [Figure 8.6](#) to [Figure 8.12](#) show the relevant radionuclide concentrations in foodstuffs. The postulated accident occurs on 1 March. Note that the severe accident source terms used for the technical assessment of EPZ requirements do not include

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Am-241, Pu-238, Pu-239, Pu-240 or Pu-242.

It can be concluded from the results that there will be a limited period following the accident during which the intervention levels listed in **Table 8.3** are exceeded. The limiting radionuclide is I-131 and its projected concentrations in leafy vegetables and milk exceed intervention levels for approximately one month, the duration required for food banning and replacement.

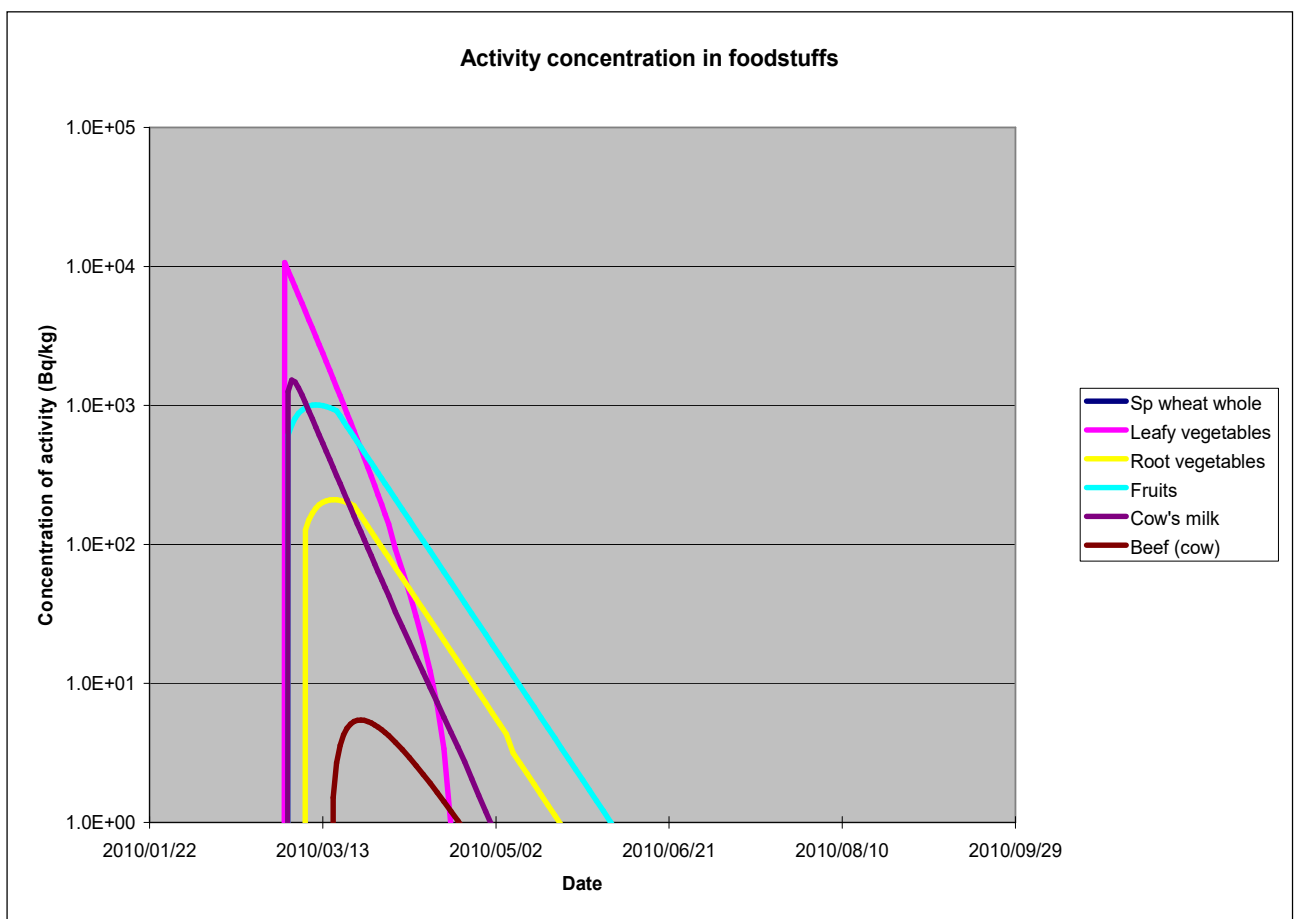


Figure 8.6: I-131 Concentration in Foodstuffs at 40 km

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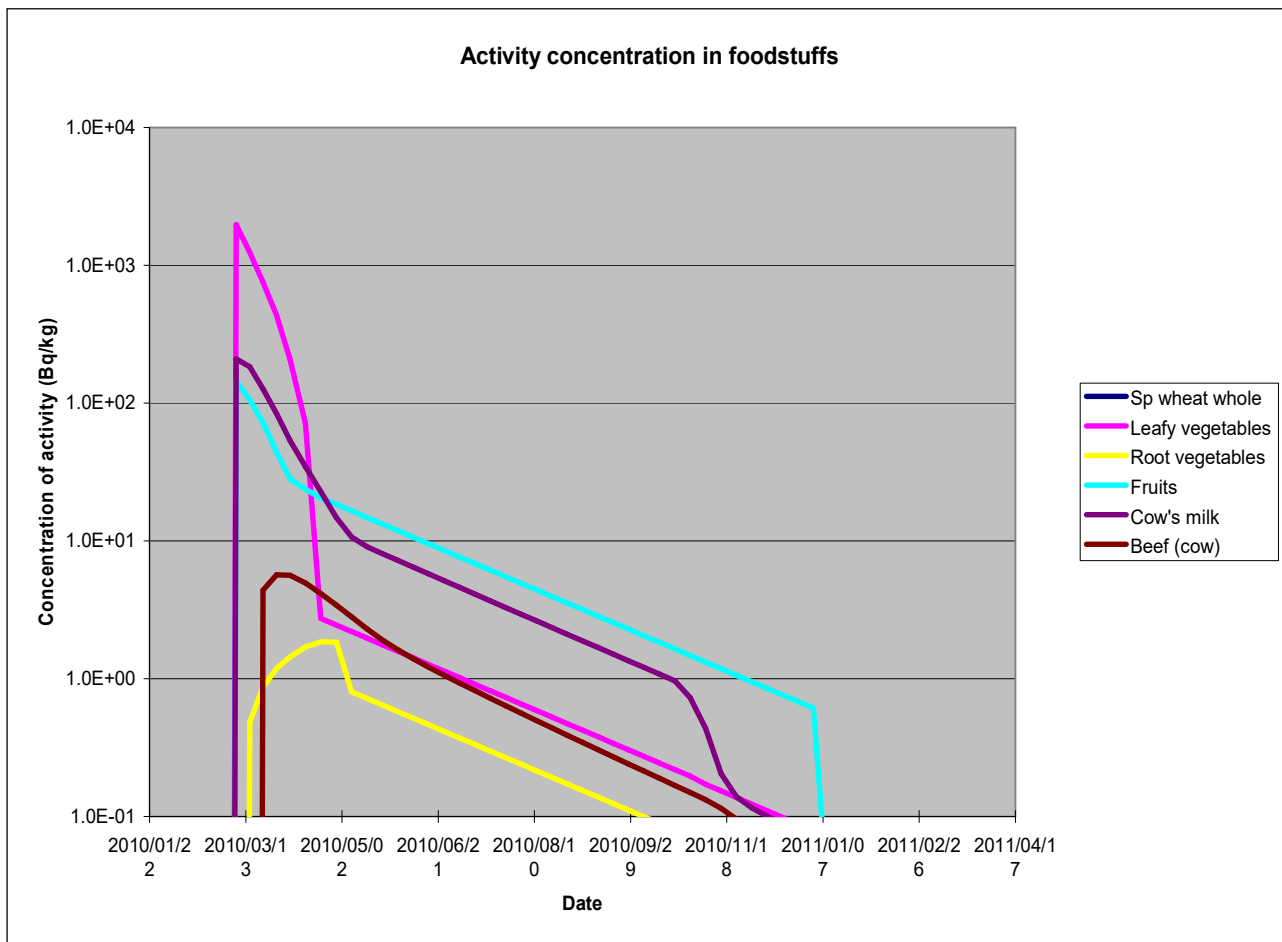


Figure 8.7: Sr-89 Concentration in Foodstuffs at 40 km

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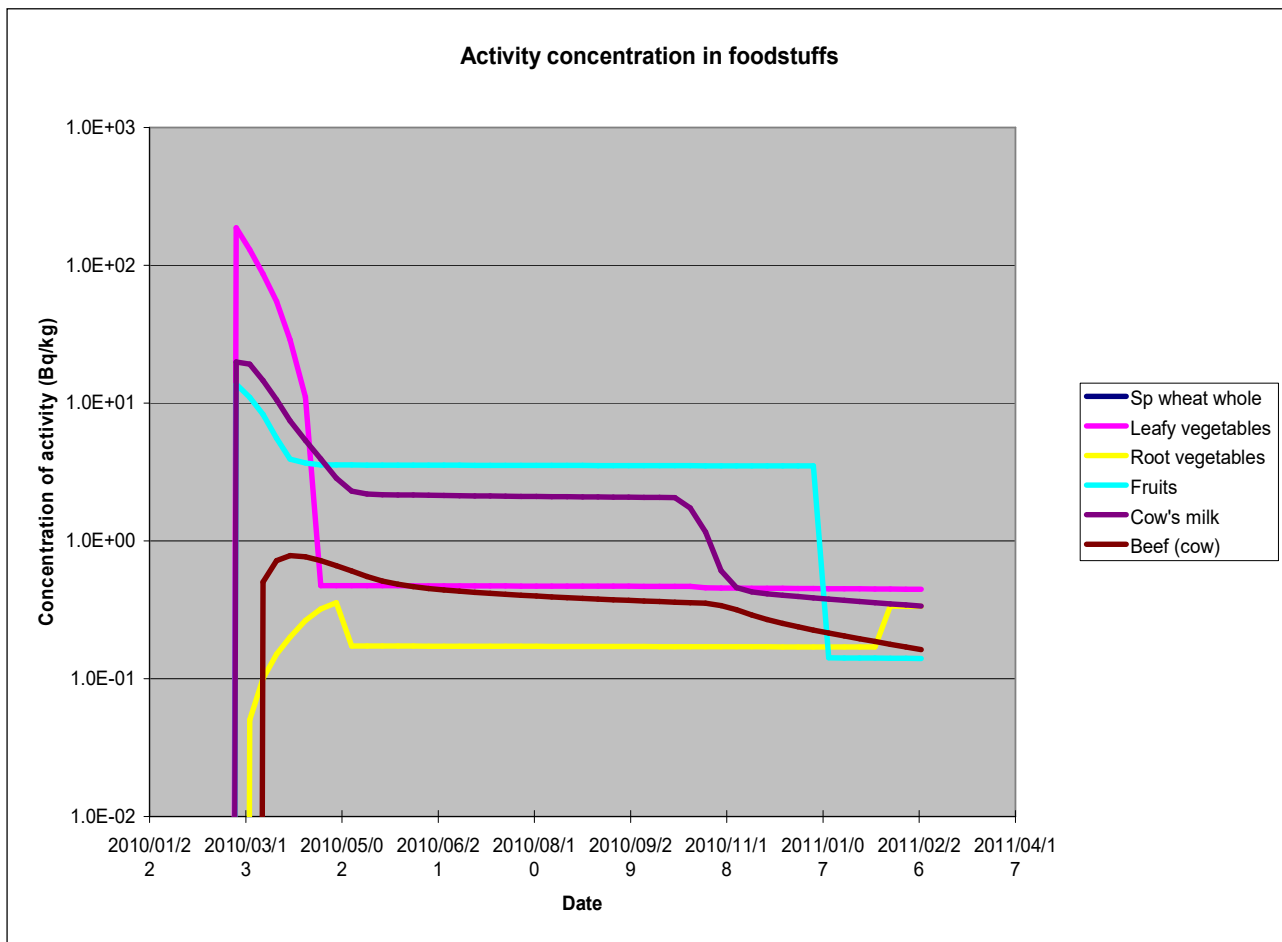


Figure 8.8: Sr-90 Concentration in Foodstuffs at 40 km

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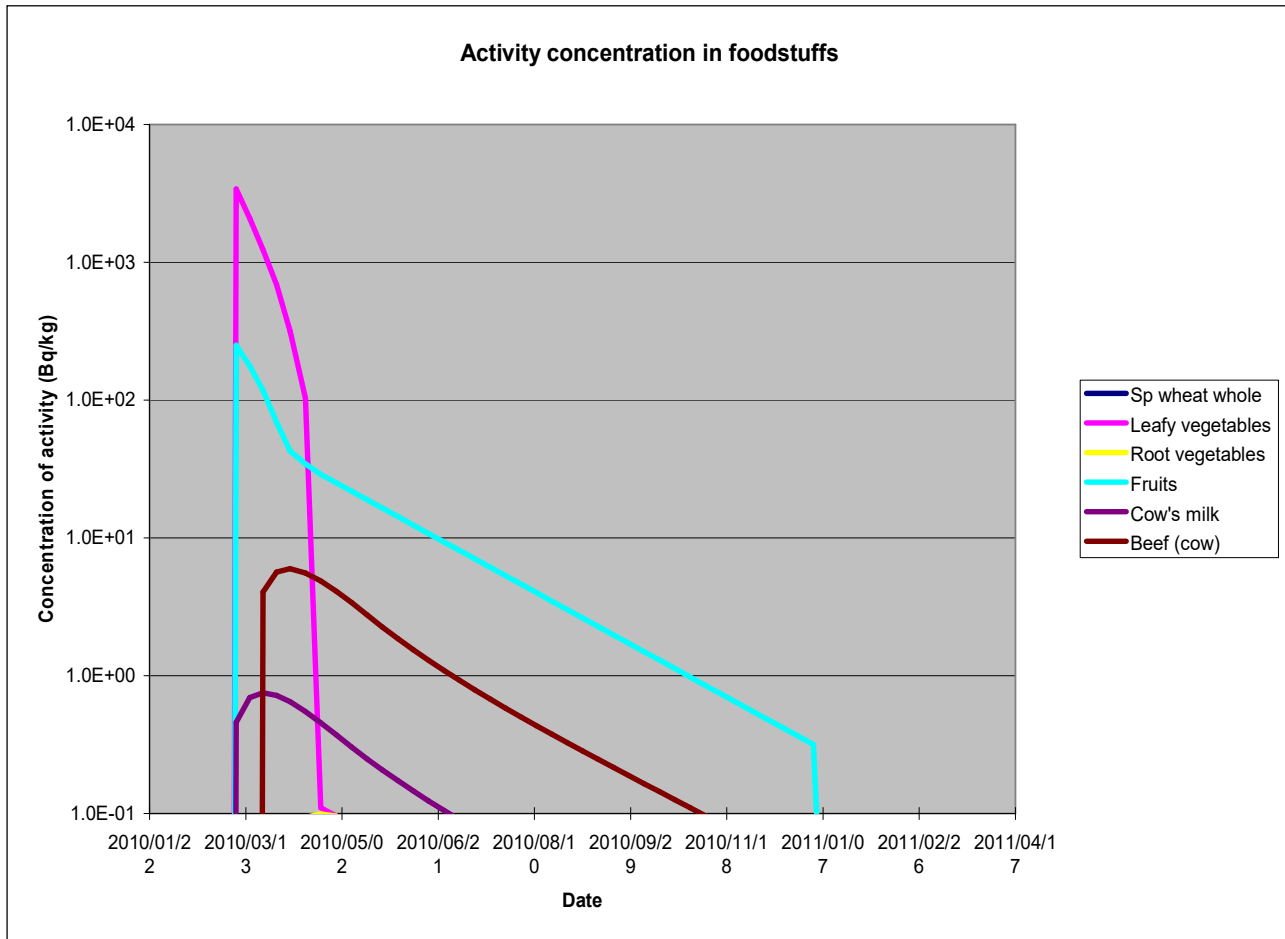


Figure 8.9: Ru-103 Concentration in Foodstuffs at 40 km

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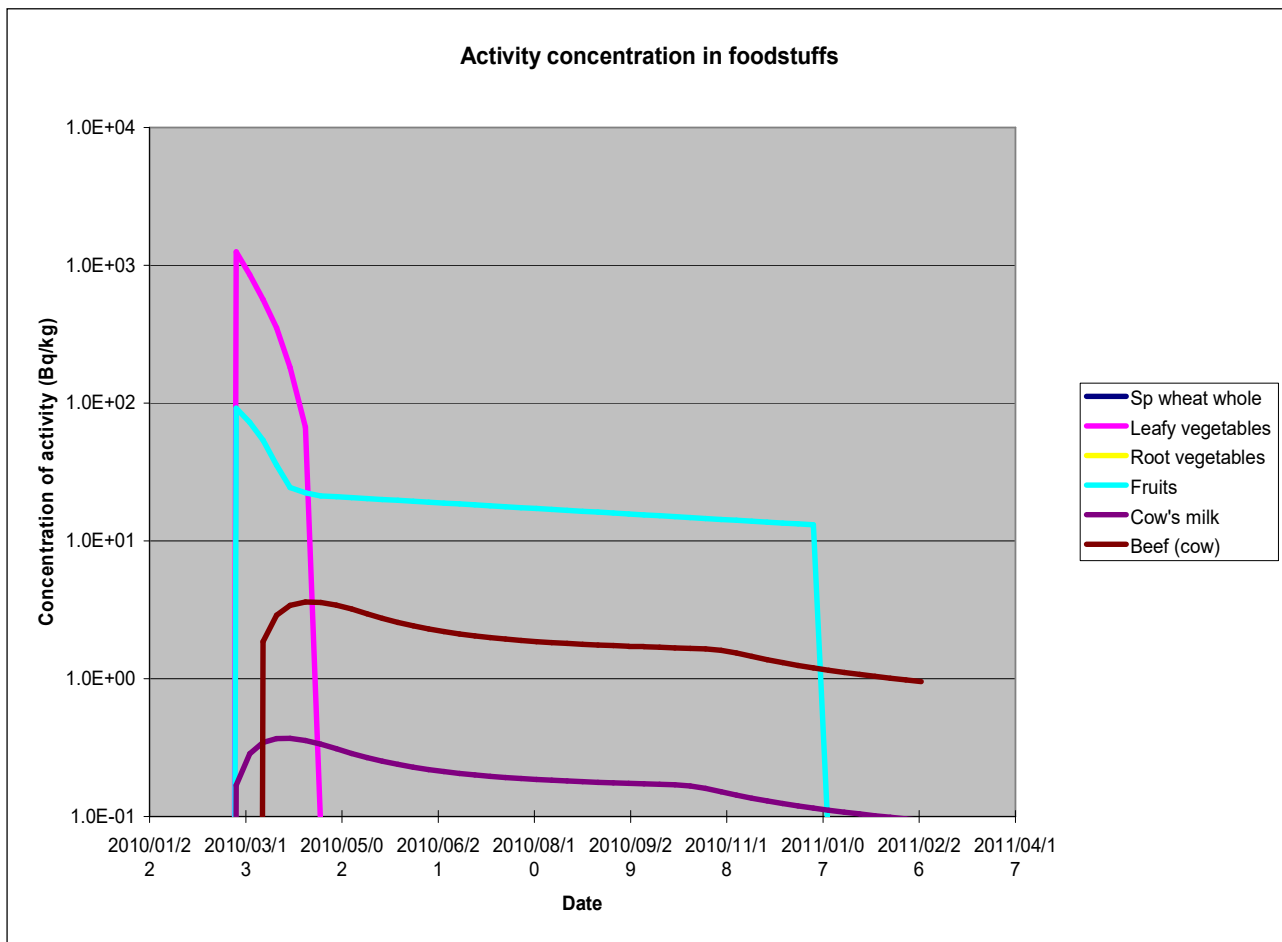


Figure 8.10: Ru-106 Concentration in Foodstuffs at 40 km

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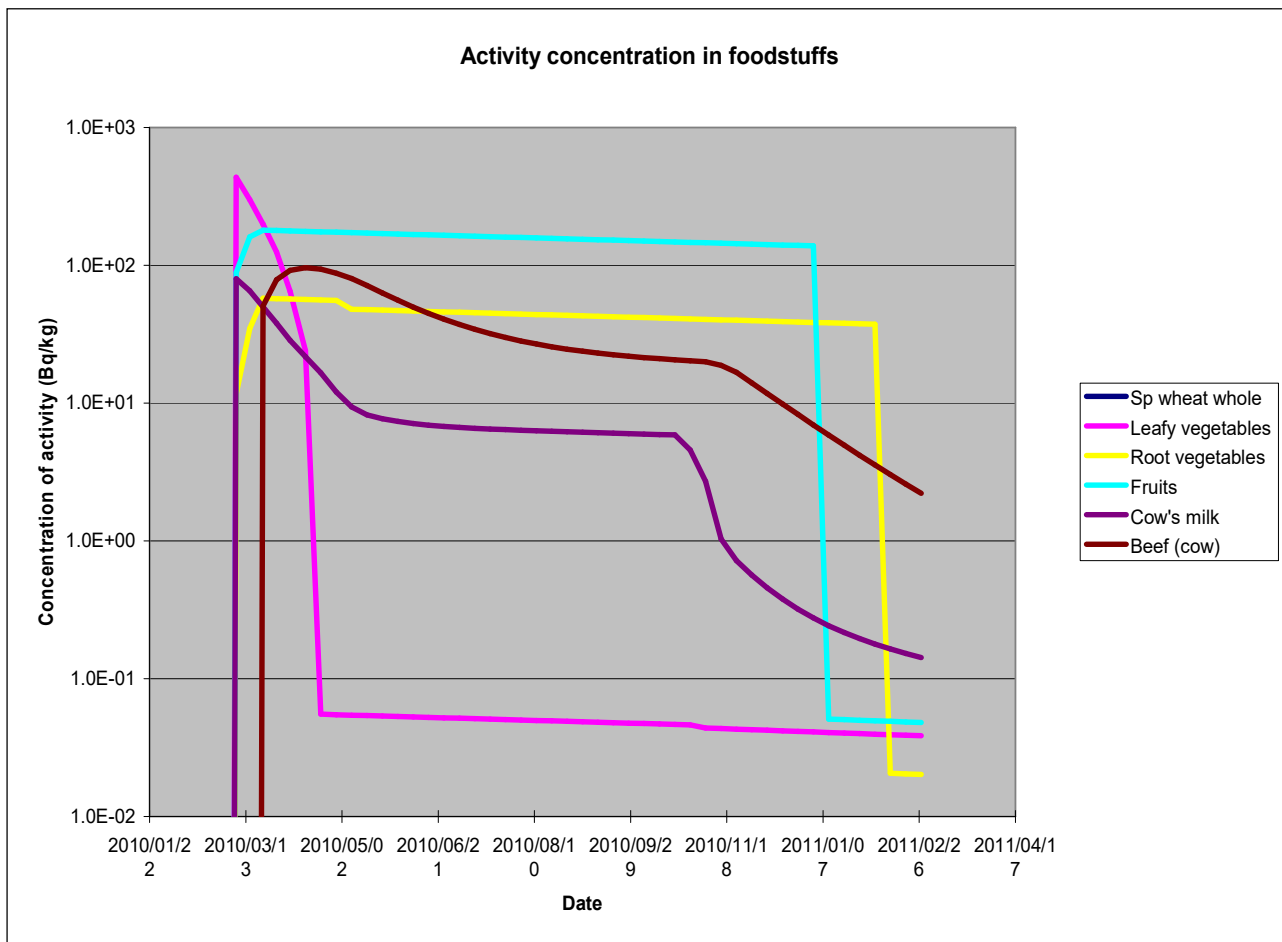


Figure 8.11: Cs-134 Concentration in Foodstuffs at 40 km

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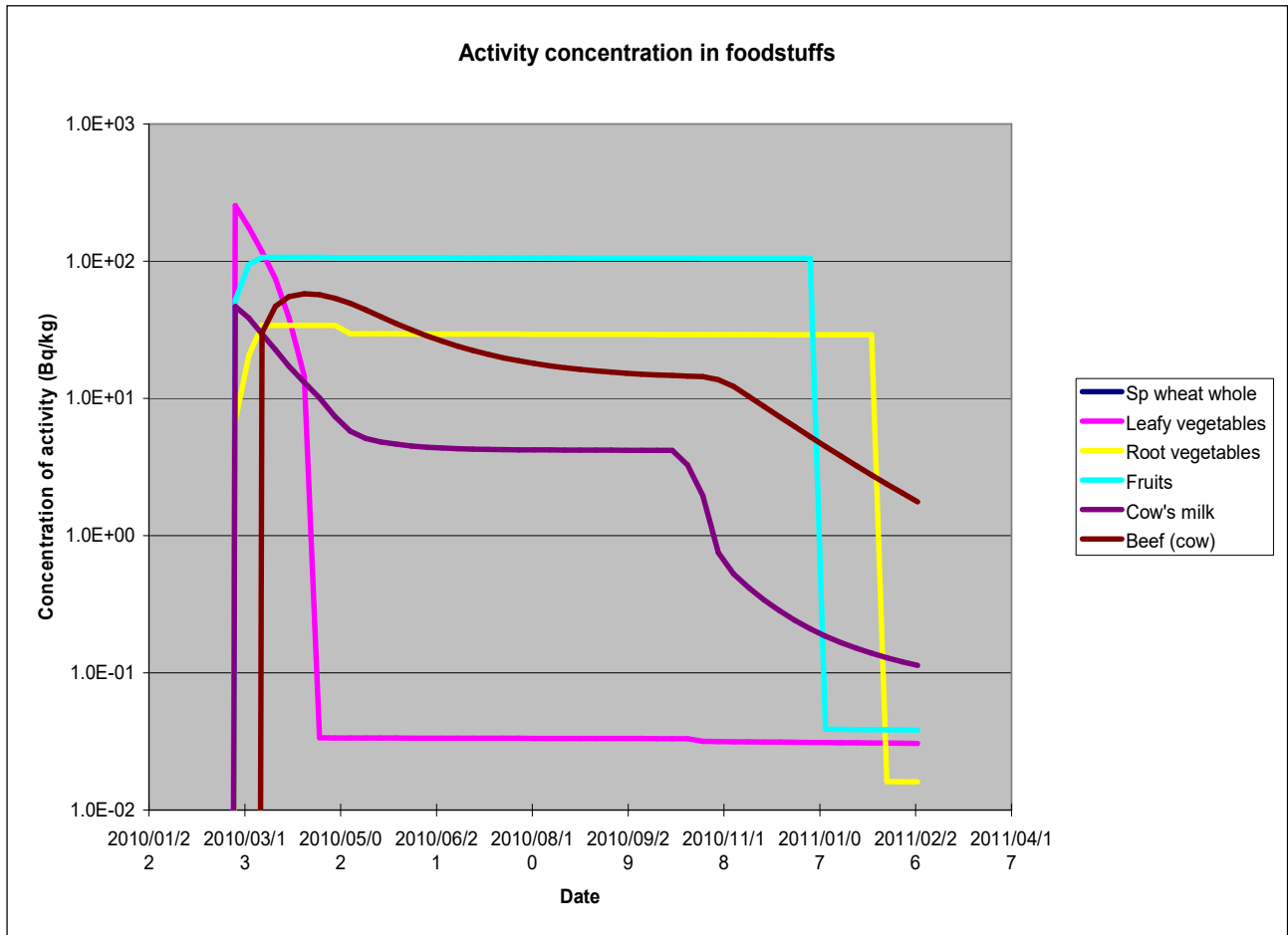


Figure 8.12: Cs-137 Concentration in Foodstuffs at 40 km

8.6.4 Conclusions on the assessment of the EPZs

It can be concluded from the above results that EPZ requirements for sheltering, evacuation, iodine prophylaxis, temporary relocation and permanent resettlement are met with one exception. The AP1000 reactor source term does not meet the requirement for sheltering if the unit is located 0.8 km from the EZ boundary. This exception is based on results obtained when performing the consequence modelling with the conservative assumptions as discussed in **Appendix A-8.C** and following the prescribed Eskom approach for selecting severe accident source terms (International Atomic Energy Agency, 2011).

It should also be borne in mind that although the EZ is defined as 800 m from the nearest reactor. Eskom has some margin available by opting for the boundary of the owner controlled area as the radius for no urgent action,

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beyond 800 m. The accident consequence modelling shows that despite the conservative assumptions, no urgent action is required beyond 2 km for an AP1000 type reactor.

A final remark is that a comparison of the results of the accident consequences of the AP1000 and EPR reactors should be made with care because of the following reason. A severe accident source term used for dispersion in the environment is very dependent on different accident modelling approaches and different application of conservative assumptions inside containments as would be the case for the AP1000 and the EPR. The AP1000 does not necessarily pose a higher radiological risk than the EPR.

8.7 Site Specific Characteristics and Emergency Plan Feasibility

8.7.1 Introduction

As required by the national legal framework and international best practice (see **Section 8.3**), before final approval of a nuclear installation site, the feasibility of an emergency plan must be demonstrated. In the case of most operating nuclear installations there must be no adverse site conditions which could hinder the sheltering or evacuation of the population in the region or the ingress or egress of external services needed to deal with an emergency (International Atomic Energy Agency, 2011).

Theoretically, it has been demonstrated in **Section 8.6** that a limited emergency plan for areas beyond the owner controlled boundary is required for the two reference reactor technologies. No urgent off-site actions are required at the distance of the nearest human settlements, Oyster Bay/Umzamowethu. The limited impact of a severe accident, and therefore no requirements for urgent actions to protect the public, indicates that an EP will be viable. However, it is foreseen that some measure of off-site extendibility of the EP urgent actions will have to be provided. This implies providing emergency response capabilities beyond those based purely on severe accident consequence analysis and the small UPZ as defined in **Subsection 8.3.2**. The degree of extendibility of the nuclear installation EP shall be a subject of negotiation with the NNR and other affected parties. It may require provisions for actions such as a precautionary evacuation of people at distances beyond the defined UPZ even though, at the time of the accident, no release has occurred.

Characteristics of the site are discussed in the following sections and demonstrate that effective emergency planning is feasible subject to infrastructure upgrade. An important aspect of infrastructure upgrade will involve improvement of the access roads that will service the site, especially during the construction phase. Flooding hazards in the region will be an important design consideration of these new roads. This will ensure successful emergency actions in the unlikely event that they are required, such as emergency support access to the site and precautionary evacuation of personnel and nearby populations, e.g. Oyster Bay/Umzamowethu. The

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final layout of the site and design of access routes therefore have to take adverse environmental conditions that could exist at the time of a nuclear emergency into consideration.

8.7.2 Population Density and Distribution

The small coastal settlement of Oyster Bay/Umzamowethu is located within 5 km of the site (west-northwest). The average population density within the 5 km radius (a land area of approximately 38 km²) is 21 persons/km² (2022). The average population density within the 6.5 km radius (a land area of approximately 64 km²) is 19 persons/km² (2022).

The projected population at Oyster Bay is estimated to be approximately 1 145 persons by 2130. The results show that approximately 9 802 persons resided within the site vicinity in 2022.

The analysis showed that a population of approximately 119 615 persons resided within the site region (50 km radius) in 2022. The average permanent population density within the 6.5 km radius is projected to be approximately 26 persons/km² by 2130. The projected maximum permanent population within 50 km of the site is approximately 245 034 persons in 2130 (planned nuclear installation decommissioning). The maximum number of tourists within the 50 km radius on any one day in the peak month (December) is estimated to be 8 743 persons in 2130.

The largest permanent populations (current and future) are located in Humansdorp/KwaNomzamo (17 km to 26 km north and north-northeast), Jeffreys Bay (24 km to 29 km northeast), Hankey (38 km to 46 km north-northeast) and Patensie (47.5 km to 50 km north and north-northeast). Oyster Bay with a permanent population of approximately 1 145 persons by 2130, is the only settlement located within 6.5 km of the site. Therefore, it is not likely that a population centre of 25 000 or more persons will develop within 6.5 km of the site over the life of the nuclear installation.

- A permanent population of approximately 238 persons is projected for the 0.0 km to 0.8 km EPZ by 2130 if current trends persist. However, this EPZ falls within the owner-controlled boundary where no permanent population is expected.
- A total cumulative population of approximately 244 persons is projected for the 0.0 km to 0.8 km EPZ by 2130 if current trends persist. However, this EPZ falls within the owner controlled boundary where no permanent population is expected.
- A permanent population of approximately 899 persons is projected for the 0.8 km to 3.0 km EPZ by 2130.
- A total cumulative population of approximately 928 persons is projected for the 0.8 km to 3.0 km EPZ by 2130.

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- A permanent population of approximately 201 860 persons is projected for the 3.0 km to 40 km EPZ by 2130.
- A total cumulative population of approximately 209 026 persons is projected for the 3.0 km to 40 km EPZ by 2130.

Large population groups at larger distances are:

- Humansdorp/KwaNomzamo (17 km to 26 km north and north-northeast) is the largest settlement within the 50 km zone and is expected to have a maximum permanent population of approximately 94 347 persons in 2130.
- The town of St. Francis Bay is the largest settlement within the 16 km radius and is estimated to have a maximum permanent population of 12 078 persons by 2130.

8.7.3 Systems and Infrastructure

8.7.3.1 Communications and emergency notification

In most countries there is a clear separation between the responsibilities of the utilities that have to manage on-site consequences of a radiological accident and the local authorities that are responsible for the protection of the surrounding population and property. In the early phase of a radiological accident, most of the objectives of the on-site emergency plan and the associated tasks are linked to the mitigation and management of any external consequences that may arise and communication with the relevant authorities and the surrounding population. An effective notification and communication system is therefore essential even though no off-site urgent actions are predicted.

The design objective of the notification system has to include as a minimum the following:

- the specific organisations or individuals, who will be responsible for notifying response organisations and the specific decision chains for rapid implementation of alerting and notification decisions;
- a capability for 24 hour per day alerting and notification;
- provisions for use of public communications media or other methods for issuing information on an emergency situation and any instructions to members of the public.

A prompt notification scheme has to include the capability of local and national agencies to provide information promptly over radio, TV, microwave towers and a car equipped with loudspeakers, patrolling through the

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residential areas at the time of activation of an alerting signal. The emergency plans will have to include evidence of such capability via agreements. Initial notifications to the public, for example, might request them to listen to radio and TV for further instructions.

A flow diagram illustrating the typical Eskom Nuclear Emergency Organisation which facilitates communication and decision making is shown in **Figure 8.13**. The functions of the main role players are briefly described as follows:

- 1) A nuclear installation operating shift performs emergency response functions.
- 2) There is an Emergency Control Centre for the nuclear installation from where control is exercised for emergencies. Additional communication facilities enable an Emergency Controller to keep all reactor units on the site abreast of developments during an emergency. The Emergency Controller is assisted by a dual function Technical Support Centre (TSC) that is equipped to deal with any severe accident.
- 3) Eskom Nuclear Installation Specialists and the nuclear installation supplier company will render the technical support to the Thyspunt Emergency Control Centre in the case of an emergency.
- 4) A Regional Emergency Control Centre will be equipped with information data and systems that clearly report nuclear installation specific conditions during an emergency.
- 5) The NNR will adapt their response plans to include the Thyspunt nuclear installation specific information.
- 6) The Megawatt Park National Emergency Centre will adapt their response plans to include Thyspunt nuclear installation-specific information.

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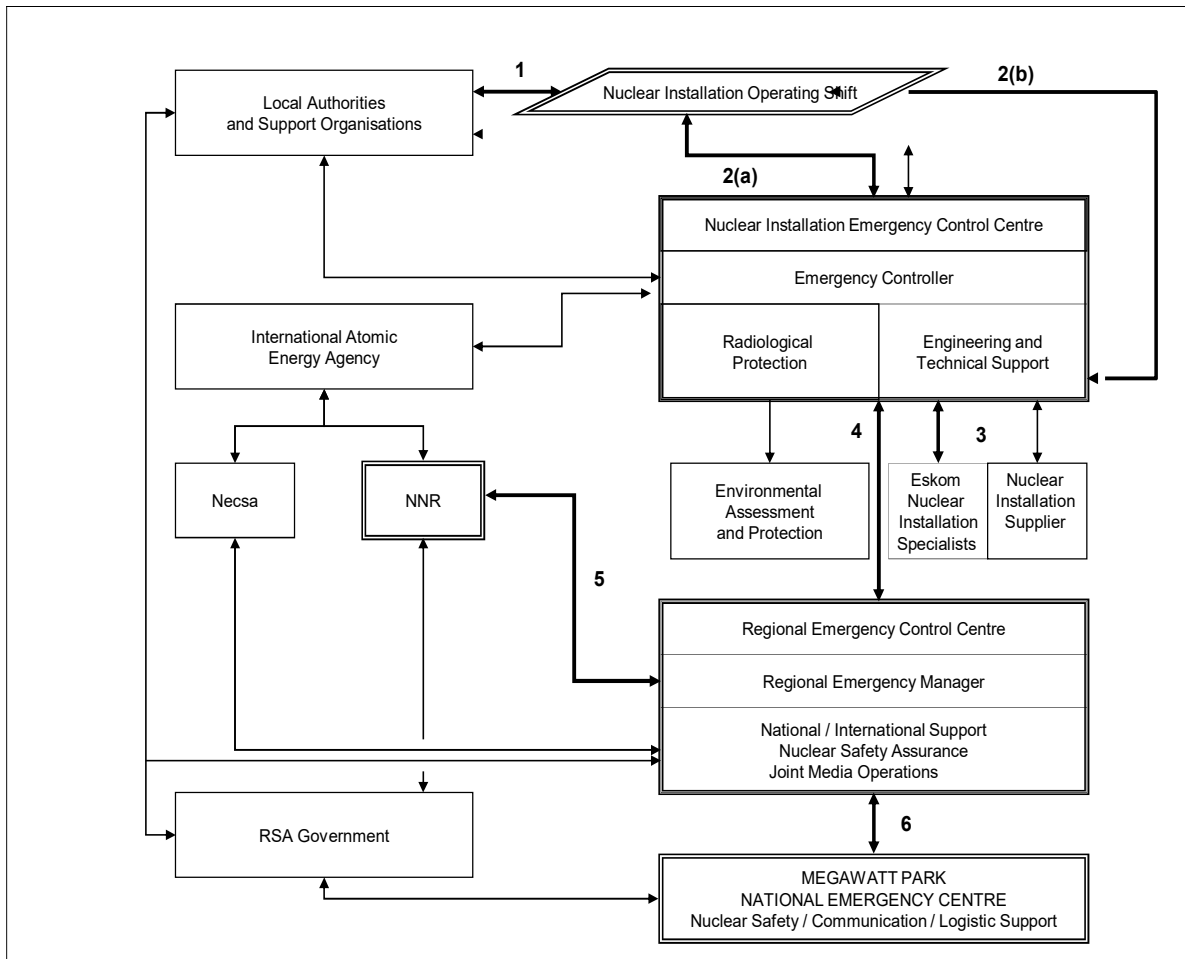


Figure 8.13: Organisational Response to a Nuclear Emergency

8.7.3.2 Telephone Communication

Diverse means of communication exist and include landline telephones, cellular phones, satellite telephones and the internet. It is therefore unlikely that any extreme natural event that could cause or be coincidental to the nuclear emergency would result in no communication possible.

The current situation is as follows. The telephone exchanges falling within a 35 km radius of the site, together with the total number of subscribers and the number of subscribers within the specified radius, are listed in **Table 8.10** below reflecting data from 2008 (**Section 5.7**) (Eskom, 2025b).

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Table 8.10: Telephone Exchanges (2008)

Exchange	Distance (km)	Direction	Number of Subscribers	
			Total	Number within 25 km Radius
T1 - Oyster Bay	5.04	WNW	79	79
T3 – St. Francis Bay	11.58	ENE	1 431	1 431
T4 - Aston Bay	22.12	ENE	644	644
T5 - Jeffreys Bay	24.75	NE	2 508	2 508
T6 - Wavecrest	26.87	NE	2 398	2 398
T7 - Humansdorp	18.80	NNE	2 800	2 484

There are also two microwave towers, one located at Oyster Bay and one at Humansdorp.

One radio tower has also been installed within a 35 km radius of the site at Humansdorp (19.43 km north-northeast of the site).

Two Telkom Street Cabinets are also located within the 35 km radius from the site. They are presented in **Table 8.11**.

Table 8.11: Street Cabinets (2008)

Street Cabinets	Distance (km)	Direction	Number of Subscribers	
			Total	Number within 25 km Radius
T3 - Cape St. Francis Shelter DLUB 700	11.70	E	213	213
T6 - Kruisfontein Shelter DLUB 400	20.44	N	127	127

The cellular communication network related telecommunication base stations that occur within the 35 km radius is presented in **Table 8.12**.

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Table 8.12: Cellular Base Stations (2008)

Code	Provider	Site Name	Direction	Distance (km)
C1	Telkom	Oyster Bay	WNW	5.02
C2	Vodacom	St Francis Bay	E	10.83
C3	Vodacom	Cooper House MC1	E	11.84
C4	Vodacom	Cape St Francis Resort MC1	E	12.12
C5	Vodacom	St Francis Drive	ENE	12.50
C6	Transtel	Cape St Francis	ESE	12.51
C7	Vodacom	Port of St Francis MC1	E	13.89
C8	Telkom	Gill Marcus Dect	NNE	19.44
C9	MTN	Humansdorp Water Reservoir	NNE	19.58
C10	Cell C	Humansdorp	NNE	19.62
C11	Vodacom	Humansdorp	NNE	20.27
C12	Vodacom	Paradise Beach	ENE	20.54
C13	Vodacom	Paradise Beach	ENE	21.47
C14	MTN	Happy Valley	NNW	21.83
C15	Vodacom	Kerkplaas	NNW	23.61
C16	Vodacom	Marina Martinique	ENE	23.98
C17	MTN	Jeffreys Bay Beach	NE	25.40
C18	Vodacom	Time Square	NE	25.42
C19	CellC	Jeffreys Bay Golf Course	NE	25.51
C20	Vodacom	Jeffreys Bay	NE	25.87
C21	Vodacom	Ozzies	NE	26.85
C22	Telkom	Wavecrest	NE	26.85

The communication infrastructure in place represents a good basis for the development of an effective public communication system. Although the number of subscribers to traditional telephones is small when compared to the population size, it has to be taken into account that cell phone communication is extensively used nowadays, also by people living in informal settlements. It can form an important element in any emergency communication.

8.7.3.3 Radio and Television Transmitters

The nearest transmitter to the site is located at Gqeberha (73.77 km east-northeast) and transmits RSG, SAFM, R2000, LOBO, 5FM, METRO FM, LOTUS FM and Radio ALGOA as well as SABC1, 2& 3, eTV and MNET. This transmitter is approximately 90 km from the site. Sentech (Pty) Ltd controls the radio and television transmitters in the region (see also

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Section 5.7 (Eskom, 2025b).

In terms of suitability, the current communication infrastructure in place represents a good basis for the development of an effective public information system.

8.7.4 Transport

Should evacuation be required for any reason, transport routes will have to function normally. Roads leading to and from the nuclear installation and connecting to the N2 must be upgraded. The current traffic volume on the N2 highway at Humansdorp interchange is low and in the order of 4 377 vehicles per day in both directions, with the percentage of trucks being 20 per cent (**Section 5.7**) (Eskom, 2025b).

Evacuation at off-site locations beyond the Owner Controlled Area (OCA) is not expected to be required in the case of the severe accidents considered for the site emergency plan.

8.7.5 Land Cover and Water Use

The land cover within a 20 km radius of the site can be classified in the following categories, in order of importance:

- cultivated (commercial dryland);
- tall shrubland (strandveld, dune fynbos and thicket);
- low shrubland (fynbos and renosterveld);
- cultivated (commercial irrigated);
- urban/built-up (residential);
- water bodies;
- bare soil (sand dunes);
- forest (indigenous);
- urban/built-up (low-density residential, golf estate);
- urban/built-up (high-density residential);
- forest plantation (pines), urban/built-up (small holdings);
- wetlands;

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- urban/built-up (light industrial);
- urban/built-up (commercial);
- mines and quarries (surface-based mining);
- urban/built-up (informal squatter settlements).

No agricultural production occurs within 2.5 km of the site (see also **Section 5.5**) (Eskom, 2025b). Land-use within 16 km of the site is dominated by agricultural land, which is for the most part utilised for dairy farming and associated agricultural production, such as beef and fodder crops. Dairy farms are the dominant type of agricultural collection, processing and distribution facility located within the 3 km to 40 km EPZ. A large number of dairies are present within the EPZ, in particular in the west-northwest, northwest and the northeast segments. Milk produced is transported to the Woodlands Dairy in Humansdorp and the Nestle processing facility in Kareedouw (located outside the 3 m to 40 km EPZ but within the 50 km site region), as well as other dairy processing facilities located outside of the site region (including Clover and Coega Dairy in Gqeberha). It is therefore an important local agricultural product with respect to the site vicinity and the potential radiological impact during a nuclear accident. Other agricultural products within the 3 km to 40 km EPZ include:

- two fruit packhouses located, both located within the Gamtoos River Basin: Ferreira Citrus Growers (39.68 km northeast) and De Koning Broers Highlands (39.91 km northeast);
- six red meat abattoirs, all of which are located between 13.26 km and 28.41 km between the west-northwest and northern segments;
- one chicken broiler located at 32.41 km northeast;
- one grain silo located in Humansdorp (19.19 km north-northeast).

Plans will be required for countermeasures that can reduce contamination of agricultural produce in the EPZ. The primary aims of such plans are normally to minimise radioactive contamination of crops and animal products and to return the land to productive use as far as, and as soon as possible. In the detailed planning and preparation of responses to an accident, protective actions appropriate to the site and the impact area must be developed in documented plans. From this, the first criteria for action to be used immediately, and for a short time after an accident, can be developed. These plans require:

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- a database which includes more specific information about the transfer of radioisotopes between local soil, water, plants, animals and marine life being harvested in the vicinity of the nuclear installation;
- data on soils, weather patterns, local dietary preferences and some feasible countermeasures with estimates of their costs;
- identification of a network of suitably accredited laboratories for radionuclide analysis;
- measures to be taken before and during deposition of radioactive fallout (e.g. housing animals and covering/replacing feed).

8.8 Special Population Groups

Special population groups are members of the public for whom special arrangements are necessary in order for effective protective actions to be taken during the early phase of a nuclear emergency whenever off-site urgent actions are predicted (International Atomic Energy Agency, 2007). Examples of these groups include disabled persons, hospital patients and prisoners.

A survey of special population groups has been carried (**Section 5.4**) out although it is unlikely that special arrangements will ever be required, based on the current position on no off-site short-term emergency interventions (Eskom, 2009).

Section 5.4 (Eskom, 2025b) indicates that special population groups were identified up to 35 km from the site. These are:

- homes for the aged - There are five homes for the aged within 35 km of the site. The nearest home to the site is Ons Tuiste at 17.25 km north-northeast with 170 residents. The majority of homes are concentrated in the northeast sector and a total of 1 023 persons reside in these five facilities.
- Hospitals and clinics - There are 4 public and private hospitals located within 50 km of the site. The two nearest hospitals to the site are the P. Z. Meyer TB Hospital (17.44 km north-northeast) with 57 beds and the Life Isivivana Private Hospital (17.59 km north-northeast) with 33 beds. One hospital, the BJ Vorster Hospital, is located further than 35 km from the site. The largest proportion of the four hospitals is located in the north-northeast. A total of 6 clinics or community health facilities are located within 35 km of the site. The Oyster Bay Care Clinic is the nearest clinic to the site (4.3 km northwest). However, it should be noted that the clinic was still undergoing renovation at the time this data was gathered. The nearest operational clinics were therefore St. Francis Bay Health Care Clinic (11.7 km east) and the Humansdorp Municipality Clinic (16.91 km north-northeast) in KwaNomzamo, which are located within the site vicinity.

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- educational facilities - There are no universities located within the site region (50 km). There is only one tertiary education facility located within 35 km of the site, namely the Injongo Further Education and Training College. It accommodates 200 students, with 1 educator for every 20 to 30 students and is located 25 km northeast of the site in Jeffreys Bay. The nearest school to the site is the Sandwater Primary School (4.28 km northwest) with 135 learners in 2023. The nearest Early Childhood Development Centres to the site is Living Ubuntu Edu-care in Oyster Bay (4.28 km northwest) with 19 children and Kokkewiet Creche (4.52 km west northwest) with 20 children.

8.9 Economic Impacts

A limited potential economic impact on a region following an accident is one of the objectives of the new generation nuclear installation with enhanced safety features (European Commission Directorate - General Environment, 2002), of which the two reference reactor technologies used in this study are examples. The objective in respect of the possible restriction on the consumption of foodstuff and crops following a severe accident which results in a release of radioactivity should be limited in terms of timescale and ground area.

Various cost elements are included in the evaluation of the total cost of an accident. These cost elements have to reflect the socioeconomic environment of the site in terms of agriculture, tourism, fishing, retail and trading and civil installations. Information on the current socioeconomic environment is provided in the Nuclear-1 Environmental Impact Assessment (EIA) (Eskom, 2011). The costs of both short-term and long-term consequences and countermeasures have to be accounted for in an economic impact model. The aspects of countermeasures that are considered in terms of costs are briefly described here without attempting to develop a detailed economic impact model for the site at this early stage of the licensing process (European Commission Directorate - General Environment, 2002).

8.9.1 Population movement

The countermeasures that could affect people through restrictions on movement are sheltering, evacuation and relocation to low radiation or uncontaminated areas. These countermeasures may be judged by the relevant authorities to be unnecessary during an emergency at the nuclear installation but there could still be non-controlled behaviour by people, such as voluntary population movements. This would be difficult to account for in any economic impact model. The typical costs arising from a countermeasure which involves population movement, without excluding other possible impacts, can be mainly associated with the following:

- transport away from and back to affected areas;

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- temporary accommodation and food;
- supervision of the evacuated area and monitoring of people;
- loss of income for people unable to reach their workplace;
- lost capital value and investment on land and property;
- psychological effects of stress and upheaval which are indirect costs to the society and difficult to estimate.

8.9.2 **Agricultural restrictions and countermeasures**

Costs will result from restrictions on the production or consumption of foodstuffs inside the 40km EPZ, because the levels of radioactivity in the food exceed regulatory criteria, or those arising from other food countermeasures which are implemented to reduce the levels of contamination in agricultural products. The costs to be considered depend on the agricultural countermeasures implemented. The main ones' concern:

- the cost of the food production lost - This cost has to be considered for all countermeasures where the banning of food is necessary. An indicator of the cost is the loss for the producer due to not being able to sell the products. The unit cost of food production lost can be evaluated through the average selling price of the food concerned. It can also be necessary to consider the cost of elimination/destruction of the contaminated foods, as well as the costs of final waste storage for the residues of the destruction process.
- the cost of food processing - This cost is related to the countermeasure consisting in processing the contaminated food into a derived food product in order to decrease the concentration of radioactivity, for example, processing whole wheat into flour or cow's milk into cheese. One way of estimating this cost consists of evaluating the difference between the selling price of one unit of the new product and the selling price of the total amount of raw food needed to produce one unit of the new product.
- the cost of food storage - This cost has to be considered when the food is stored for long period of time in order to decrease the radioactivity. The cost will depend on the type of storage implemented (ambient temperature, refrigerated or freezing storage).
- the cost of alternative supplies - This cost concerns the feeding of animals with non-contaminated feed, or when animals are removed from contaminated pasture, and the replacement of foodstuff for the population. The evaluation of this cost considers the selling price of the

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unit animal feed or foodstuff, as well as cost of transportation from the production area to the contaminated area of concern.

- The cost of lost capital value of land and stock - This cost arises when the population is relocated or if long-term restrictions are imposed on the land use. The value of agricultural land per unit area is used.

8.9.3 Decontamination of land areas and structures

Decontamination is performed to reduce ambient radioactivity levels top re-accident levels where possible or to a predetermined reference value. This countermeasure influences the duration of the ban on any evacuated area, but also the degree of radiation exposure of the population. The costs of decontamination consist of:

- cost of the cleaning process, including the necessary equipment and materials, as well as the disposal and transportation of the generated waste;
- cost of labour;
- cost of health effects induced in the workforce.

Decontamination costs will be determined by the level of decontamination or dose rate reduction aimed for and on the type of environment being decontaminated.

8.9.4 Cost of radiation-induced health effects

The estimation of the economic cost resulting from the predicted number of health effects is an important part of the assessment of the full economic consequences of an accident. It includes direct health care costs and indirect costs due to the loss of incomes during treatment and convalescence or of the total expected future incomes in the case of death. There are also non-monetary costs such as pain, grief and suffering associated with health effects.

The psychological distress is an important effect in itself. A sudden change in living conditions for those affected by the countermeasures can also lead to an increase in cases of stress related illness and the associated cost thereof.

8.10 Management of Uncertainties

The following uncertainties were identified and for which documented management actions will be provided:

- severe accident analysis and safety analysis, which evolve continuously
 - Accident occurrence frequencies and the radioactivity release fractions to the environment may change and new insights have to be considered,

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(see **Appendix A-8.F**). Insights on emergency planning are also emerging from the nuclear accident at Fukushima Dai-ichi. It is accepted that the two reference technologies would have had a higher survival probability under the extreme challenges at Fukushima. However, it is expected that these designs will undergo further confirmatory safety analysis, especially in terms of prolonged station black-out and multi-source term events. Developments in this area have to be considered in the future review of accident source terms. The frequencies and consequences of severe accidents that consider internal events as well as external events for the specific design of the nuclear installation to be built at the site and described in a site and technology specific probabilistic risk assessment will be assessed to confirm the final EPZs. Although a conservative and deterministic approach was followed, further studies in modelling uncertainties and sensitivity studies will be carried out.

- Regulatory requirements for emergency planning may change and review of the technical basis of emergency planning may be necessary. The results of EPZ analysis for the reference nuclear installation technologies were arrived at by following the prescribed approach in (Eskom, 2013). Licensing interface with the NNR will provide direction in respect of this uncertainty.
- The development of infrastructure that influences the viability of an emergency plan, mainly roads and their ability to withstand natural events such as flooding, is not defined at this stage. Emergency access to and egress from the site must be possible during extremely adverse environmental conditions. The design of a road system that will provide access to the plant has not been finalised. Aspects of emergency planning such as evacuation time estimates, should this be required, can only be performed when the road system design has been finalised.
- Prediction of economic impacts and development of countermeasures involve large uncertainties. A framework for performing such an assessment with development of specific procedures for the site will be required. A baseline study that demonstrates site specific implementation may be necessary. It has to include marine impacts as well.
- Information that is required includes data on soils, improved prediction capability of environmental transport and exposure pathways in the EPZ, local dietary preferences and feasibility of countermeasures with estimates of their costs. In devising and applying agricultural countermeasures, consideration has to be given to the management of the whole contaminated environment and the interaction between environmental components, e.g. land water bodies and agricultural land. There will be a need to develop secondary reference levels (so-called

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‘operational intervention levels’) for animal feeds and pasture and this requires information on site specific environmental factors. Consideration also has to be given to criteria for decisions regarding the change from an emergency exposure situation to an existing exposure situation. This transition may take place at different geographical locations inside the EPZ at different times (International Commission on Radiological Protection, 2007).

- Demographical, marine and land-use aspects of the EPZ have to be periodically reviewed and updated. It forms part of the required monitoring programme referred to in **Section 8.11**.

8.11 Monitoring Programme

Monitoring of aspects of the site important to the viability and development of an emergency plan are described in the relevant sections of **Chapter 5**. It provides for compliance with Government Notice No. 287 (Department of Minerals and Energy, 2004a) which requires Eskom to:

- monitor the current and planned population distribution, disaster management infrastructure and new development to ensure that the emergency plan, as contemplated in section 38 of the act (Republic of South Africa, 1999), can be implemented effectively at all times;
- report to the NNR on the implementation and the results of the monitoring processes at intervals acceptable to the NNR.

8.12 Impact on the Nuclear Installation

8.12.1 Prior to construction of the Nuclear Installation

Prior to construction the following measures have to be completed:

- monitoring of infrastructure design and development at this early stage so that the feasibility of the emergency plan remains valid.
- Confirmation of EPZs to be confirmed with information from the safety analysis and postulated accident source terms from the final selected technology.
- Development of a detailed emergency plan as part of the Safety Assessment Report for the nuclear installation linked to the national and local emergency plans (National Nuclear Regulator, 2005) that will be coordinated with the plans for non-radiological emergencies, both on and off site.

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8.12.2 Prior to Nuclear Installation Operation

- Prior to receipt of nuclear fuel on the site the following measures have to be completed:
 - specific provisions have to be put in place for keeping of a record of all persons and habitation information in the 40 km EPZ;
 - the emergency plan has to be tested (International Atomic Energy Agency, 1994).
- Eskom has to enter into agreements with the relevant municipalities and provincial authorities to establish an emergency plan within a period determined by the NNR. Eskom will also be required to cover the costs of the establishment, implementation and management of such emergency plan insofar as it relates to the relevant nuclear installation or any action (Republic of South Africa, 1999).
 - A public safety information forum must be established as prescribed by the Regulator in order to inform the persons living in the municipal area in respect of which an emergency plan has been established (Department of Minerals and Energy, 2004b).
 - Eskom has to submit an emergency plan for NNR approval (Republic of South Africa, 1999).

8.12.3 During Nuclear Installation Operation, Shut-down and Decommissioning

Once the nuclear installation commences operation:

- The emergency plan has to be reviewed, tested and updated regularly at a frequency agreed to by the Regulator with due consideration to operational and other experience at this and other nuclear installations (National Nuclear Regulator, 2005)
- Training and emergency drills have to be performed (National Nuclear Regulator, 2005) and (Republic of South Africa, 1999).
- In case of an accident, the local and national safety authorities/NNR and the public have to be informed (Department of Minerals and Energy, 2006), as well as the IAEA and the neighbouring countries, if required, have to be notified through the national contact point (International Atomic Energy Agency, 1986a).

8.13 Management System

The evaluation of emergency planning for the site has been conducted in

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line with the management system for this SSR (presented in detail in **Chapter 10**) and Eskom's management system.

The activities that have been carried out with their respective links to other SSR sections/chapters and quality control requirements are presented in **Table 8.13**.

Table 8.13: Summary of Activities, Links and Quality Requirements

Activity	Links		Quality Requirements
	Inputs	Outputs	
Accident Consequence Modelling	Introduction – Chapter 1	Section 8.5 - Compliance Assessment of Emergency Planning Zones	Justification is provided for using specific and international recognized nuclear accident consequence assessment software together with conservative input data
	Overview of Planned Activities at the Site– Chapter 3		
	Land and Water Use – Section 5.5		
	Demography – Section 5.4		
	Meteorology – Section 5.8		
Emergency Plan Feasibility Assessment	Nearby transport – Section 5.7	Section 8.11 – Feasibility of an emergency plan	Peer review
	Demography - Section 5.4		
	Accident Consequence Modelling Results		

Compliance to the NNR regulations on licensing of sites (Department of Energy, 2011) is measured and reported in **Table 8.14**.

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Table 8.14: Regulatory Compliance Matrix

Regulation relevant to Emergency Planning	Section where covered	Comments
(7) The identification and determination of <i>emergency planning zones</i> using the characteristics of the site, <i>source term</i> analysis and PRA established in accordance with Regulations 5(3), 5(4) and 5(5) respectively. In determining the <i>emergency planning zones</i> due account must be taken of physical boundaries such as rivers, dams, mountain ranges as well as municipal boundaries. The <i>emergency planning zones</i> must include the following:	Section 8.6 and relevant Chapter 5 sections 8.5 and Appendix A-8.B for source term from available probabilistic risk assessments and their use in the EPZ analysis	The aspect of external events and its potential impact on infrastructure of which the availability will be important during an emergency has to be reviewed as detail becomes available. The level 2 probability risk assessment of the two technologies that provide the plant parameter envelope source terms, do not reflect site specific external events. A review of the accident source terms and associated frequencies have to be reviewed when the vendor provides plant detail and safety analysis information.
(a) An exclusion zone which is a radius determined for the purposes of evacuating persons in the event of a nuclear accident. Within the boundaries of that zone or within any erven intersecting with that zone there must be no members of the public resident, no uncontrolled recreational activities, no commercial activities, or institutions which are not <u>directly</u> linked to the operation of nuclear installations situated within this zone, or for which an authorization has been not been granted;	8.5 and Appendices A-8.C to A-8.E	
(b) An overall <i>Emergency Planning Zone</i> (EPZ) of such size that emergency or remedial measures must be considered where the potential exists that any members		

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of the public may receive more than an annual effective dose of 1 mSv due to the <i>source term</i> ;		
(c) A Long Term Protective Action Planning Zone (LPZ), where preparations for effective implementation of protective actions to reduce the risk of stochastic health effects from long term exposure to deposition and ingestion must be developed in advance consistent with international standards.		
(8) An analysis to demonstrate the viability of an emergency plan taking into account relevant data established in accordance with Regulations 5(3), 5(4), and 5(5), including <i>disaster management infrastructure</i> . It must be shown that risks to the public, as well as the financial consequences; not located near large industrial areas, potential economic impact on farming and holiday resorts) caused by damage and radioactive contamination, are as low as reasonably achievable.	Sections 8.6 to 8.9	A disaster management organisation is discussed but no specific details on disaster management infrastructure are provided at this early stage. A general discussion of potential economic impacts provided and proposals are made for further work on this aspect.

8.14 Conclusions

Based on the currently available data presented in this SSR and in particular, **Sections 5.4** (Demography) and **5.5** (Land and Water Use) and also subject to proper management of the uncertainties listed in **Section 8.10**, it can be concluded that it is feasible to develop an effective EP for the site. The risk associated with the location of the proposed nuclear facility at the Thyspunt site is below the regulatory requirements.

Eskom's requirements for emergency planning in terms of radiological consequences for new sites are met except for sheltering in the case of the AP1000 reference technology. It is foreseen that the inclusion of the OCA, which extends beyond 800 m from a reactor unit, and an optimised site

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layout should enable Eskom to technically demonstrate that the objective of no urgent off-site emergency action is met.

Although it is concluded that an emergency plan for the site is feasible, further work will continue on the following aspects of emergency planning:

- The economic aspects, especially the agricultural importance of the area, have to be defined in detail for purposes of developing agricultural counter-measures and the estimation of potential economic impacts. Particular attention will need to be given to measures directed at preventing contamination of the food chain. A baseline economic impact assessment specific to the EPZ should be performed and maintained throughout the life of the nuclear installation.
- Nuclear installation emergency response systems must provide for on-site emergency response to be extended beyond the OCA, in particular for precautionary evacuation of the Oyster Bay/Umzamowethu and Cape St. Francis/St. Francis Bay, population areas which are situated in the prevailing wind directions.
- Given that the small coastal settlement of Oyster Bay/Umzamowethu is located within 5 km of the site, further expansion of Oyster Bay/Umzamowethu should be restricted so that the required EPZ for no temporary relocation (3 km) is satisfied with some margin at all times in the operational future of the nuclear installation.

Elements of emergency planning that are deemed to be either organisational or logistical are not influenced by the selected site. This does not mean that these elements are less important, but they can be addressed during a later licensing phase. Provided that the right efforts and resources are invested in the development of those elements, these site independent elements of an emergency plan should be no impediment to the implementation of effective emergency arrangements.

The main uncertainty in this EP feasibility assessment is introduced by the currently available information on severe accident analysis and radioactivity release fractions from the containment into the environment. The information on the reference accident source terms used in this report must be confirmed whether it is bounding of the nuclear installation(s) design that will eventually be built. If it is not bounding the off-site radiological impacts must be reviewed and the EP feasibility be re-assessed.

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Appendix A-8.A

Internationally Agreed Safety Requirements and Guides

International experience on emergency planning for nuclear installations and best practice have shown that for new nuclear installations the following is required (International Atomic Energy Agency, 2019):

- For each proposed site the potential radiological impacts in operational states and in accident conditions on people in the region, including impacts that could lead to emergency measures, need to be evaluated with due consideration of the relevant factors, including population distribution, dietary habits, use of land and water, and the radiological impacts of any other releases of radioactive material in the region.
- In the evaluation of a site to determine its potential radiological impact on the region for operational states and accident conditions that could lead to emergency measures, appropriate estimates shall be made of expected or potential releases of radioactive material, with account taken of the design of the installation and its safety features. These estimates shall be confirmed when the design and its safety features have been confirmed.
- The radiological risk to the population associated with accident conditions, including those that could lead to emergency measures being taken, is acceptably low.
- The external zone⁸ for a proposed site shall be established with account taken of the potential for radiological consequences for people and the feasibility of implementing emergency plans, and of any external events or phenomena that may hinder their implementation. Before construction of the nuclear installation is started, it shall be confirmed that there will be no insurmountable difficulties in establishing an emergency plan for the external zone before the start of operation of the plant.

There is international consensus that the practical goal of emergency preparedness is to ensure that arrangements are in place for a timely, managed, controlled, co-ordinated and effective response at the scene, and at the local, regional, national and international level, to any nuclear or radiological emergency (Electric Power Research Institute, 2007). It is also required that:

- Emergency plans are prepared which specify how the responsibilities for the management of interventions will be discharged on the site, off the site and across national borders, as appropriate, in separate but interconnecting plans.

⁸The area immediately surrounding a proposed site area in which population distribution and density, and land and water uses are considered with respect to their effects on the possible implementation of emergency measures ([Reference 8.17](#)).

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- The plans for response to a nuclear or radiological emergency are coordinated with any other plans (such as plans for physical security, law enforcement or fire fighting) that may be implemented in an emergency in order to ensure that the simultaneous implementation of the plans would not seriously reduce their effectiveness or cause conflicts.
- The content, features and extent of emergency plans take into account the results of any threat assessment and any lessons learned from operating experience and from emergencies that have occurred with sources of a similar type.
- Plans for emergency response shall be based on the assessment of the threats, including events with potentially severe consequences.
- Emergency plans are periodically reviewed and updated.
- Off-site emergency plans and any transboundary plan shall be implemented by the response organisations.

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Appendix A-8.B

Severe Accident Source Terms, Release Categories and Release Fractions to the Environment used in Determining EPZs

1. Introduction

Postulated severe accidents considered for the site are based on the accidents described in the Safety Analysis Reports (SARs) for the EPR and AP1000 reference technologies (Areva, 2006) and (Westinghouse, 2004).

Severe accidents occur when safety systems are impaired and are unable to prevent significant core damage. The source terms for these severe accidents and their estimated frequencies of occurrence are derived by performing a Level 2 Probabilistic Safety Assessment (PSA) which deals with the performance of a reactor containment under severe accident conditions (International Atomic Energy Agency, 2010). These source terms, along with calculations of the off-site dose as a function of distance, are used as inputs into the development of off-site emergency planning.

Level 2 PSAs are essential parts of the safety cases for advanced light water reactors such as the AP1000 and EPR, to demonstrate the capability to address severe accident containment challenges. This capability is based on design features and characteristics to achieve an extremely low probability for core damage sequences which could bypass containment and that the containment can withstand loads representing those associated with core damage sequences (International Atomic Energy Agency, 2010).

The occurrence frequency objective for large off-site releases requiring urgent off-site response is 1×10^{-5} per reactor-year for existing plants. The numerical value for a large off-site radioactive release for new generation plants is required to be significantly lower and the aim is practical elimination of accident sequences that could lead to large early radioactive releases. The Level 1 and Level 2 PSAs for the EPR (Areva, 2006) and AP1000 (Westinghouse, 2004) demonstrate significantly lower frequencies than $1 \times 10^{-5}/y$ and provide information on source terms and release categories to the environment. PSA mean frequencies for internal events greater than $1 \times 10^{-7}/y$ are analysed for containment response and EP source terms (Electric Power Research Institute, 2007).

2. AP1000 Source Term for EPZ analysis

The AP1000 has a severe accident mitigation goal which is to ensure the functioning of the containment in the event of an accident resulting in a significant structural degradation of the reactor core (Westinghouse, 2004).

Specific design features have been incorporated for the retention and stabilisation of the molten core inside the containment as well as for the mitigation of environmental effects that can compromise its fission product retention capability. These design features provide redundant and diverse mitigation of challenging phenomena in the unlikely event of a severe accident. These features include the reactor coolant automatic

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depressurisation system (ADS), the ability to flood the reactor vessel cavity, hydrogen igniters in the large dry containment and the passive containment cooling system (PCS). These design features act to maintain reactor coolant system (RCS) integrity, prevent containment overpressurisation from hydrogen detonation or deflagration and remove heat from the containment. These mitigation features maintain the potential for fission-product release from the AP1000 containment very low.

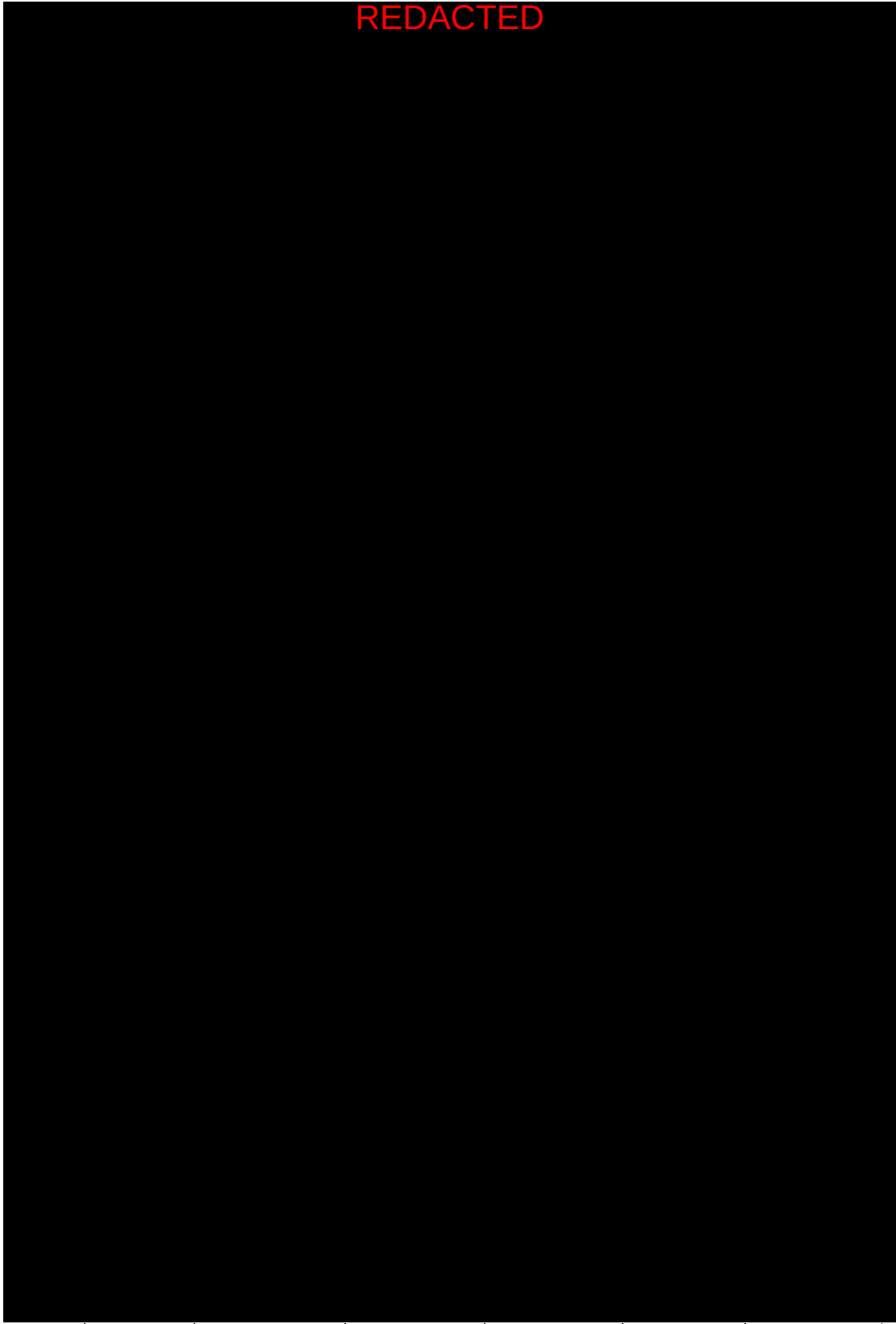
The EP requirements in respect of the AP1000 are based on Release Category IC (see **Table A-8.B.1**). It represents the release of fission products from an intact containment during a severe accident and a release frequency that complies with the Eskom position stated in **Subsection 8.3.2** (Eskom, 2013). Normal containment leakage rates account for the fission-product releases to the environment.

Table A-8.B.1
AP1000 Release Categories and Frequencies

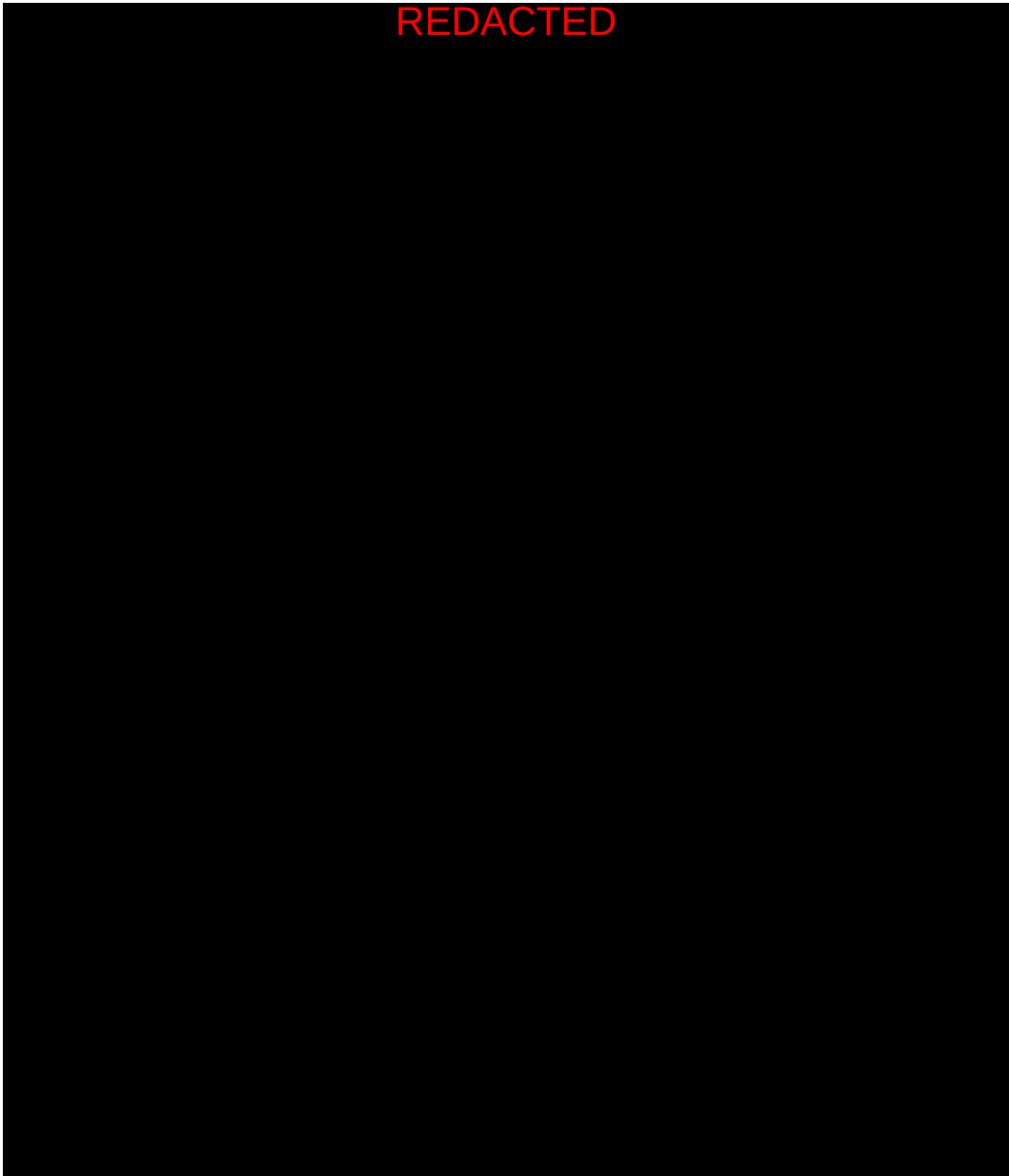
Release Category		Release Frequency (per y)
Containment failure after core melt <24h	CFI	1.89×10^{-10}
Containment failure during core melt	CFE	7.47×10^{-9}
Intact containment leakage	IC	2.21×10^{-7}
Containment bypass	BP	1.05×10^{-8}
Un-isolated containment	CI	1.33×10^{-9}
Containment failure after core melt >24h	CFL	3.45×10^{-13}
Total		2.40×10^{-7}

The source term used for assessing the AP1000 against the EPZ requirements is defined in **Table A-8.B.2**.

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3. EPR Source Term for EPZ analysis

The EPR has a severe accident mitigation goal similar to the AP1000. Design features to address severe accident challenges include (Areva, 2006):

- Provision of dedicated valves for rapid depressurisation of the reactor coolant system (RCS).
- Multiple Passive Autocatalytic Hydrogen Recombiners (PARs) to minimise the risk of hydrogen detonation.
- The containment is designed to promote atmospheric mixing with the ability to withstand the loads produced by hydrogen deflagration.
- A dedicated compartment to spread and cool molten core debris for long-term stabilisation.
- A severe accident heat removal system with two trains allowing one train to be serviced or repaired in the long term if necessary.
- Electrical and instrumentation and control systems dedicated and qualified to support severe accident mitigation features.
- The reactor building consisting of an inner containment building and an outer shield building with a sub-atmospheric annulus.

The EPR severe accident release categories and frequencies are summarised in **Table A-8.B.3**.

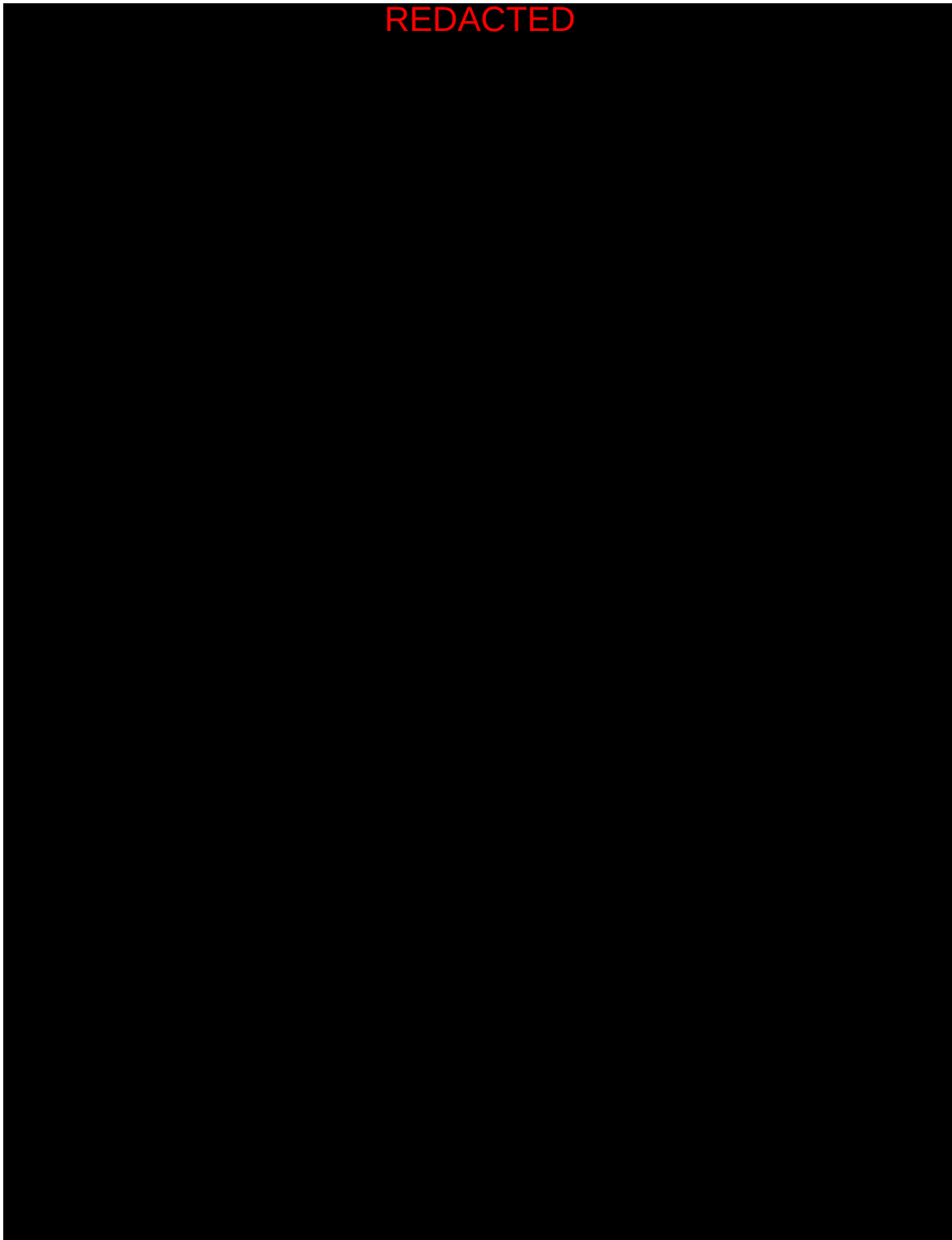
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Table A-8.B.3
EPR Release Categories and Frequencies

Release Category		Release Frequency (per year)
Failure of containment isolation (0.442m ² leak)	RC1	1.56x10 ⁻⁹
Early containment rupture (1m ²) at time of RPV failure	RC2	2.58x10 ⁻⁸
Non-isolated steam generator tube rupture (STGR) – High reactor coolant system (RCS) pressure	RC3	2.25x10 ⁻⁸
Early small containment failure (100cm ²), <u>no</u> spray	RC4	3.83x10 ⁻⁸
Early small containment failure (100cm ²), spray	RC5	4.49x10 ⁻⁸
Large interfacing system LOCA	RC6a	2.26x10 ⁻⁹
Small interfacing system LOCA		3.63x10 ⁻⁸
Late (48h) large containment failure (1m ²)	RC7	3.81x10 ⁻⁸
No containment failure	RC8	3.58x10 ⁻⁷
Total		5.68x10⁻⁷

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The source term used for assessing the EPR against the EPZ requirements is defined in **Table A-8.B.4.**



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Appendix A-8.C

Deterministic Health Effects and the PAZ Radius

The AP1000 source term released to the environment envelopes the EPR source term. The AP1000 source term was therefore used to investigate the potential for deterministic effects for distances from the point of release, which is at ground level at the nuclear installation building, up to 800m away.

A dispersion factor based on the Gaussian plume methodology can be estimated for distances equal to or greater than 200m. The SCREEN3 (United States Environmental Protection Agency, 1995) software model was used to estimate a dispersion coefficient (**Figure A-8.C.1**). The results are presented in **Table A-8.C.1**. Acute doses for atmospheric concentrations close to the point of release were investigated using a dispersion coefficient $1\text{E-}02 \text{ sec/m}^3$. This value is of similar magnitude as the dispersion coefficients used when assessing control rooms for design basis accident dose analysis (Westinghouse, 2004).

Acute doses were calculated using the AcutDose computer code (Eckerman K. F., 2006)). The code computes age-specific absorbed dose coefficients for specified times after inhalation and ingestion intakes of radionuclides. AcutDose uses the absorbed dose rate data for inhalation and ingestion intakes of radionuclides that were computed during the preparation of United States Federal Guidance Report 13 (United States Environmental Protection Agency, 1999).

In the case of inhalation or ingestion of radioactive material, a value of the 30 day committed RBE weighted absorbed dose is used to specify the threshold for the possible onset of severe deterministic effects in the organ concerned.

Table A-8.C.1 lists a summary of the results, **Table A-8.C.2** shows the deterministic dose calculation and **Table A-8.C.3** shows the calculated airborne radionuclide concentrations used in **Table A-8.C.2**.

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TABLE A-8.C.1
AP1000 Core Inventory and Intact Containment Release Fraction
to the Environment

Deterministic dose	External Cloud Dose, Gy/h	Thyroid Dose 30 days, Gy	Red Marrow 30 days Dose, Gy	Lung Dose 30 days, Gy	Alveolar- Interstitial Dose 30 days, Gy
Dispersion coefficient 2.4E-04 at 200 m	2.94E-02	1.39E-01	2.44E-03	5.47E-02	2.80E-02
Dispersion coefficient 1E-02	1.22E+00	5.79E+00	1.02E-01	2.28E+00	1.17E+00
Generic criteria for Acute Doses for which Protective Actions and other response actions are expected to be taken under any circumstances to avoid or minimise Severe Deterministic Effects (PC Cosyma Users Manual, 1995)		Thyroid 2 Gy	Red Marrow 2 Gy	Lung and Alveolar- Interstitial 30 Gy	

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An extract from (International Atomic Energy Agency, 2011) is provided here listing the generic criteria for acute doses.

TABLE 2. GENERIC CRITERIA FOR ACUTE DOSES FOR WHICH PROTECTIVE ACTIONS AND OTHER RESPONSE ACTIONS ARE EXPECTED TO BE TAKEN UNDER ANY CIRCUMSTANCES TO AVOID OR TO MINIMIZE SEVERE DETERMINISTIC EFFECTS

Generic criteria	Examples of protective actions and other response actions
External acute exposure (<10 hours)	If the dose is projected:
$AD_{\text{Red marrow}}^a$ 1 Gy	— Take precautionary urgent protective actions immediately (even under difficult conditions) to keep doses below the generic criteria
AD_{Fetus}^b 0.1 Gy	— Provide public information and warnings
AD_{Tissue}^b 25 Gy at 0.5 cm	— Carry out urgent decontamination
AD_{Skin}^c 10 Gy to 100 cm ²	
Internal exposure from acute intake ($\Delta = 30$ days)^d	If the dose has been received:
$AD(\Delta)_{\text{Red marrow}}$ 0.2 Gy for radionuclides with $Z \geq 90^e$ 2 Gy for radionuclides with $Z \leq 89^e$	— Perform immediate medical examination, consultation and indicated medical treatment
$AD(\Delta)_{\text{Thyroid}}$ 2 Gy	— Carry out contamination control
$AD(\Delta)_{\text{Lung}}^g$ 30 Gy	— Carry out immediate decorporation ^f (if applicable)
$AD(\Delta)_{\text{Colon}}$ 20 Gy	— Carry out registration for long term health monitoring (medical follow-up)
$AD(\Delta)_{\text{Fetus}}^h$ 0.1 Gy	— Provide comprehensive psychological counselling

^a $AD_{\text{Red marrow}}$ represents the average RBE weighted absorbed dose to internal tissues or organs (e.g. red marrow, lung, small intestine, gonads, thyroid) and to the lens of the eye from exposure in a uniform field of strongly penetrating radiation.

^b Dose delivered to 100 cm² at a depth of 0.5 cm under the body surface in tissue due to close contact with a radioactive source (e.g. source carried in the hand or pocket).

^c The dose is to the 100 cm² dermis (skin structures at a depth of 40 mg/cm² (or 0.4 mm) below the body surface).

^d $AD(\Delta)$ is the RBE weighted absorbed dose delivered over the period of time Δ by the intake (I_{05}) that will result in a severe deterministic effect in 5% of exposed individuals.

^e Different criteria are used to take account of the significant difference in the radionuclide specific intake threshold values for the radionuclides in these groups [3].

^f The generic criterion for decorporation is based on the projected dose without decorporation. Decorporation is the biological processes, facilitated by a chemical or biological agent, by which incorporated radionuclides are removed from the human body.

^g For the purposes of these generic criteria, 'lung' means the alveolar-interstitial region of the respiratory tract.

^h For this particular case, Δ' means the period of in utero development.

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TABLE A-8.C.2

AP1000 On-Site Projected Deterministic Dose at 200m

Accident Source Term Radionuclide Group	Radio-nuclide	Airborne concentration at 200m, Bq/m ³	External Cloud Dose Coefficient (Dcf); (Sv/sec)/(Bq/m ³)	External Cloud Dose, Gy/h	Thyroid Dcf - Acute Inhalation Worker 30days; Gy/Bq	Red Marrow Dcf - Acute Inhalation Worker 30days; Gy/Bq	Lung Dcf - Acute Inhalation Worker 30days; Gy/Bq	Alveolar-Interstitial - Acute Inhalation Worker 30days; Gy/Bq	Thyroid Dose, Gy	Red Marrow Dose, Gy	Lung Dose, Gy	Alveolar-Interstitial Dose, Gy
Noble Gases	Kr-85m	1.04E+07	2.24E-14	8.40E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	-	-	-	-
	Kr-85	4.20E+05	1.32E-14	2.00E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	-	-	-	-
	Kr-87	2.01E+07	3.97E-14	2.87E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	-	-	-	-
	Kr-88	2.83E+07	9.71E-14	9.89E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	-	-	-	-
	Xe-131m	4.20E+05	3.49E-16	5.28E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	-	-	-	-
	Xe-133m	2.31E+06	1.28E-15	1.07E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	-	-	-	-
	Xe-133	7.53E+07	1.33E-15	3.61E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	-	-	-	-
	Xe-135m	1.53E+07	1.90E-14	1.05E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	-	-	-	-
	Xe-135	1.92E+07	1.10E-14	7.60E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	-	-	-	-
	Xe-138	6.55E+07	5.44E-14	1.28E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	-	-	-	-
CsI	I-130	6.71E+03	9.67E-14	2.34E-06	3.35E-08	7.28E-11	1.30E-09	4.79E-10	2.70E-04	5.86E-07	1.05E-05	3.86E-06
	I-131	1.76E+05	1.69E-14	1.07E-05	3.68E-07	8.78E-11	1.07E-08	3.17E-09	7.78E-02	1.86E-05	2.26E-03	6.70E-04

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Accident Source Term Radionuclide Group	Radio- nuclide	Airborne concentration at 200m,Bq/m ³	External Cloud Dose Coefficient (Dcf); (Sv/sec)/(Bq/m ³)	External Cloud Dose, Gy/h	Thyroid Dcf - Acute Inhalation Worker 30days; Gy/Bq	Red Marrow Dcf - Acute Inhalation Worker 30days; Gy/Bq	Lung Dcf - Acute Inhalation Worker 30days; Gy/Bq	Alveolar- Interstitial - Acute Inhalation Worker 30days; Gy/Bq	Thyroid Dose, Gy	Red Marrow Dose, Gy	Lung Dose, Gy	Alveolar- Interstitial Dose, Gy
	I-132	2.56E+05	1.05E-13	9.68E-05	3.66E-09	2.68E-11	6.01E-10	3.16E-11	1.12E-03	8.23E-06	1.85E-04	9.71E-06
	I-133	3.64E+05	2.76E-14	3.62E-05	7.61E-08	4.42E-11	2.02E-09	8.10E-10	3.32E-02	1.93E-05	8.82E-04	3.54E-04
	I-134	3.98E+05	1.22E-13	1.75E-04	7.01E-10	1.29E-11	5.38E-10	6.27E-11	3.35E-04	6.17E-06	2.57E-04	3.00E-05
	I-135	3.40E+05	7.54E-14	9.23E-05	1.54E-08	3.87E-11	7.42E-10	2.69E-10	6.28E-03	1.58E-05	3.03E-04	1.10E-04
TeO ₂	Te-127m	1.91E+03	1.12E-16	7.70E-10	5.85E-09	4.02E-09	3.97E-08	1.09E-08	1.34E-05	9.21E-06	9.10E-05	2.50E-05
	Te-127	1.48E+04	3.34E-16	1.78E-08	5.89E-11	3.47E-11	8.31E-10	1.81E-10	1.04E-06	6.15E-07	1.47E-05	3.21E-06
	Te-129m	6.50E+03	1.56E-15	3.65E-08	1.01E-08	6.80E-09	4.04E-08	1.85E-08	7.88E-05	5.31E-05	3.15E-04	1.44E-04
	Te-129	4.40E+04	2.86E-15	4.54E-07	7.54E-12	6.39E-12	1.63E-10	5.54E-11	3.99E-07	3.38E-07	8.62E-06	2.93E-06
	Te-131m	2.03E+04	6.55E-14	4.78E-06	3.71E-08	4.45E-10	5.16E-09	1.67E-09	9.02E-04	1.08E-05	1.25E-04	4.06E-05
	Te-132	2.00E+05	9.32E-15	6.70E-06	7.58E-08	8.23E-10	1.14E-08	5.01E-09	1.82E-02	1.97E-04	2.73E-03	1.20E-03
SrO	Sr-89	1.62E+05	4.37E-16	2.55E-07	1.57E-10	1.85E-09	3.18E-08	1.91E-08	3.05E-05	3.59E-04	6.17E-03	3.71E-03
	Sr-90	1.39E+04	9.83E-17	4.92E-09	2.73E-10	3.60E-09	6.77E-08	3.97E-08	4.56E-06	6.01E-05	1.13E-03	6.63E-04
	Sr-91	2.01E+05	3.27E-14	2.36E-05	2.61E-11	1.10E-10	1.45E-09	7.43E-10	6.29E-06	2.65E-05	3.50E-04	1.79E-04
	Sr-92	2.16E+05	6.41E-14	4.99E-05	1.55E-11	6.10E-11	8.02E-10	4.11E-10	4.02E-06	1.58E-05	2.08E-04	1.07E-04
MoO ₂	Ru-103	2.87E+05	2.08E-14	2.15E-05	4.18E-10	4.73E-10	1.53E-08	4.45E-09	1.44E-04	1.63E-04	5.27E-03	1.53E-03

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Accident Source Term Radionuclide Group	Radio- nuclide	Airborne concentration at 200m,Bq/m ³	External Cloud Dose Coefficient (Dcf); (Sv/sec)/(Bq/m ³)	External Cloud Dose, Gy/h	Thyroid Dcf - Acute Inhalation Worker 30days; Gy/Bq	Red Marrow Dcf - Acute Inhalation Worker 30days; Gy/Bq	Lung Dcf - Acute Inhalation Worker 30days; Gy/Bq	Alveolar- Interstitial - Acute Inhalation Worker 30days; Gy/Bq	Thyroid Dose, Gy	Red Marrow Dose, Gy	Lung Dose, Gy	Alveolar- Interstitial Dose, Gy
	Ru-105	1.95E+05	3.56E-14	2.50E-05	2.24E-11	3.24E-11	7.97E-10	2.37E-10	5.23E-06	7.57E-06	1.86E-04	5.54E-05
	Ru-106	9.43E+04	0.00E+00	0.00E+00	2.59E-09	2.61E-09	6.83E-08	5.54E-08	2.93E-04	2.95E-04	7.73E-03	6.27E-03
	Rh-105	1.78E+05	3.47E-15	2.23E-06	1.66E-11	1.73E-11	2.30E-09	4.81E-10	3.55E-06	3.70E-06	4.92E-04	1.03E-04
	Mo-99	3.64E+05	6.99E-15	9.17E-06	2.11E-11	4.51E-11	6.00E-09	2.37E-09	9.22E-06	1.97E-05	2.62E-03	1.04E-03
	Tc-99m	3.19E+05	5.25E-15	6.02E-06	3.93E-11	1.67E-12	8.39E-11	1.40E-11	1.50E-05	6.39E-07	3.21E-05	5.35E-06
CsOH	Cs-134	3.25E+04	7.06E-14	8.27E-06	1.26E-09	1.26E-09	2.26E-08	1.01E-08	4.92E-05	4.92E-05	8.82E-04	3.94E-04
	Cs-136	9.26E+03	9.94E-14	3.31E-06	8.43E-10	8.25E-10	1.63E-08	5.48E-09	9.37E-06	9.17E-06	1.81E-04	6.09E-05
	Cs-137	1.89E+04	9.28E-17	6.33E-09	7.86E-10	7.86E-10	2.90E-08	1.12E-08	1.79E-05	1.79E-05	6.59E-04	2.55E-04
	Cs-138	3.05E+05	1.15E-13	1.26E-04	4.27E-12	3.91E-12	1.13E-10	6.41E-11	1.56E-06	1.43E-06	4.14E-05	2.35E-05
	Rb-86	3.84E+02	4.94E-15	6.82E-09	5.92E-10	1.14E-09	2.66E-08	1.67E-08	2.73E-07	5.25E-07	1.22E-05	7.69E-06
BaO	Ba-139	3.25E+05	9.32E-15	1.09E-05	1.71E-12	1.17E-11	2.33E-10	1.08E-10	6.67E-07	4.57E-06	9.09E-05	4.21E-05
	Ba-140	3.12E+05	8.07E-15	9.08E-06	1.07E-10	1.26E-09	3.62E-08	1.91E-08	4.01E-05	4.72E-04	1.36E-02	7.16E-03
La ₂ O ₃	Y-90	1.85E+03	7.92E-16	5.27E-09	3.28E-11	9.48E-10	7.82E-09	5.07E-09	7.28E-08	2.10E-06	1.73E-05	1.12E-05
	Y-91	2.86E+04	6.22E-16	6.40E-08	9.28E-11	4.27E-09	3.32E-08	2.02E-08	3.18E-06	1.46E-04	1.14E-03	6.93E-04
	Y-92	2.77E+04	1.32E-14	1.32E-06	1.10E-11	4.24E-11	6.95E-10	4.49E-10	3.66E-07	1.41E-06	2.31E-05	1.49E-05

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Accident Source Term Radionuclide Group	Radio- nuclide	Airborne concentration at 200m,Bq/m ³	External Cloud Dose Coefficient (Dcf); (Sv/sec)/(Bq/m ³)	External Cloud Dose, Gy/h	Thyroid Dcf - Acute Inhalation Worker 30days; Gy/Bq	Red Marrow Dcf - Acute Inhalation Worker 30days; Gy/Bq	Lung Dcf - Acute Inhalation Worker 30days; Gy/Bq	Alveolar- Interstitial - Acute Inhalation Worker 30days; Gy/Bq	Thyroid Dose, Gy	Red Marrow Dose, Gy	Lung Dose, Gy	Alveolar- Interstitial Dose, Gy
	Y-93	3.18E+04	5.28E-15	6.04E-07	1.62E-11	1.40E-10	1.62E-09	1.03E-09	6.18E-07	5.34E-06	6.18E-05	3.93E-05
	Nb-95	3.56E+04	3.49E-14	4.47E-06	1.68E-10	3.68E-10	8.18E-09	2.75E-09	7.18E-06	1.57E-05	3.50E-04	1.18E-04
	Zr-95	3.54E+04	3.36E-14	4.28E-06	2.67E-10	1.67E-09	2.11E-08	6.28E-09	1.13E-05	7.09E-05	8.96E-04	2.67E-04
	Zr-97	3.50E+04	8.90E-15	1.12E-06	7.08E-11	3.52E-10	3.81E-09	1.87E-09	2.97E-06	1.48E-05	1.60E-04	7.85E-05
	La-140	3.88E+04	1.11E-13	1.55E-05	9.01E-11	2.95E-10	4.41E-09	2.32E-09	4.20E-06	1.37E-05	2.05E-04	1.08E-04
	La-141	3.45E+04	2.88E-15	3.58E-07	7.82E-12	1.97E-11	7.07E-10	3.50E-10	3.24E-07	8.16E-07	2.93E-05	1.45E-05
	La-142	3.35E+04	1.37E-13	1.65E-05	9.61E-12	1.20E-11	2.68E-10	1.37E-10	3.86E-07	4.82E-07	1.08E-05	5.50E-06
	Pr-143	3.11E+04	1.94E-16	2.17E-08	5.41E-12	6.60E-10	1.60E-08	6.50E-09	2.02E-07	2.46E-05	5.98E-04	2.43E-04
	Nd-147	1.38E+04	5.72E-15	2.85E-07	1.91E-11	9.59E-10	1.63E-08	5.16E-09	3.17E-07	1.59E-05	2.71E-04	8.56E-05
CeO ₂	Ce-141	3.73E+04	3.10E-15	4.16E-07	5.95E-11	7.12E-10	2.18E-08	5.21E-09	2.66E-06	3.18E-05	9.75E-04	2.33E-04
	Ce-143	3.47E+04	1.21E-14	1.51E-06	2.80E-11	2.39E-10	4.72E-09	1.92E-09	1.17E-06	9.96E-06	1.97E-04	8.01E-05
	Ce-144	2.81E+04	7.63E-16	7.72E-08	4.39E-10	6.66E-09	7.70E-08	4.99E-08	1.48E-05	2.25E-04	2.60E-03	1.68E-03
Sb	Sb-127	2.04E+04	3.12E-14	2.29E-06	8.03E-11	5.08E-10	1.21E-08	4.25E-09	1.96E-06	1.24E-05	2.96E-04	1.04E-04
	Sb-129	6.13E+04	6.71E-14	1.48E-05	1.78E-11	4.46E-11	9.62E-10	3.72E-10	1.31E-06	3.28E-06	7.08E-05	2.74E-05
					2.94E-02				1.39E-01	2.44E-03	5.47E-02	2.80E-02

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Accident Source Term Radionuclide Group	Radio- nuclide	Airborne concentration at 200m,Bq/m ³	External Cloud Dose Coefficient (Dcf); (Sv/sec)/(Bq/m ³)	External Cloud Dose, Gy/h	Thyroid Dcf - Acute Inhalation Worker 30days; Gy/Bq	Red Marrow Dcf - Acute Inhalation Worker 30days; Gy/Bq	Lung Dcf - Acute Inhalation Worker 30days; Gy/Bq	Alveolar- Interstitial - Acute Inhalation Worker 30days; Gy/Bq	Thyroid Dose, Gy	Red Marrow Dose, Gy	Lung Dose, Gy	Alveolar- Interstitial Dose, Gy
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Generic criteria for Acute Doses for which Protective Actions and other response actions are expected to be taken under any circumstances to avoid or minimise Severe Deterministic Effects		2Gy	2Gy	30Gy
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TABLE A-8.C.3

AP1000 Source Term Concentrations at 200 m using a Dispersion Coefficient $X/Q = 2.5E-04 \text{ sec/m}^3$

Accident Source Term Radionuclide Group	Radionuclide	Activity Released (1 h duration assumed). Bq	Containment Free Air Volume. m^3	Concentration following complete mixing in the containment volume prior to release. Bq/m^3	Atmospheric dispersion factor, X/Q	Airborne concentration at 200m. Bq/m^3
Noble Gases	Kr-85m	2.53E+15	5.83E+04	4.34E+10	2.40E-04	1.04E+07
	Kr-85	1.02E+14	5.83E+04	1.75E+09	2.40E-04	4.20E+05
	Kr-87	4.88E+15	5.83E+04	8.37E+10	2.40E-04	2.01E+07
	Kr-88	6.87E+15	5.83E+04	1.18E+11	2.40E-04	2.83E+07
	Xe-131m	1.02E+14	5.83E+04	1.75E+09	2.40E-04	4.20E+05
	Xe-133m	5.62E+14	5.83E+04	9.64E+09	2.40E-04	2.31E+06
	Xe-133	1.83E+16	5.83E+04	3.14E+11	2.40E-04	7.53E+07
	Xe-135m	3.72E+15	5.83E+04	6.38E+10	2.40E-04	1.53E+07
	Xe-135	4.66E+15	5.83E+04	7.99E+10	2.40E-04	1.92E+07
	Xe-138	1.59E+16	5.83E+04	2.73E+11	2.40E-04	6.55E+07
CsI	I-130	1.63E+12	5.83E+04	2.80E+07	2.40E-04	6.71E+03
	I-131	4.28E+13	5.83E+04	7.34E+08	2.40E-04	1.76E+05
	I-132	6.22E+13	5.83E+04	1.07E+09	2.40E-04	2.56E+05
	I-133	8.84E+13	5.83E+04	1.52E+09	2.40E-04	3.64E+05
	I-134	9.68E+13	5.83E+04	1.66E+09	2.40E-04	3.98E+05
	I-135	8.26E+13	5.83E+04	1.42E+09	2.40E-04	3.40E+05
TeO ₂	Te-127m	4.64E+11	5.83E+04	7.96E+06	2.40E-04	1.91E+03

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Accident Source Term Radionuclide Group	Radionuclide	Activity Released (1 h duration assumed). Bq	Containment Free Air Volume. m ³	Concentration following complete mixing in the containment volume prior to release. Bq/m ³	Atmospheric dispersion factor, X/Q	Airborne concentration at 200m. Bq/m ³
	Te-127	3.59E+12	5.83E+04	6.16E+07	2.40E-04	1.48E+04
	Te-129m	1.58E+12	5.83E+04	2.71E+07	2.40E-04	6.50E+03
	Te-129	1.07E+13	5.83E+04	1.84E+08	2.40E-04	4.40E+04
	Te-131m	4.92E+12	5.83E+04	8.44E+07	2.40E-04	2.03E+04
	Te-132	4.85E+13	5.83E+04	8.32E+08	2.40E-04	2.00E+05
SrO	Sr-89	3.93E+13	5.83E+04	6.74E+08	2.40E-04	1.62E+05
	Sr-90	3.38E+12	5.83E+04	5.80E+07	2.40E-04	1.39E+04
	Sr-91	4.88E+13	5.83E+04	8.37E+08	2.40E-04	2.01E+05
	Sr-92	5.25E+13	5.83E+04	9.01E+08	2.40E-04	2.16E+05
MoO ₂	Ru-103	6.97E+13	5.83E+04	1.20E+09	2.40E-04	2.87E+05
	Ru-105	4.73E+13	5.83E+04	8.11E+08	2.40E-04	1.95E+05
	Ru-106	2.29E+13	5.83E+04	3.93E+08	2.40E-04	9.43E+04
	Rh-105	4.33E+13	5.83E+04	7.43E+08	2.40E-04	1.78E+05
	Mo-99	8.85E+13	5.83E+04	1.52E+09	2.40E-04	3.64E+05
	Tc-99m	7.74E+13	5.83E+04	1.33E+09	2.40E-04	3.19E+05
CsOH	Cs-134	7.90E+12	5.83E+04	1.36E+08	2.40E-04	3.25E+04
	Cs-136	2.25E+12	5.83E+04	3.86E+07	2.40E-04	9.26E+03
	Cs-137	4.60E+12	5.83E+04	7.89E+07	2.40E-04	1.89E+04
	Cs-138	7.41E+13	5.83E+04	1.27E+09	2.40E-04	3.05E+05
	Rb-86	9.32E+10	5.83E+04	1.60E+06	2.40E-04	3.84E+02

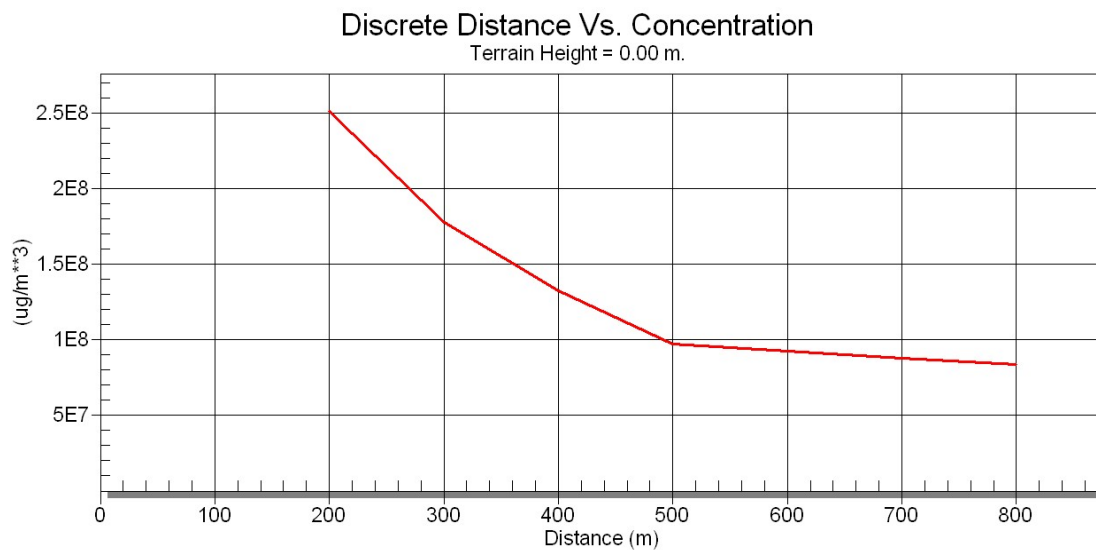
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Accident Source Term Radionuclide Group	Radionuclide	Activity Released (1 h duration assumed). Bq	Containment Free Air Volume. m ³	Concentration following complete mixing in the containment volume prior to release. Bq/m ³	Atmospheric dispersion factor, X/Q	Airborne concentration at 200m. Bq/m ³
BaO	Ba-139	7.90E+13	5.83E+04	1.36E+09	2.40E-04	3.25E+05
	Ba-140	7.59E+13	5.83E+04	1.30E+09	2.40E-04	3.12E+05
La ₂ O ₃	Y-90	4.49E+11	5.83E+04	7.70E+06	2.40E-04	1.85E+03
	Y-91	6.94E+12	5.83E+04	1.19E+08	2.40E-04	2.86E+04
	Y-92	6.73E+12	5.83E+04	1.15E+08	2.40E-04	2.77E+04
	Y-93	7.72E+12	5.83E+04	1.32E+08	2.40E-04	3.18E+04
	Nb-95	8.65E+12	5.83E+04	1.48E+08	2.40E-04	3.56E+04
	Zr-95	8.60E+12	5.83E+04	1.48E+08	2.40E-04	3.54E+04
	Zr-97	8.50E+12	5.83E+04	1.46E+08	2.40E-04	3.50E+04
	La-140	9.43E+12	5.83E+04	1.62E+08	2.40E-04	3.88E+04
	La-141	8.39E+12	5.83E+04	1.44E+08	2.40E-04	3.45E+04
	La-142	8.13E+12	5.83E+04	1.39E+08	2.40E-04	3.35E+04
	Pr-143	7.56E+12	5.83E+04	1.30E+08	2.40E-04	3.11E+04
	Nd-147	3.36E+12	5.83E+04	5.76E+07	2.40E-04	1.38E+04
CeO ₂	Ce-141	9.05E+12	5.83E+04	1.55E+08	2.40E-04	3.73E+04
	Ce-143	8.44E+12	5.83E+04	1.45E+08	2.40E-04	3.47E+04
	Ce-144	6.83E+12	5.83E+04	1.17E+08	2.40E-04	2.81E+04
Sb	Sb-127	4.95E+12	5.83E+04	8.49E+07	2.40E-04	2.04E+04
	Sb-129	1.49E+13	5.83E+04	2.56E+08	2.40E-04	6.13E+04

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A minimum dispersion coefficient was determined for a ground level release considering all atmospheric stability classes. A hypothetical source term was used for determining a dispersion coefficient as a function of distance that is representative of any gaseous release. A dispersion coefficient, $X/Q = 2.5E-04 \text{ sec/m}^3$ at a distance of 200 m, can be derived from **Figure 8.C.1**.

FigureA-8.C.1 Derivation of a Dispersion coefficient



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Appendix A-8.D

Consequence Modelling for Severe Accidents $\geq 800\text{m}$

1. Introduction

An overview is provided of the data and conservative assumptions used in PC Cosyma. The COSYMA programme⁹ (CODE SYSTEM from MARIA project (PC Cosyma Users Manual, 1995) was used for performing the deterministic accident consequence analysis for the site with exception of the projected radioactivity concentrations in foodstuff where ECOSYS was used ([Appendix A-8.E](#)).

2. Projected doses for the UPZ and relocation assessment

[Table A-8.D.1](#) lists the input data and run options used.

TABLE A-8.D.1
PC COSYMA off-site consequence input data

Software	PC COSYMA Version 2.02 (Release Notes 11/06/2009)
Calculations	
Run type	Deterministic
Results	In the population
Countermeasures	No
Endpoints	• Radionuclide concentrations; • Short- term & long-term individual doses
Ingestion	No, except for calculations concerning the LPZ/EPZ. Site-specific inputs to PC COSYMA, such as eating habits, food production and consumption inside EPZ, to be obtained from site-specific habit studies.
Dispersion	
Site	10 m measurement height of wind speed with smooth terrain ¹⁰

⁹COSYMA was developed jointly by Forschungszentrum Karlsruhe, Germany and NRPB (National Radiological Protection Board, UK) as a part of the European Commission's MARIA project (Methods for Assessing the Radiological Impact of Accidents).

¹⁰A smooth surface yields higher dose results than a rough surface. The terrain is conservatively assumed to be a smooth surface even though the roughness of the surface in the area under consideration is not uniform.

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Software	PC COSYMA Version 2.02 (Release Notes 11/06/2009)
conditions	as choice of surface roughness
Plume shape	Default settings
Deposition	Default settings for aerosols, elemental iodine and organically bound iodine
Source Term	
Number of release phases	1 (The first 24 hours of the release is conservatively assumed to be released at the start of the release.)
Number of nuclide groups	Defined in Appendix A-8.B
Release parameters ¹¹	The following conservative parameters were used: Building width = 40 m; Building height = 40 m (AP1000 and EPR have larger dimensions) Starting hour = 0 hour Release height = 0 m Energy = 0 MW
Inventory and groups	Defined in Appendix A-8.B
Scaling factor	1 (default)
Nuclide selection cut-off	Cloudshine = 0.1% Groundshine = 0.1% Inhalation = 0.1% Skin = 1% Ingestion = 99.9%
Release fractions	Defined in Appendix A-8.B
Iodine	Elemental = 0.99 Organic = 0.01

¹¹Each release phase is defined within PC Cosyma to have a release duration of 1 hour.

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Software	PC COSYMA Version 2.02 (Release Notes 11/06/2009)
fractions ¹²	Aerosol = 0.00
Met Sampling	Wind speed 4 m/s; Stability category D
Single sequence definition	Atmospheric conditions to be determined by parameters for a single stability category
Single dispersion conditions	Pasquill stability category = 4 (for Category D) Mixing layer height for Category D = 560 m (default) Wind speed = 4 m/s at a height of 10 m Rain rate = 0 mm/h Wind direction in degrees from = 360 (default) Winter or summer = W or S (use default)
Spatial Distribution Data	
Number of distance bands	20
Number of sectors	72
Outer distances (km)	0.3, 0.5, 0.7, 0.9, 1.1, 1.5, 2.5, 3.5, 4, 8, 10, 15, 20, 25, 30, 38, 42, 45, 50, 80
Population distribution	Uniform
Shielding	
Location factors during normal activity	Cloudshine = 1 Groundshine = 1 Inhalation = 1 Resuspension = 1

¹²The results of sensitivity analysis performed using, firstly iodine chemical form of 99% I₂ and 1% CsI (PC Cosyma defaults), and secondly 5% I₂ and 95% CsI from Reference [Oak Ridge National Laboratory, "Iodine Chemical Forms in LWR Severe Accidents", NUREG/CR-5732, ORNL/TM-11861, Revision 3, January 1992.], indicate that the PC Cosyma defaults are the most penalising and therefore was adopted.

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Software	PC COSYMA Version 2.02 (Release Notes 11/06/2009)
	Deposition on skin and clothes = 1
Doses & Health Effects	
Dose-risk pathways for early individual doses & risks	Integration times and pathways: 1) Sheltering: <i>Sum of</i> - the 2-day projected whole-body effective dose via cloudshine, groundshine, resuspension and deposition on skin and clothing and - the long-term (50-year) projected whole-body effective dose via inhalation 2) Evacuation: <i>Sum of</i> - the 7-day projected whole-body effective dose via cloudshine, groundshine, resuspension and deposition on skin and clothing and - the long-term (50-year) projected whole-body effective dose via inhalation 3) Iodine prophylaxis: Thyroid dose <i>from the iodine component of the source term in question</i> via the inhalation and resuspension pathways (integrated over 50 years)
Dose response parameters	Default settings for morbidity and mortality
Individual risk threshold for early effects	0.01 (default)
Skin mortality fraction	0.05 (default)
Dose-risk pathways for late individual doses &	Integration times and pathways: Temporary relocation: 30 days; pathways: groundshine and resuspension Permanent resettlement: 50 years; pathways: groundshine and

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Software	PC COSYMA Version 2.02 (Release Notes 11/06/2009)
risks	resuspension
Cancer risk factors	ICRP-60
Cancer mortality fractions	Default settings
Effective dose option	ICRP-60
Breathing rate	3.333E-04 m ³ /s
Resuspension	Default settings
Skin parameters	Default settings
Results interface:	Results at grid-points and plume centre-line used Sector 37.

The severe accident source terms selected for EPZ determination have a probabilistic basis whereas the consequence modelling is mainly deterministic in nature and contains conservative values for variables for which the results are sensitive. In order to provide some perspective on aspects of the conservatism in the EPZ modelling, further discussion of some of the assumptions in the model is included here.

- Wind speed and direction:

The frequency of the wind blowing at 4 m/s or slower in the direction of the nearest representative communities, Oyster Bay/Umzamowethu, is less than 5 per cent of the time (refer to **Table A-8.D.2**). **Figure A-8.D.1** shows the area and two wind roses for one year's weather data for Thyspunt and Cape St. Francis obtained from **Section 5.8**. Note that a distinction is made between a representative person, considered in normal operating and design basis accident and risk analysis, and a representative community for emergency planning purposes. A representative community involves a significant number of people,

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typically several tens to hundreds of people that have to be accommodated in urgent emergency response plans. The representative community may include the representative person.

- Surface roughness of the terrain across which the airborne radioactivity is dispersed:

The assumption of a roughness factor equal to 'smooth' has a significant impact on the projected dose, especially when considering that a ground release is assumed. When PC Cosyma modelling is performed assuming a rough surface, the projected dose is approximately 50 per cent less and would result in the AP1000 meeting the criteria for no sheltering beyond 800m. **Figure A-8.D.3** shows the land cover between the site and Oyster Bay. Assuming a smooth surface is therefore conservative and the actual roughness of the surface that will be encountered by a plume during an accident will decrease airborne concentrations as a function of distance.

- Radioactivity release duration during the accident:

The total accident release is assumed to occur during one single phase lasting one hour. The wind direction and atmospheric stability are assumed to be constant and in the direction of the representative community. During an actual accident a release will last many hours and it is unlikely that the wind direction will be constant during this period. The released radioactivity will therefore be more dispersed in respect of the affected land surface area. The dose at the location where the highest dose will be experienced should be significantly less than reported here.

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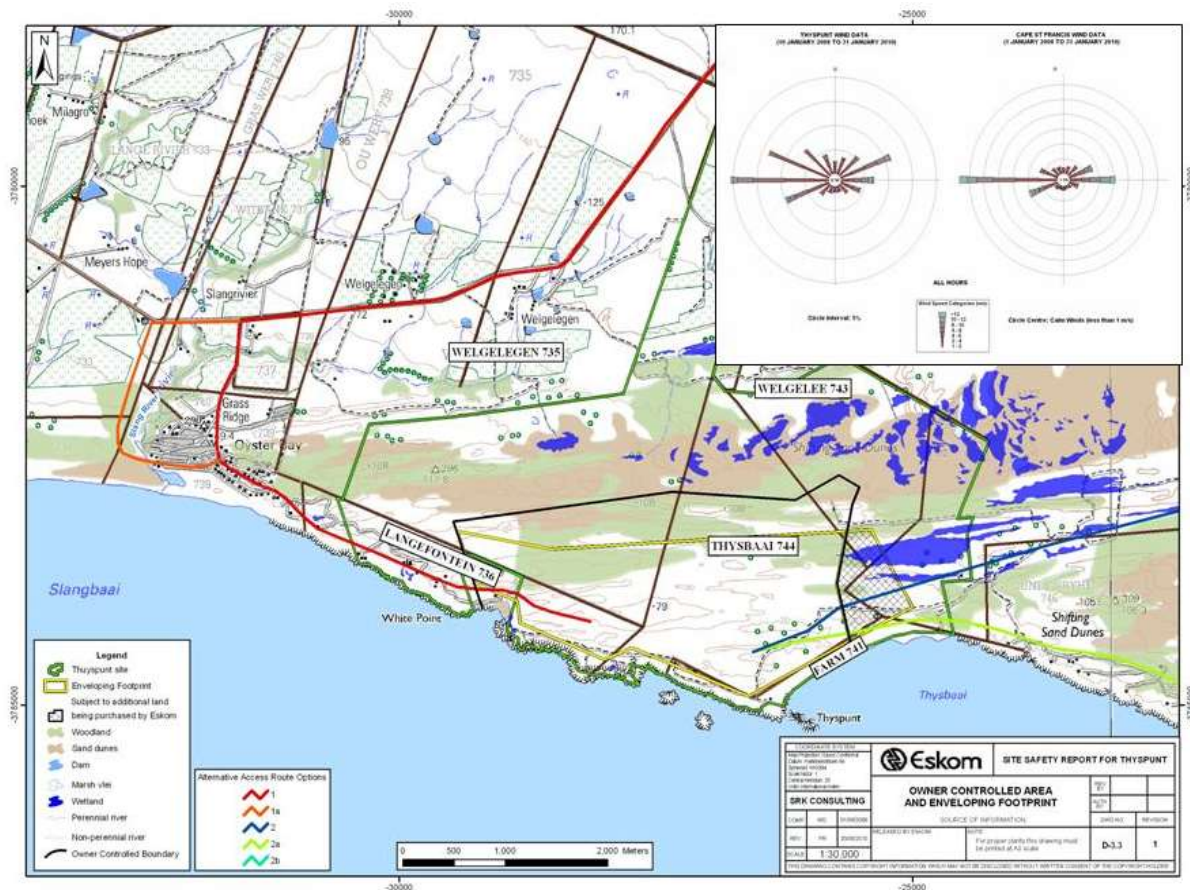


Figure A-8.D.1
Thyspunt Site and Wind data

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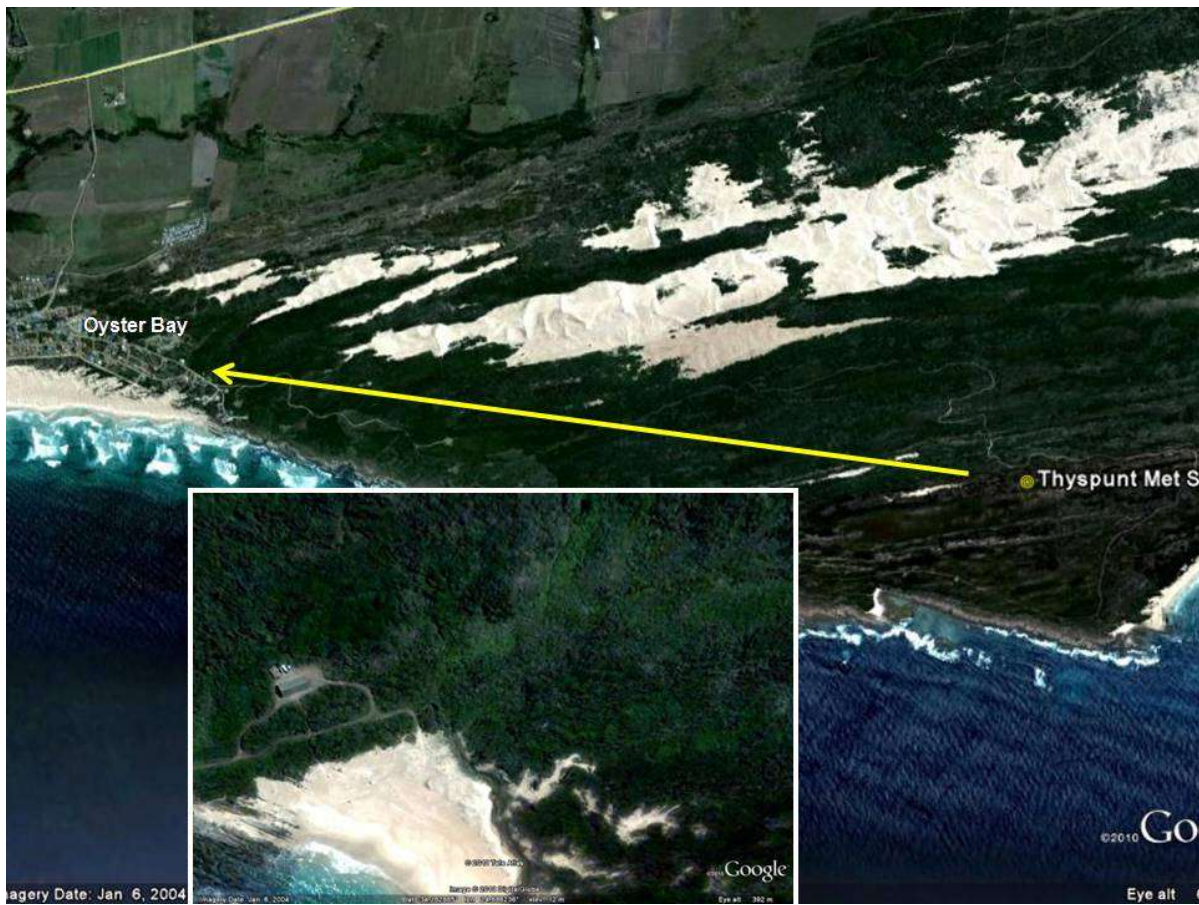


Figure A-8.D.2
Land Cover at Thyspunt

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Sector 37 Smooth Terrain			
Distance; km	Non-Inhalation Dose; Sv	Inhalation Committed Dose; Sv	Total Dose; mSv
0.2	3.26E-02	1.28E-01	160.910
0.4	1.38E-02	4.12E-02	54.990
0.6	9.51E-03	2.39E-02	33.396
0.8	6.85E-03	1.60E-02	22.803
1.0	5.50E-03	1.16E-02	17.094
1.3	4.12E-03	7.91E-03	12.030
2.0	2.52E-03	4.19E-03	6.715
3.0	1.52E-03	2.29E-03	3.810
3.8	1.13E-03	1.64E-03	2.771
6.0	6.26E-04	8.10E-04	1.435
9.0	3.47E-04	4.39E-04	0.786
12.5	2.13E-04	2.68E-04	0.481
17.5	1.53E-04	1.93E-04	0.346
22.5	1.18E-04	1.57E-04	0.275
27.5	9.34E-05	1.33E-04	0.226
34.0	7.70E-05	1.11E-04	0.188
40.0	5.85E-05	9.75E-05	0.156
43.5	5.22E-05	9.04E-05	0.143
47.5	4.81E-05	8.32E-05	0.131
65.0	3.14E-05	6.40E-05	0.095

Sector 37 Rough Terrain			
Distance; km	Non-Inhalation Dose; Sv	Inhalation Committed Dose; Sv	Total Dose; mSv
0.2	2.53E-02	9.30E-02	118.350
0.4	9.63E-03	2.58E-02	35.428
0.6	6.33E-03	1.39E-02	20.196
0.8	4.36E-03	8.78E-03	13.132
1.0	3.39E-03	6.12E-03	9.508
1.3	2.42E-03	3.98E-03	6.401
2.0	1.37E-03	1.96E-03	3.328
3.0	7.55E-04	9.98E-04	1.753
3.8	5.36E-04	6.89E-04	1.225
6.0	2.82E-04	3.33E-04	0.615
9.0	2.03E-04	2.42E-04	0.446
12.5	1.55E-04	1.89E-04	0.344
17.5	1.14E-04	1.42E-04	0.256
22.5	8.71E-05	1.16E-04	0.204
27.5	6.90E-05	9.85E-05	0.168
34.0	5.70E-05	8.25E-05	0.140
40.0	4.36E-05	7.28E-05	0.116
43.5	3.89E-05	6.75E-05	0.106
47.5	3.59E-05	6.21E-05	0.098
65.0	2.35E-05	4.80E-05	0.072

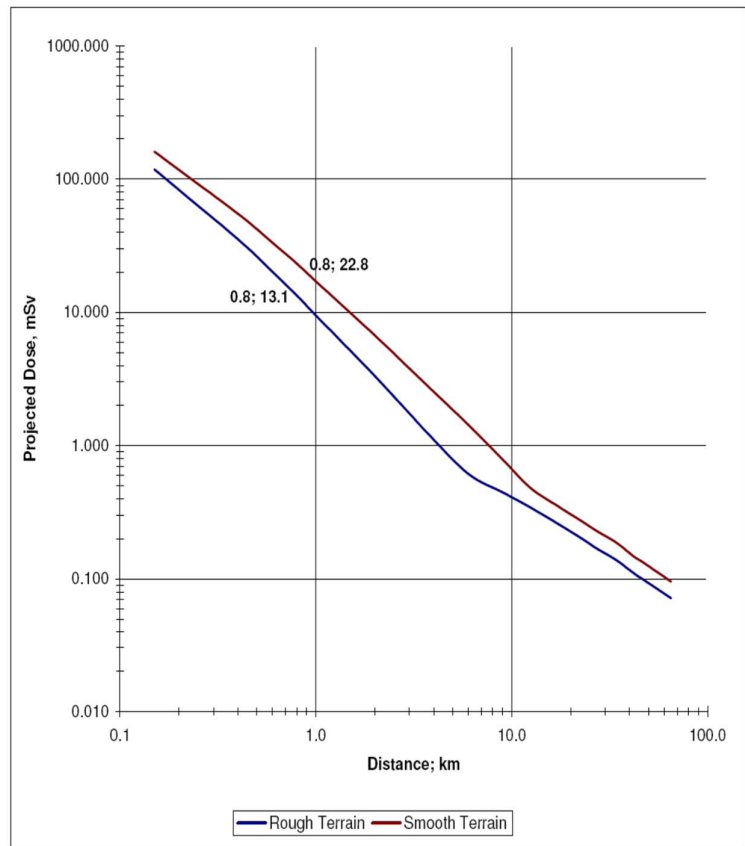


Figure A-8.D.3
A Comparison of Results for Different Roughness Factor Assumptions in PC Cosyma

The atmospheric conditions are critical in determining the spatial and temporal distributions of the dispersed radionuclides. Hourly data from **Section 5.8** is repeated here. Conservative values for wind speed and atmospheric stability class were selected as indicated in the tables.

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TABLE A-8.D2
Wind Speed for Thyspunt

Wind Direction	Wind Speed [m/s] at 9 m level, Sigma-Theta Method												Total
	<0.5	0.5-1.0	1.0-2.0	2.0-3.0	3.0-4.0	4.0-5.0	5.0-6.0	6.0-8.0	8.0-10.0	10.0-13.0	13.0-18.0	>18.0	
N	0.01%	0.02%	0.21%	0.44%	0.50%	0.57%	0.37%	0.32%	0.07%	0.01%	0.00%	0.00%	2.52%
NNE	0.01%	0.01%	0.18%	0.31%	0.47%	0.35%	0.21%	0.15%	0.02%	0.00%	0.00%	0.00%	1.71%
NE	0.02%	0.03%	0.24%	0.42%	0.68%	0.66%	0.55%	0.53%	0.13%	0.02%	0.00%	0.00%	3.28%
ENE	0.02%	0.03%	0.18%	0.45%	0.80%	1.09%	1.32%	2.36%	1.37%	0.33%	0.03%	0.00%	7.98%
E	0.01%	0.01%	0.19%	0.27%	0.55%	0.60%	0.72%	2.04%	2.25%	1.41%	0.11%	0.00%	8.16%
ESE	0.01%	0.02%	0.11%	0.33%	0.45%	0.41%	0.34%	0.54%	0.19%	0.03%	0.00%	0.00%	2.43%
SE	0.01%	0.01%	0.14%	0.44%	0.80%	0.78%	0.45%	0.10%	0.01%	0.00%	0.00%	0.00%	2.74%
SSE	0.00%	0.01%	0.10%	0.20%	0.32%	0.31%	0.11%	0.04%	0.02%	0.01%	0.00%	0.00%	1.12%
S	0.00%	0.02%	0.09%	0.29%	0.43%	0.27%	0.07%	0.03%	0.01%	0.01%	0.00%	0.00%	1.22%
SSW	0.00%	0.02%	0.13%	0.38%	0.58%	0.30%	0.11%	0.06%	0.02%	0.01%	0.00%	0.00%	1.61%
SW	0.00%	0.01%	0.11%	0.50%	0.77%	0.74%	0.37%	0.15%	0.05%	0.04%	0.01%	0.00%	2.75%
WSW	0.01%	0.01%	0.11%	0.44%	1.07%	1.55%	1.77%	2.65%	1.01%	0.50%	0.13%	0.00%	9.25%
W	0.01%	0.02%	0.15%	0.81%	2.07%	4.10%	6.82%	14.45%	8.65%	3.84%	0.52%	0.00%	41.44%
WNW	0.01%	0.02%	0.18%	0.68%	1.25%	1.81%	1.57%	2.29%	0.91%	0.41%	0.05%	0.00%	9.18%
NW	0.00%	0.02%	0.19%	0.34%	0.57%	0.38%	0.26%	0.29%	0.09%	0.02%	0.00%	0.00%	2.16%
NNW	0.01%	0.01%	0.18%	0.24%	0.44%	0.30%	0.30%	0.47%	0.36%	0.09%	0.00%	0.00%	2.40%
TOTAL	0.15%	0.29%	2.52%	6.53%	11.75%	14.23%	15.35%	26.48%	15.15%	6.71%	0.84%	0.00%	100.00%

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TABLE A-8.C3
Atmospheric Stability for Thyspunt

Wind Direction	Stability Classification							
	A	B	C	D	E	F	G	Total
N	0.26%	0.10%	0.33%	1.03%	1.07%	0.01%	0.00%	2.80%
NNE	0.27%	0.11%	0.24%	0.70%	2.23%	0.02%	0.00%	3.58%
NE	0.27%	0.16%	0.29%	1.34%	3.39%	0.01%	0.00%	5.46%
ENE	0.24%	0.13%	0.44%	3.26%	5.47%	0.03%	0.00%	9.57%
E	0.18%	0.15%	0.36%	3.34%	2.18%	0.00%	0.00%	6.21%
ESE	0.13%	0.09%	0.21%	1.00%	2.72%	0.00%	0.00%	4.14%
SE	0.13%	0.07%	0.19%	1.13%	0.95%	0.00%	0.00%	2.46%
SSE	0.11%	0.07%	0.20%	0.46%	0.49%	0.00%	0.00%	1.32%
S	0.11%	0.07%	0.26%	0.50%	0.50%	0.00%	0.00%	1.44%
SSW	0.14%	0.07%	0.26%	0.66%	0.56%	0.00%	0.00%	1.69%
SW	0.14%	0.07%	0.22%	1.13%	1.29%	0.00%	0.00%	2.85%
WSW	0.22%	0.12%	0.31%	3.78%	5.24%	0.01%	0.00%	9.69%
W	0.28%	0.17%	0.58%	16.95%	2.75%	0.02%	0.00%	20.76%
WNW	0.32%	0.17%	0.41%	3.75%	7.58%	1.52%	0.00%	13.76%
NW	0.31%	0.14%	0.28%	0.89%	6.34%	0.93%	0.00%	8.90%
NNW	0.22%	0.14%	0.29%	0.98%	3.40%	0.35%	0.00%	5.38%
Total	3.33%	1.84%	4.88%	40.89%	46.14%	2.92%	0.01%	100%

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3. Examples of PC COSYMA Summary Files: Projected Dose for Sheltering Determination (AP1000 and EPR)

```

*****
*
*                               PC COSYMA                               *
*                               VERSION 2.02                           *
*
*                               RUN DATE : 14-OCT-10                     *
*
*
* RUN NAME           : AP1000_1                                         *
* DESCRIPTION OF RUN :                                                 *
* AP1000_1 Sheltering                                                 *
*                               Version 2.03                             *
*****

```

SUMMARY OF THE OPTIONS CHOSEN FOR THIS RUN

***** DETERMINISTIC RUN *****

*** RESULTS CALCULATED IN THE POPULATION ***

```

MET SAMPLING PROGRAM           : NOT USED

SOURCE TERM PROGRAM           : USED
SOURCE TERM INPUT FILE :
    \PCCOSYM2\DATA\AP1000_1.ST3

RADIONUCLIDE CONCENTRATIONS   : YES

COUNTERMEASURES CONSIDERED    : NO
COUNTERMEASURES AS ENDPOINT   : NO
COUNTERMEASURES - SHORT TERM
- PATTERN, POTENTIAL DOSES    : NO
  AND PROBABILITIES           : NO
- NUMBERS AND AREAS          : NO
COUNTERMEASURES - LONG TERM
- PATTERN, POTENTIAL DOSES    : NO
  AND PROBABILITIES           : NO
- NUMBERS AND AREAS          : NO

SHORT TERM INDIVIDUAL DOSES    : YES
LONG TERM INDIVIDUAL DOSES     : YES
SHORT TERM INDIVIDUAL RISKS    : NO
LONG TERM INDIVIDUAL RISKS     : NO
SHORT TERM HEALTH EFFECTS     : NO
LONG TERM COLLECTIVE DOSES     : NO
LONG TERM HEALTH EFFECTS      : NO
ECONOMIC CONSEQUENCES         : NO

```

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SHORT TERM DOSES CALCULATED TO : 2 DAYS
ALL PHASES TRAVEL IN WIND DIRECTION OF 1st HOUR OF 1st PHASE

SPATIAL DISTRIBUTION DATA

THIS RUN USES 20 DISTANCE BANDS
THE OUTER LIMITS OF THE DISTANCES (IN KM) ARE

3.0000E-01	5.0000E-01	7.0000E-01	9.0000E-01	1.1000E+00
1.5000E+00	2.5000E+00	3.5000E+00	4.0000E+00	8.0000E+00
1.0000E+01	1.5000E+01	2.0000E+01	2.5000E+01	3.0000E+01
3.8000E+01	4.2000E+01	4.5000E+01	5.0000E+01	8.0000E+01

THE CUT-OFF DISTANCE FOR CALCULATIONS WHICH INVOLVE EARLY COUNTERMEASURES
OR EFFECTS, IF REQUIRED, IS SET AT 8.0000E+01 KM.

DETAILED INFORMATION IS GIVEN AT THE FOLLOWING 2 GRID POINTS
8.0000E-01 KM 3.0000E+00 KM

THIS RUN USES 72 SECTORS.

NUMBERS OF EFFECTS ARE BASED ON A UNIFORM POPULATION DENSITY OF 2.5000E+02
PEOPLE PER KM**2.

DOSE PARAMETERS

EFFECTIVE DOSE IS CALCULATED (ICRP-60)

BREATHING RATE : 3.3333E-04 M**3/S

RESUSPENSION PARAMETERS WLAMR : 3.5000E-08 /S

RESE : 1.0000E-09 /M

RES0 : 5.0000E-08 /M

THIS COSYMA RUN CONSIDERS CONSEQUENCES USING A SINGLE STABILITY CATEGORY:

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WIND DIRECTION : 360 DEGREE
 WINDSPEED : 400/100 M/S
 STABILITY CATEGORY : D
 RAIN INTENSITY : 0/100 MM/H
 SEASON : S

 SPERSION

INPUT LIST OF THE METEOROLOGICAL ZONE

HEIGHT OF MIXING LAYER (M) OF THE DIFFUSION CATEGORY

A	B	C	D	E	F
1600	1200	800	560	320	200

SURFACE ROUGHNESS : SMOOTH TERRAIN (LOW PLANTS, RURAL AREAS; Z0 = 10 CM TO 1 M)

INPUT LIST OF THE PARAMETERS FOR THE WIND PROFILE

WIND PROFILE EXPONENT FOR THE DIFFUSION CATEGORY

D : 3.4000E-01

THE FOLLOWING PARAMETERS ARE A FUNCTION OF THE FOLLOWING HEIGHTS

HEIGHT (M)	5.0000E+01	1.0000E+02	1.8000E+02
------------	------------	------------	------------

DISPERSION COEFFICIENTS FOR SMOOTH TERRAIN

CAT.	PY	QY	PY	QY	PY	QY
D	4.1800E-01	7.9600E-01	4.1800E-01	7.9600E-01	4.1800E-01	7.9600E-01

CAT.	PZ	QZ	PZ	QZ	PZ	QZ
D	5.2000E-01	7.1100E-01	5.2000E-01	7.1100E-01	5.2000E-01	7.1100E-01

HORIZONTAL STANDARD DEVIATION (DEGREE) OF WIND DIRECTION

D	6.9000E+00	6.9000E+00	6.9000E+00
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 SOURCE TERM AND DEPOSITION

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INPUT LIST OF THE NUCLIDE DATA - USING SOURCE TERM PROGRAM

THE SOURCE TERM PROGRAM MAY NOT USE ALL THE NUCLIDES IN THIS FULL LIST.
DEPENDING ON THE CUT-OFF SPECIFIED. REFER TO THE OUTPUT FILE :
"\PCCOSYM2\RESULTS\SRC*.SRC"
WHERE * IS THE NAME OF THE *.ST1 FILE

NO. NUCLIDE	HALF-LIFE	DEPOSIT.	WASHOUT COEFFICIENT FOR RAIN
VELOCITY	TERM A	TERM B	
	(Y)	(M/S)	*

* CORRECTION FACTOR FOR CALCULATING THE GROUND CONTAMINATION OF

NOBLE GASES:	1.0000E+00
AEROSOLS:	1.0000E+00
ELEMENTAL IODINE:	1.0000E+00
ORG. BOUND IODINE:	1.0000E+00

EXPOSURE PATHWAYS FOR EACH NUCLIDE ARE DETERMINED
BY THE SOURCE TERM PROGRAM. SEE OUTPUT FILE "\PCCOSYM2\RESULTS\SRC*.SRC".
WHERE * IS THE NAME OF THE *.ST1 FILE.

GROWTH OF THE FOLLOWING DAUGHTERS DURING DISPERSION IS CONSIDERED:

DAUGHTER PRODUCT	PARENT	YIELD
NO. NAME	NO. NAME	

INPUT LIST OF THE SOURCE TERM

NUMBER OF RELEASE PHASES: 1
SHIFT OF THE STARTING POINT: 0 H

	DELAY	THERMAL	INITIAL RELEASE	SOURCE	
		ENERGY	HEIGHT	WIDTH	HEIGHT
	(H)	(MW)	(M)	(M)	(M)
1. PHASE:	1	0.0000E+00	0	4.0000E+01	4.0000E+01

LIST OF THE AMOUNT OF ACTIVITY RELEASED FOR EACH NUCLIDE FOR EACH PHASE IN BQ

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		PHASE 1	PHASE
NUCLIDE	SUM	T = 1H	T =

THE NUCLIDES AND THE AMOUNTS RELEASED ARE CALCULATED
 USING THE SOURCE TERM PROGRAM. A PRINT OUT OF
 THESE QUANTITIES IS FOUND IN FILE "\PCCOSYM2\RESULTS\SRC*.SRC"
 WHERE * IS THE NAME OF THE *.ST1 FILE.

 COUNTERMEASURES

CALCULATIONS ARE MADE ASSUMING NO COUNTERMEASURES

THE PARAMETER VALUES LISTED IN THIS SECTION ARE THOSE PC COSYMA USES
 TO MODEL THIS ASSUMPTION

SHELTER THEN EVACUATE AUTOMATICALLY

THIS COUNTERMEASURE IS NOT CONSIDERED.

SHELTER THEN EVACUATE, ON DOSE LEVEL

THIS COUNTERMEASURE IS NOT CONSIDERED.

SHELTERING ON A DOSE LEVEL, NO EVACUATION

THIS COUNTERMEASURE IS NOT CONSIDERED.

SHELTERING IN A CIRCLE, NO EVACUATION

THIS COUNTERMEASURE IS NOT CONSIDERED.

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STABLE IODINE TABLETS

THIS COUNTERMEASURE IS NOT CONSIDERED.

RELOCATION AND RESETTLEMENT

THIS COUNTERMEASURE IS NOT CONSIDERED.

LOCATION FACTORS

THERE ARE 4 TYPES OF LOCATION FACTORS, NOT ALL OF WHICH MAY APPLY TO THE PATTERN OF COUNTERMEASURES AND POPULATION BEHAVIOUR IN THIS CALCULATION. THE CORRESPONDING GROUPS AND LOCATION FACTORS ARE:

	L O C A T I O N F A C T O R S				
	CL	GR	IH	IHR	SK
NORMAL ACTIVITY	: 1.000E+00	1.000E+001	1.000E+001	1.000E+001	1.000E+00
INITIAL DELAY	: 1.000E+00	1.000E+001	1.000E+001	1.000E+001	1.000E+00
SHELTERING (BUILDINGS)	: 1.000E+00	1.000E+001	1.000E+001	1.000E+001	1.000E+00
CARS	: 1.000E+00	1.000E+001	1.000E+001	1.000E+001	1.000E+00

SHORT TERM DOSES AND RISKS

THE FOLLOWING PATHWAYS ARE TAKEN INTO ACCOUNT
FOR EARLY DOSE AND RISK CALCULATIONS

- CLOUDSHINE : YES
- GROUNDSHINE : YES
- INHALATION : NO
- RESUSPENION : YES
- SKIN/CLOTHES : YES

PARAMETERS OF THE DOSE-RISK RELATIONSHIPS

MORBIDITY

=====

EFFECT	SHAPE	THETA-1	THETA-INFINITY
--------	-------	---------	----------------

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	PARAMETER	GY**2/H	GY
LUNG IMPAIRMENT	7.0000E+00	1.5000E+01	5.0000E+00
HYPOTHYROIDISM	1.3000E+00	3.0000E+01	6.0000E+01
CATARACTAE	5.0000E+00	1.0000E-02	3.0000E+00
MENTAL RETARD.	1.0000E+00	0.0000E+00	1.5000E+00
EFFECTS ON SKIN	5.0000E+00	5.0000E+00	2.0000E+01

MORTALITY
=====

EFFECT	SHAPE PARAMETER	THETA-1 GY**2/H	THETA-INFINITY GY
PULMONARY SYNDR	7.0000E+00	3.0000E+01	1.0000E+01
HEMATOP.SYNDR.	6.0000E+00	1.0000E-01	4.5000E+00
GASTROINT.SYNDR	1.0000E+01	0.0000E+00	1.5000E+01
PRE/NEON. DEATH	3.0000E+00	0.0000E+00	1.5000E+00
SKIN BURNS	5.0000E+00	5.0000E+00	2.0000E+01

RATIO OF ACTIVITY CONCENTRATIONS ON SKIN TO DRY DEPOSITED ACTIVITY
CONCENTRATIONS ON GROUND SURFACE

1	NOBLE GASES:	1.0000E+00
2	AEROSOLS:	1.0000E+00
3	ELEMENTAL IODINE:	1.0000E+00
4	ORG. BOUND IODINE:	1.0000E+00

LONG TERM DOSES AND RISKS

THE FOLLOWING PATHWAYS ARE TAKEN INTO ACCOUNT
FOR LATE DOSE AND RISK CALCULATIONS

- CLOUDSHINE : NO
- GROUNDSHINE : NO
- INHALATION : YES
- INGESTION : NO
- RESUSPENION : NO
- SKIN/CLOTHES : NO

INTEGRATION TIME FOR SKIN DOSES (DAYS) : 1.0000E+04
FRACTION OF SKIN CONTAMINATED : 1.0000E-01

THE FOLLOWING PARAMETERS ARE USED TO CALCULATE THE
STOCHASTIC HEALTH EFFECTS:

CANCER MORTALITY FACTORS (PER SV)	CANCER MORTALITY FRACTIONS
--------------------------------------	-------------------------------

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BONE MARROW	5.0000E-03	1.0000E+00
BONE SURF.	5.0000E-04	1.0000E+00
BREAST	2.0000E-03	4.0000E-01
LUNG	8.5000E-03	7.5000E-01
STOMACH	1.1000E-02	8.5000E-01
COLON	8.5000E-03	5.5000E-01
LIVER	1.5000E-03	1.0000E+00
PANCREAS	2.6000E-03	9.0000E-01
THYROID	8.0000E-04	1.0000E-01
REMAINDER	9.3000E-03	6.0000E-01
SKIN	2.0000E-04	1.0000E-02
HERED.EFF.	1.0000E-02	

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```

*****
*
*                      PC COSYMA                      *
*                      VERSION 2.02                     *
*
*                      RUN DATE : 14-OCT-10              *
*
*
* RUN NAME              : EPR01                          *
* DESCRIPTION OF RUN :
* EPR Sheltering
*
*                      Version 2.03                      *
*****

```

SUMMARY OF THE OPTIONS CHOSEN FOR THIS RUN

***** DETERMINISTIC RUN *****

*** RESULTS CALCULATED IN THE POPULATION ***

```

MET SAMPLING PROGRAM           : NOT USED

SOURCE TERM PROGRAM           : USED
SOURCE TERM INPUT FILE :
    \PCCOSYM2\DATA\EPR01.ST3

RADIONUCLIDE CONCENTRATIONS   : YES

COUNTERMEASURES CONSIDERED    : NO
COUNTERMEASURES AS ENDPOINT   : NO
COUNTERMEASURES - SHORT TERM
- PATTERN, POTENTIAL DOSES    : NO
  AND PROBABILITIES           : NO
- NUMBERS AND AREAS          : NO
COUNTERMEASURES - LONG TERM
- PATTERN, POTENTIAL DOSES    : NO
  AND PROBABILITIES           : NO
- NUMBERS AND AREAS          : NO

SHORT TERM INDIVIDUAL DOSES    : YES
LONG TERM INDIVIDUAL DOSES     : YES
SHORT TERM INDIVIDUAL RISKS    : NO
LONG TERM INDIVIDUAL RISKS     : NO
SHORT TERM HEALTH EFFECTS      : NO
LONG TERM COLLECTIVE DOSES     : NO
LONG TERM HEALTH EFFECTS       : NO
ECONOMIC CONSEQUENCES         : NO

SHORT TERM DOSES CALCULATED TO : 2 DAYS
ALL PHASES TRAVEL IN WIND DIRECTION OF 1st HOUR OF 1st PHASE

```

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SPATIAL DISTRIBUTION DATA

THIS RUN USES 20 DISTANCE BANDS
THE OUTER LIMITS OF THE DISTANCES (IN KM) ARE

3.0000E-01	5.0000E-01	7.0000E-01	9.0000E-01	1.1000E+00
1.5000E+00	2.5000E+00	3.5000E+00	4.0000E+00	8.0000E+00
1.0000E+01	1.5000E+01	2.0000E+01	2.5000E+01	3.0000E+01
3.8000E+01	4.2000E+01	4.5000E+01	5.0000E+01	8.0000E+01

THE CUT-OFF DISTANCE FOR CALCULATIONS WHICH INVOLVE EARLY COUNTERMEASURES
OR EFFECTS, IF REQUIRED, IS SET AT 8.0000E+01 KM.

DETAILED INFORMATION IS GIVEN AT THE FOLLOWING 2 GRID POINTS
8.0000E-01 KM 3.0000E+00 KM

THIS RUN USES 72 SECTORS.

NUMBERS OF EFFECTS ARE BASED ON A UNIFORM POPULATION DENSITY OF 2.5000E+02
PEOPLE PER KM**2.

DOSE PARAMETERS

EFFECTIVE DOSE IS CALCULATED (ICRP-60)

BREATHING RATE : 3.3330E-04 M**3/S

RESUSPENSION PARAMETERS WLAMR : 3.5000E-08 /S

RESE : 1.0000E-09 /M

RES0 : 5.0000E-08 /M

THIS COSYMA RUN CONSIDERS CONSEQUENCES USING A SINGLE STABILITY CATEGORY:

WIND DIRECTION : 360 DEGREE
WINDSPEED : 400/100 M/S
STABILITY CATEGORY : D
RAIN INTENSITY : 0/100 MM/H
SEASON : S

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 DISPERSION

INPUT LIST OF THE METEOROLOGICAL ZONE

HEIGHT OF MIXING LAYER (M) OF THE DIFFUSION CATEGORY					
A	B	C	D	E	F
1600	1200	800	560	320	200

SURFACE ROUGHNESS : SMOOTH TERRAIN (LOW PLANTS, RURAL AREAS; Z0 = 10 CM TO 1 M)

INPUT LIST OF THE PARAMETERS FOR THE WIND PROFILE

WIND PROFILE EXPONENT FOR THE DIFFUSION CATEGORY

D : 3.4000E-01

THE FOLLOWING PARAMETERS ARE A FUNCTION OF THE FOLLOWING HEIGHTS

HEIGHT (M)	5.0000E+01	1.0000E+02	1.8000E+02
------------	------------	------------	------------

DISPERSION COEFFICIENTS FOR SMOOTH TERRAIN

CAT.	PY	QY	PY	QY	PY	QY
D	4.1800E-01	7.9600E-01	4.1800E-01	7.9600E-01	4.1800E-01	7.9600E-01
CAT.	PZ	QZ	PZ	QZ	PZ	QZ
D	5.2000E-01	7.1100E-01	5.2000E-01	7.1100E-01	5.2000E-01	7.1100E-01

HORIZONTAL STANDARD DEVIATION (DEGREE) OF WIND DIRECTION

D	6.9000E+00	6.9000E+00	6.9000E+00
---	------------	------------	------------

 SOURCE TERM AND DEPOSITION

INPUT LIST OF THE NUCLIDE DATA - USING SOURCE TERM PROGRAM

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THESE QUANTITIES IS FOUND IN FILE "\PCCOSYM2\RESULTS\SRC*.SRC"
WHERE * IS THE NAME OF THE *.ST1 FILE.

COUNTERMEASURES

CALCULATIONS ARE MADE ASSUMING NO COUNTERMEASURES

THE PARAMETER VALUES LISTED IN THIS SECTION ARE THOSE PC COSYMA USES
TO MODEL THIS ASSUMPTION

SHELTER THEN EVACUATE AUTOMATICALLY

THIS COUNTERMEASURE IS NOT CONSIDERED.

SHELTER THEN EVACUATE, ON DOSE LEVEL

THIS COUNTERMEASURE IS NOT CONSIDERED.

SHELTERING ON A DOSE LEVEL, NO EVACUATION

THIS COUNTERMEASURE IS NOT CONSIDERED.

SHELTERING IN A CIRCLE, NO EVACUATION

THIS COUNTERMEASURE IS NOT CONSIDERED.

STABLE IODINE TABLETS

THIS COUNTERMEASURE IS NOT CONSIDERED.

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RELOCATION AND RESETTLEMENT

THIS COUNTERMEASURE IS NOT CONSIDERED.

LOCATION FACTORS

THERE ARE 4 TYPES OF LOCATION FACTORS, NOT ALL OF WHICH MAY APPLY TO THE PATTERN OF COUNTERMEASURES AND POPULATION BEHAVIOUR IN THIS CALCULATION. THE CORRESPONDING GROUPS AND LOCATION FACTORS ARE:

	L O C A T I O N F A C T O R S				
	CL	GR	IH	IHR	SK
NORMAL ACTIVITY	: 1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
INITIAL DELAY	: 1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
SHELTERING (BUILDINGS)	: 1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
CARS	: 1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00

***** SHORT TERM DOSES AND RISKS *****

THE FOLLOWING PATHWAYS ARE TAKEN INTO ACCOUNT
FOR EARLY DOSE AND RISK CALCULATIONS

- CLOUDSHINE : YES
- GROUNDSHINE : YES
- INHALATION : NO
- RESUSPENION : YES
- SKIN/CLOTHES : YES

PARAMETERS OF THE DOSE-RISK RELATIONSHIPS

MORBIDITY

=====

EFFECT	SHAPE PARAMETER	THETA-1 GY**2/H	THETA-INFINITY GY
LUNG IMPAIRMENT	7.0000E+00	1.5000E+01	5.0000E+00
HYPOTHYROIDISM	1.3000E+00	3.0000E+01	6.0000E+01
CATARACTAE	5.0000E+00	1.0000E-02	3.0000E+00
MENTAL RETARD.	1.0000E+00	0.0000E+00	1.5000E+00

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EFFECTS ON SKIN 5.0000E+00 5.0000E+00 2.0000E+01

MORTALITY
=====

EFFECT	SHAPE PARAMETER	THETA-1 GY**2/H	THETA-INFINITY GY
PULMONARY SYNDR	7.0000E+00	3.0000E+01	1.0000E+01
HEMATOP.SYNDR.	6.0000E+00	1.0000E-01	4.5000E+00
GASTROINT.SYNDR	1.0000E+01	0.0000E+00	1.5000E+01
PRE/NEON. DEATH	3.0000E+00	0.0000E+00	1.5000E+00
SKIN BURNS	5.0000E+00	5.0000E+00	2.0000E+01

RATIO OF ACTIVITY CONCENTRATIONS ON SKIN TO DRY DEPOSITED ACTIVITY
CONCENTRATIONS ON GROUND SURFACE

1 NOBLE GASES:	1.0000E+00
2 AEROSOLS:	1.0000E+00
3 ELEMENTAL IODINE:	1.0000E+00
4 ORG. BOUND IODINE:	1.0000E+00

LONG TERM DOSES AND RISKS

THE FOLLOWING PATHWAYS ARE TAKEN INTO ACCOUNT
FOR LATE DOSE AND RISK CALCULATIONS

- CLOUDSHINE : NO
- GROUNDSHINE : NO
- INHALATION : YES
- INGESTION : NO
- RESUSPENION : NO
- SKIN/CLOTHES : NO

INTEGRATION TIME FOR SKIN DOSES (DAYS) : 1.0000E+04
FRACTION OF SKIN CONTAMINATED : 1.0000E-01

THE FOLLOWING PARAMETERS ARE USED TO CALCULATE THE
STOCHASTIC HEALTH EFFECTS:

	CANCER MORTALITY FACTORS (PER SV)	CANCER MORTALITY FRACTIONS
BONE MARROW	5.0000E-03	1.0000E+00
BONE SURF.	5.0000E-04	1.0000E+00
BREAST	2.0000E-03	4.0000E-01
LUNG	8.5000E-03	7.5000E-01
STOMACH	1.1000E-02	8.5000E-01

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COLON	8.5000E-03	5.5000E-01
LIVER	1.5000E-03	1.0000E+00
PANCREAS	2.6000E-03	9.0000E-01
THYROID	8.0000E-04	1.0000E-01
REMAINDER	9.3000E-03	6.0000E-01
SKIN	2.0000E-04	1.0000E-02
HERED.EFF.	1.0000E-02	

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Appendix A-8.E

Projected Radioactive Contamination of Foodstuffs and the LPZ = 40 km

Introduction

Airborne radioactivity calculated with PC Cosyma was used in a radioecological model, ECOSYS for Excel 1.5 (Conrad, 2011), for assessing the transfer of radionuclides to foodstuffs after deposition on agricultural land, and the radiation exposure of people via all relevant exposure pathways. ECOSYS is a further developed program version of the model ECOSYS-87, which is the basis for the dose assessment in the German Integrated Measurement- and Information System (IMIS). Moreover, the ECOSYS-87 model is used in the European Realtime Decision Support System RODOS for dose assessment, as well as in radiological decision support systems of Austria, Switzerland and Hong Kong. ECOSYS has been specifically adapted by the code developers for Southern Hemisphere seasonal conditions to perform the LPZ assessment in **Chapter 8**.

The agricultural activities and produce reported in **Chapter 5** were considered for assessing radioactivity concentration at the 40 km LPZ radius. The airborne radioactivity was calculated assuming negligible deposition. This approach provided a maximum air concentration at 40 km. Deposition was then determined by ECOSYS and in this manner forcing a maximum possible deposition on the land area where the agricultural activity is assumed to take place. Conservative estimates are therefore determined for radioactivity concentrations in foodstuff. The results are shown in **Table A-8.E.1** and **Figures A-8.E.2** and **A-8.E.3**. Note that drinking water is not included for reasons explained earlier in **Subsection 8.5.3**.

A subset of all radionuclides comprising the accident source term contributes to the longer term impacts. **Tables A-8.E.2 and A-8.E.3** provides the basis for selection of this subset.

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TABLE A-8.E.1
Ingestion Dose at 40 km as a Function of Time

Ingestion Dose, mSv					
Time	Total	Vegetables, fruit	Cereals	Milk products	Meat
1 day	4.4E-02	4.4E-02	0	0	0
1 week	2.9E-01	2.4E-01	0	4.6E-02	1.4E-04
2 weeks	4.5E-01	3.7E-01	0	8.6E-02	1.7E-04
1 month	6.0E-01	4.8E-01	0	1.2E-01	1.8E-03
6 months	8.0E-01	6.2E-01	0	1.4E-01	3.7E-02
1 year	9.5E-01	7.2E-01	0	1.5E-01	8.1E-02
2 years	9.6E-01	7.2E-01	5.2E-04	1.5E-01	9.7E-02
5 years	9.7E-01	7.2E-01	1.7E-03	1.5E-01	9.7E-02
10 years	9.8E-01	7.2E-01	2.9E-03	1.6E-01	9.7E-02
50 years	9.9E-01	7.2E-01	4.5E-03	1.6E-01	9.7E-02
70 years	9.9E-01	7.2E-01	4.5E-03	1.6E-01	9.7E-02

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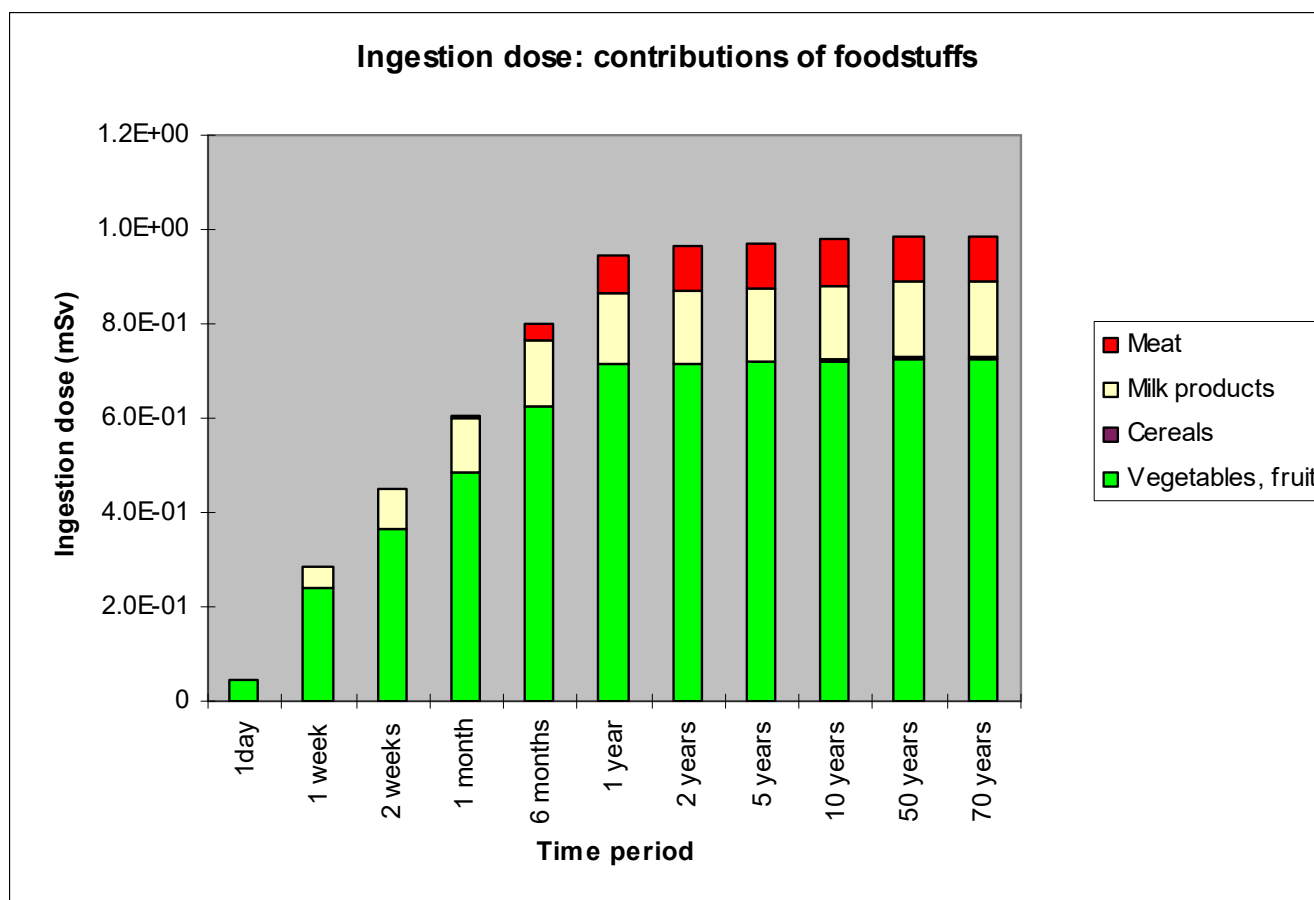


Figure A-8.E.2
Ingestion Dose at 40 km as a Function of Time

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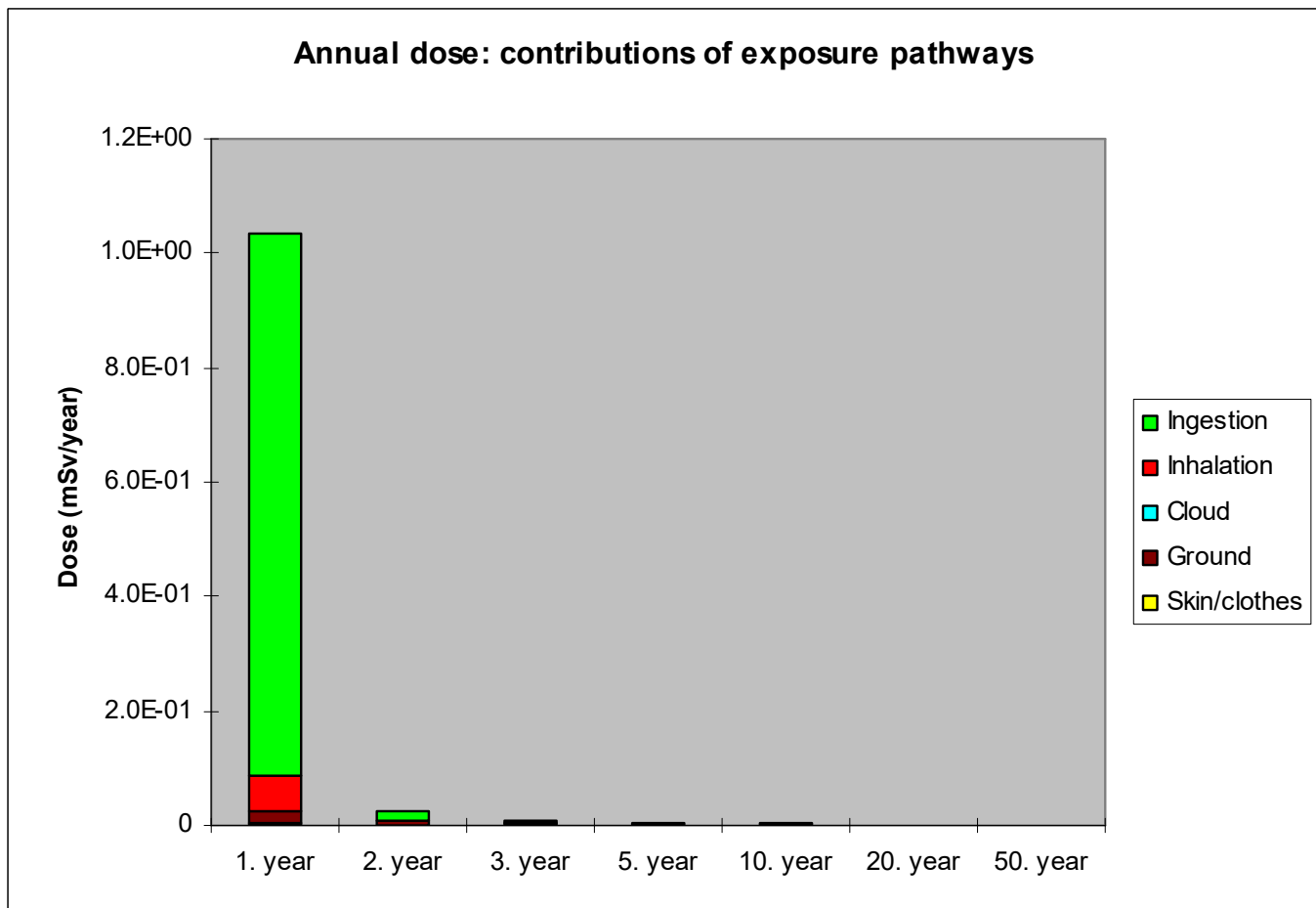


Figure A-8.E.3
Dose from All Exposure Pathways at 40 km as a Function of Time

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TABLE A-8.E.2

**AP1000 Airborne Concentrations of Important Ingestion Pathway
Radionuclides Calculated with PC Cosyma using Negligible
Deposition Factors**

Radionuclide	Bq.s.m ⁻³ at 2.5 km	5 km	10 km	20 km	30 km	40 km	80 km
I-131	1.16E+08	4.13E+07	1.46E+07	6.78E+06	4.90E+06	3.92E+06	2.23E+06
I-132	1.67E+08	5.87E+07	2.03E+07	9.14E+06	6.42E+06	4.99E+06	2.67E+06
I-133	2.32E+08	8.20E+07	2.86E+07	1.31E+07	9.26E+06	7.23E+06	3.85E+06
Te-129m	4.34E+06	1.54E+06	5.43E+05	2.54E+05	1.83E+05	1.47E+05	8.41E+04
Te-132	1.32E+08	4.66E+07	1.64E+07	7.61E+06	5.48E+06	4.36E+06	2.45E+06
Sr-89	1.07E+08	3.81E+07	1.34E+07	6.28E+06	4.54E+06	3.64E+06	2.09E+06
Sr-90	9.24E+06	3.28E+06	1.16E+06	5.41E+05	3.92E+05	3.14E+05	1.80E+05
Sr-91	1.23E+08	4.30E+07	1.48E+07	6.57E+06	4.54E+06	3.44E+06	1.68E+06
Ru-103	1.91E+08	6.77E+07	2.39E+07	1.12E+07	8.08E+06	6.47E+06	3.70E+06
Ru-106	6.26E+07	2.22E+07	7.84E+06	3.66E+06	2.65E+06	2.13E+06	1.22E+06
Mo-99	2.39E+08	8.47E+07	2.98E+07	1.38E+07	9.94E+06	7.91E+06	4.43E+06
Cs-134	2.16E+07	7.67E+06	2.71E+06	1.27E+06	9.15E+05	7.34E+05	4.21E+05
Cs-136	6.16E+06	2.18E+06	7.70E+05	3.59E+05	2.60E+05	2.08E+05	1.19E+05
Cs-137	1.26E+07	4.46E+06	1.58E+06	7.37E+05	5.33E+05	4.27E+05	2.45E+05
Ba-140	2.07E+08	7.35E+07	2.59E+07	1.21E+07	8.75E+06	7.00E+06	3.99E+06
Nb-95	2.37E+07	8.40E+06	2.96E+06	1.39E+06	1.00E+06	8.04E+05	4.61E+05
Zr-95	2.35E+07	8.34E+06	2.94E+06	1.38E+06	9.95E+05	7.97E+05	4.57E+05
Ce-141	2.47E+07	8.77E+06	3.09E+06	1.45E+06	1.05E+06	8.38E+05	4.79E+05
Ce-144	1.87E+07	6.63E+06	2.34E+06	1.09E+06	7.91E+05	6.34E+05	3.63E+05

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Assessment of the AP1000 Source Term - Radionuclide importance for ingestion pathways

Group No	Group Description	Radionuclide	Activity Released, Bq	Release rate; Bq/s	Atmospheric dispersion coefficient. X/Q (sec/m ³) for >800m (example)	Integrated airborne activity concentration on Bq.h.m-3 (1 hour release duration)	Radionuclide half-life, T1/2		T1/2 sec	Ingestion Dose Coefficient. Dcf, Sv/Bq (Adult) Reference 8.31	T1/2×Dcf	Importance weighting relative to I-131. ratio (T1/2×Dcf×A):(I131) >1%
1	Noble Gases	Kr-85m	2.53E+15	7.03E+11	1.00E-04	7.03E+07	4.48E+00	h	1.613E+04			
		Kr-85	1.02E+14	2.83E+10	1.00E-04	2.83E+06	10.7	y	3.377E+08			
		Kr-87	4.88E+15	1.36E+12	1.00E-04	1.36E+08	76.3	min	4.578E+03			
		Kr-88	6.87E+15	1.91E+12	1.00E-04	1.91E+08	2.84	h	1.022E+04			
		Xe-131m	1.02E+14	2.83E+10	1.00E-04	2.83E+06	11.9	d	1.028E+06			
		Xe-133m	5.62E+14	1.56E+11	1.00E-04	1.56E+07	2.19	d	1.892E+05			
		Xe-133	1.83E+16	5.08E+12	1.00E-04	5.08E+08	5.25	d	4.536E+05			
		Xe-135m	3.72E+15	1.03E+12	1.00E-04	1.03E+08	15.3	min	9.180E+02			
		Xe-135	4.66E+15	1.29E+12	1.00E-04	1.29E+08	9.09	h	3.272E+04			
		Xe-138	1.59E+16	4.42E+12	1.00E-04	4.42E+08	14.2	min	8.520E+02			
2	CsI	I-130	1.63E+12	4.53E+08	1.00E-04	4.53E+04	12.4	h	4.464E+04	2.00E-09	8.928E-05	0.00
		I-131	4.28E+13	1.19E+10	1.00E-04	1.19E+06	8.04	d	6.947E+05	2.20E-08	1.528E-02	1.00
		I-132	6.22E+13	1.73E+10	1.00E-04	1.73E+06	2.3	h	8.280E+03	2.90E-10	2.401E-06	0.00
		I-133	8.84E+13	2.46E+10	1.00E-04	2.46E+06	20.8	h	7.488E+04	4.30E-09	3.220E-04	0.04
		I-134	9.68E+13	2.69E+10	1.00E-04	2.69E+06	52.6	min	3.156E+03	1.10E-10	3.472E-07	0.00
		I-135	8.26E+13	2.29E+10	1.00E-04	2.29E+06	6.61	h	2.380E+04	9.30E-10	2.213E-05	0.00
3	TeO ₂	Te-127m	4.64E+11	1.29E+08	1.00E-04	1.29E+04	109	d	9.418E+06	2.30E-09	2.166E-02	0.02
		Te-127	3.59E+12	9.97E+08	1.00E-04	9.97E+04	9.35	h	3.600E+03	1.70E-10	6.120E-07	0.00
		Te-129m	1.58E+12	4.39E+08	1.00E-04	4.39E+04	33.6	d	2.903E+06	3.00E-09	8.709E-03	0.02
		Te-129	1.07E+13	2.97E+09	1.00E-04	2.97E+05	69.6	min	4.176E+03	6.30E-11	2.631E-07	0.00
		Te-131m	4.92E+12	1.37E+09	1.00E-04	1.37E+05	30	h	1.080E+05	1.90E-09	2.052E-04	0.00
		Te-132	4.85E+13	1.35E+10	1.00E-04	1.35E+06	78.2	h	2.815E+05	3.80E-09	1.070E-03	0.08
4	SrO	Sr-89	3.93E+13	1.09E+10	1.00E-04	1.09E+06	50.5	d	4.363E+06	2.60E-09	1.134E-02	0.68

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Group No	Group Description	Radionuclide	Activity Released, Bq	Release rate; Bq/s	Atmospheric dispersion coefficient. X/Q (sec/m ³) for >800m (example)	Integrated airborne activity concentration on Bq.h.m ⁻³ (1 hour release duration)	Radionuclide half-life, T _{1/2}		T _{1/2} sec	Ingestion Dose Coefficient. Dcf, Sv/Bq (Adult) Reference 8.31	T _{1/2} ×Dcf	Importance weighting relative to I-131. ratio (T _{1/2} ×Dcf×A):(I131) >1%
		Sr-90	3.38E+12	9.39E+08	1.00E-04	9.39E+04	29.1	y	9.183E+08	2.80E-08	2.571E+01	132.87
		Sr-91	4.88E+13	1.36E+10	1.00E-04	1.36E+06	9.5	h	3.420E+04	6.50E-10	2.223E-05	0.00
		Sr-92	5.25E+13	1.46E+10	1.00E-04	1.46E+06	2.71	h	9.756E+03	4.30E-10	4.195E-06	0.00
5	MoO ₂	Ru-103	6.97E+13	1.94E+10	1.00E-04	1.94E+06	39.3	d	3.396E+06	7.30E-10	2.479E-03	0.26
		Ru-105	4.73E+13	1.31E+10	1.00E-04	1.31E+06	4.44	h	1.598E+04	2.60E-10	4.156E-06	0.00
		Ru-106	2.29E+13	6.36E+09	1.00E-04	6.36E+05	368	d	3.180E+07	7.00E-09	2.226E-01	7.79
		Rh-105	4.33E+13	1.20E+10	1.00E-04	1.20E+06	35.4	h	1.274E+05	3.70E-10	4.715E-05	0.00
		Mo-99	8.85E+13	2.46E+10	1.00E-04	2.46E+06	66	h	2.376E+05	6.00E-10	1.426E-04	0.02
		Tc-99m	7.74E+13	2.15E+10	1.00E-04	2.15E+06	6.02	h	2.167E+04	2.20E-11	4.768E-07	0.00
6	CsOH	Cs-134	7.90E+12	2.19E+09	1.00E-04	2.19E+05	2.06	y	6.501E+07	1.90E-08	1.235E+00	14.92
		Cs-136	2.25E+12	6.25E+08	1.00E-04	6.25E+04	13.1	d	1.132E+06	3.00E-09	3.396E-03	0.01
		Cs-137	4.60E+12	1.28E+09	1.00E-04	1.28E+05	30	y	9.467E+08	1.30E-08	1.231E+01	86.55
		Cs-138	7.41E+13	2.06E+10	1.00E-04	2.06E+06	32.2	min	1.932E+03	9.20E-11	1.777E-07	0.00
		Rb-86	9.32E+10	2.59E+07	1.00E-04	2.59E+03	18.7	d	1.616E+06	2.80E-09	4.524E-03	0.00
7	BaO	Ba-139	7.90E+13	2.19E+10	1.00E-04	2.19E+06	82.7	min	4.962E+03	1.20E-10	5.954E-07	0.00
		Ba-140	7.59E+13	2.11E+10	1.00E-04	2.11E+06	12.7	d	1.097E+06	2.60E-09	2.853E-03	0.33
8	La ₂ O ₃	Y-90	4.49E+11	1.25E+08	1.00E-04	1.25E+04	64	h	2.304E+05	2.70E-09	6.221E-04	0.00
		Y-91	6.94E+12	1.93E+09	1.00E-04	1.93E+05	58.5	d	5.054E+06	2.40E-09	1.213E-02	0.13
		Y-92	6.73E+12	1.87E+09	1.00E-04	1.87E+05	3.54	h	1.274E+04	4.90E-10	6.245E-06	0.00
		Y-93	7.72E+12	2.14E+09	1.00E-04	2.14E+05	10.1	h	3.636E+04	1.20E-09	4.363E-05	0.00
		Nb-95	8.65E+12	2.40E+09	1.00E-04	2.40E+05	35.1	d	3.033E+06	5.80E-10	1.759E-03	0.02
		Zr-95	8.60E+12	2.39E+09	1.00E-04	2.39E+05	64	d	5.530E+06	9.50E-10	5.253E-03	0.07
		Zr-97	8.50E+12	2.36E+09	1.00E-04	2.36E+05	16.9	h	6.084E+04	2.10E-09	1.278E-04	0.00
		La-140	9.43E+12	2.62E+09	1.00E-04	2.62E+05	40.3	h	1.451E+05	2.00E-09	2.902E-04	0.00
		La-141	8.39E+12	2.33E+09	1.00E-04	2.33E+05	3.93	h	1.415E+04	3.60E-10	5.093E-06	0.00
		La-142	8.13E+12	2.26E+09	1.00E-04	2.26E+05	92.5	min	5.550E+03	1.80E-10	9.990E-07	0.00

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Group No	Group Description	Radionuclide	Activity Released, Bq	Release rate; Bq/s	Atmospheric dispersion coefficient. X/Q (sec/m ³) for >800m (example)	Integrated airborne activity concentration on Bq.h.m-3 (1 hour release duration)	Radionuclide half-life, T1/2		T1/2 sec	Ingestion Dose Coefficient. Dcf, Sv/Bq (Adult) <u>Reference 8.31</u>	T1/2×Dcf	Importance weighting relative to I-131. ratio (T1/2×Dcf×A):(I131) >1%
9	CeO ₂	Pr-143	7.56E+12	2.10E+09	1.00E-04	2.10E+05	13.6	d	1.175E+06	1.20E-09	1.410E-03	0.02
		Nd-147	3.36E+12	9.33E+08	1.00E-04	9.33E+04	11	d	9.504E+05	1.10E-09	1.045E-03	0.01
		Ce-141	9.05E+12	2.51E+09	1.00E-04	2.51E+05	32.5	d	2.808E+06	7.10E-10	1.994E-03	0.03
		Ce-143	8.44E+12	2.34E+09	1.00E-04	2.34E+05	33	h	1.188E+05	1.10E-09	1.307E-04	0.00
		Ce-144	6.83E+12	1.90E+09	1.00E-04	1.90E+05	2.84E+02	d	2.454E+07	5.20E-09	1.276E-01	1.33
10	Sb	Sb-127	4.95E+12	1.38E+09	1.00E-04	1.38E+05	3.85	d	3.326E+05	1.70E-09	5.655E-04	0.00
		Sb-129	1.49E+13	4.14E+09	1.00E-04	4.14E+05	4.32	h	1.555E+04	4.20E-10	6.532E-06	0.00
11	UO ₂	Np-239	0.00E+00	0.00E+00	1.00E-04	0.00E+00	2.35	d	2.030E+05	8.00E-10	1.624E-04	0.00
		Pu-238	0.00E+00	0.00E+00	1.00E-04	0.00E+00	87.7	y	2.768E+09	2.30E-07	6.365E+02	0.00
		Pu-239	0.00E+00	0.00E+00	1.00E-04	0.00E+00	2.41E+04	y	7.605E+11	2.50E-07	1.901E+05	0.00
		Pu-240	0.00E+00	0.00E+00	1.00E-04	0.00E+00	6.54E+03	y	2.064E+11	2.50E-07	5.160E+04	0.00
		Pu-241	0.00E+00	0.00E+00	1.00E-04	0.00E+00	14.4	y	4.544E+08	4.80E-09	2.181E+00	0.00
		Am-241	0.00E+00	0.00E+00	1.00E-04	0.00E+00	4.32E+02	y	1.363E+10	2.00E-07	2.727E+03	0.00
		Cm-242	0.00E+00	0.00E+00	1.00E-04	0.00E+00	1.63E+02	d	1.408E+07	1.20E-08	1.690E-01	0.00
		Cm-244	0.00E+00	0.00E+00	1.00E-04	0.00E+00	18.1	y	5.712E+08	1.20E-07	6.854E+01	0.00

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Appendix A-8.F **Uncertainties in Severe Accident Analysis and** **Radioactivity Release Fractions from a Containment into** **the Environment**

Severe accident analysis and containment response to these accidents involve complex phenomena. Some aspects are still poorly understood and are the subjects of on-going research programmes. These programmes have reportedly made significant progress towards reducing uncertainty in severe accident source terms. Issues giving rise to uncertainties in source terms can be summarised as follows (International Atomic Energy Agency, 2010):

- uncertainties in core damage processes and containment behaviour;
- effects of fuel exposure (burn up) on the release rate of radioactive material from fuel;
- chemical forms of volatile and semi-volatile species;
- chemical interactions with fuel, neutron absorbers and structural materials during core degradation;
- deposition rates of radioactive material and aerosols on the surfaces of the reactor coolant circuit;
- deposition of radioactive material in piping and other components in accident sequences with containment bypass;
- release of radioactive material and aerosols during molten core–concrete interaction;
- chemical processes during molten core–concrete interaction;
- interaction between hydrogen burn or radicals in flame fronts and airborne radioactive material;
- scrubbing efficiency of aerosols and vapours in suppression pools, ice beds or bubble towers;
- aqueous chemistry of radioactive material captured in water pools;
- re-vaporisation and resuspension of radioactive material from surfaces;
- chemical decomposition of radioactive material aerosols.

It is therefore imperative that it be confirmed in the SAR for the construction licensing phase that severe accident source terms and release frequencies have not increased when compared to the assumptions made during the siting licensing phase and the assessment of EPZs.