CHAPTER 6: EVALUATION OF EXTERNAL EVENTS	
File name: 598690_DSSR Chapter 6 Rev 1b	
Author declaration:	I declare that appropriate diligence was applied in the compilation of this report which is based on the external event information in Chapter 5. Name: A Kilian Date: 2024-03-31
Peer Reviewer:	I declare that this report has undergone independent peer review by myself, that comments were addressed to my satisfaction, and that as such, it is considered fit for publication. Name: I Sekoko Date: 2024-03-31
Manager Nuclear Analysis and Siting	Name: I Sekoko Date: 2024-03-31
Eskom Acceptance	Name: I Sekoko Date: 2024-03-31

AMENDMENT RECORD			
Rev	Draft	Date	Amendments
0		04 June 2015	New chapter, replacing old KSSR Rev. 0
1		21 July 2022	Chapter updated to reflect the latest external hazards to the site.
1a		15 March 2024	Chapter updated to address NNR comments.
1b		31 March 2024	Minor corrections made – page numbers and cross-reference links corrected.

EXECUTIVE SUMMARY

Chapter 6 of the DSSR provides a summary of external events (EEs) important to the design and safety of the existing nuclear installation(s) (i.e., Koeberg Nuclear Power Station - KNPS) and proposed facilities within the Duynefontyn site (i.e. New Nuclear Installation – NNI) as detailed in ***Chapter 5***.

For the existing facilities, data presented in this chapter can be used as input to perform a safety re-assessment of the plant and to identify potential changes in EEs that could have an impact on the current design and licensing basis for the plant. Although EEs are identified and evaluated in the DSSR, the assessment of the expected impact of each hazard and the potential propagation mechanism and predicted effects on the installation do not form part of the scope of the DSSR. The DSSR does however provide a summary of those hazards that may require further attention based on a qualitative screening of the event, current information on the Koeberg design and licensing basis and the design consideration for a new nuclear installation (NNI).

For the NNI, the main purpose of ***Chapter 6*** is to summarise the information on EEs and to perform a preliminary screening of those events identified in ***Chapter 5*** against the Plant Parameter Envelope (PPE) criteria. This is an initial step in determining the degree at which the design of the NNI may be impacted by the identified hazards and to identify potential implications on the standard designs of the potential NNI against the PPE. The complete analysis of how EEs can interact with the SSCs of an NNI will be carried out in the next licensing phase involving the specific NNI design.

Table 6-1 lists the EEs assessed and screened for the NNI and KNPS. A qualitative screening status is assigned to each EE as follows:

- screened out unconditionally;
- screened out conditionally (a measure of uncertainty exists, and design confirmation or further studies are required);
- screened in (design mitigation is required or the site is potentially excluded).

For the NNI, screening criteria are applied with caution since the layout and detailed design of the NNI to be built are not available at this stage. EEs screened out unconditionally should not require additional consideration as a potential design basis external event for an NNI. There are events that are screened out conditional to confirmation when assessing the detailed NNI design. For KNPS, EEs are reviewed against the existing design basis provided in **Appendix 6-F**.

Table 6-1: Screening of Duynefontyn Site External Events

External Event	New Nuclear Installation		Koeberg Nuclear Power Station	
	Screening Result	Comment	Screening Result	Comment
Earthquake Induced Ground Shaking and Surface Faulting	In	SSHAC studies completed. Seismic PSA to be completed.	In	SSHAC results shows a slight increase in the PGA value from 0.3 to 0.36. Seismic PSA to be completed.
Volcanism	Out	Volcanic flank collapse a potential tsunamigenic source (screened in under flooding from the sea)	Out	Volcanic flank collapse a potential tsunamigenic source (screened in under flooding from the sea).
Groundwater Level	In	Groundwater levels at the new build site could rise to a maximum of 4 to 5 m above current levels. This would bring the groundwater in many of the lower-lying parts of the site to within 1 m (and higher) of ground surface, thus increasing the potential for local flooding. To be considered during the design of the NNI	Out (conditionally)	Not of safety significance but need to be monitored for the LTO operational period. Monitored as part of the groundwater monitoring programme.
Water Quality	In	Corrosion risk to foundations is considered to be low. Mild/carbon steel high corrosion rates should be expected. Because of the coastal environment, use of corrosion resistant	Out (conditionally)	Not of safety significance however a groundwater protection programme is being implemented to monitor corrosion risk to the foundations for the LTO operational period.

External Event	New Nuclear Installation		Koeberg Nuclear Power Station	
	Screening Result	Comment	Screening Result	Comment
		materials must be considered in the NNI design.		
Collapse, Subsurface Movement or Uplift of the Site Surface	Out	The event is of equal or lesser damage potential than the events for which the NNI is planned to be designed.	Out	The event is of equal or lesser damage potential than the events for which the plant is designed. Incorporated into the design.
Soil Liquefaction	In	Liquefaction risks to be taken into consideration in design and construction of a new nuclear installation(s). Same method could be used as was used for KNPS to eliminate liquefaction potential.	Out	Liquefaction potential was eliminated for the KNPS nuclear island using cement stabilised soils during construction.
Slope Instability	Out (conditionally).	The event is of equal or lesser damage potential than the events for which the NNI is planned to be designed. To be considered during construction of NNI.	Out	The event is of equal or lesser damage potential than the events for which the KNPS is designed. Incorporated into the design.
Behaviour of Foundation Materials	Out (conditionally).	The event is of equal or lesser damage potential than the events for which the NNI is planned to be designed.	Out	Not applicable to KNPS
Meteorological events: - wind field parameters, including wind speeds and gusts - air temperature, including dry-	Out	The event is of equal or lesser damage potential than the events for which the NNI is planned to be designed. The event has a significantly low mean	Out (conditionally)	F3-F4 does not occur on the site Hurricane force winds and tornadoes were not considered in the original design for KNPS. Events

External Event	New Nuclear Installation		Koeberg Nuclear Power Station	
	Screening Result	**Comment**	**Screening Result**	**Comment**
and wet-bulb temperatures - rainfall - lightning - blizzards - barometric pressure - corrosivity potential - tornadoes - atmospheric turbulence - prolonged inversions - snowfall - lightning - thunder - hail - frost - fog - relative humidity - solar radiation - evapotranspiration		frequency of occurrence when considering regulatory target safety goals, taking into account the uncertainties in the estimates, where available data permit.		have very low frequency of occurrence.
Hydrological events: - flooding from the sea; - extreme low water levels; - thermal plume dispersion and recirculation;	In	Tsunami risk and storm-surge are significant hazards that must be considered in the design of the NNI. Terrace to be located above the PMT. Coastline erosion is identified as a	Out (conditionally)	Although the Tsunami risk resulting from a volcanic flank collapse indicate a Probable Maximum Tsunami (PMT) higher than the current terrace level, further

External Event	New Nuclear Installation		Koeberg Nuclear Power Station	
	Screening Result	Comment	Screening Result	Comment
- extreme seawater temperatures; - sedimentation and scour; - erosion from the sea; - landslide into water		significant hazard that will need to be taken into account in the design of the NNI.		analyses have shown that the frequency is lower than 1E-5 which does not affect the design of the plant. Coastline erosion is evolving very slow and it is monitored as part of the engineering programme.
Biological Phenomena and Related Events	Out (conditionally)	The event is of equal or lesser damage potential than the events for which the NNI is planned to be designed. NNI intakes could be designed to cope with the marine species found at the site and to minimise the risk of complete blockage of the intake. It has to be confirmed that design and management measures will be adequate in respect of the ultimate heat sink when the NNI becomes available.	Out (conditionally)	The potential impact of marine organisms on the cooling water supply can be dealt with through appropriate design and management measures. Monitoring required. Eskom has developed process and procedures to deal with this phenomenon.
External Flooding from Terrestrial Sources: - failure of human-made water	Out	The event cannot occur close enough to the NNI to affect it. The event is included in the definition of	Out	The average vulnerability and safety consequences are low.

External Event	New Nuclear Installation		Koeberg Nuclear Power Station	
	Screening Result	Comment	Screening Result	Comment
retaining structures (e.g. dams) - changes in the natural channel for a river (including river diversions) - waterspouts - snow melt		another event.		
On-site hydrology aspects (e.g. surrounding ponding areas)	In	The recommended terrace and other platform levels for the nuclear installation(s) would need to be considered during the detailed design phase.	Out	The majority of run-off occurs along drainage lines and temporary ponds within the low-lying areas.
Loss of Freshwater Supply	Out (conditionally)	A design specification for stored water volume to compensate for a loss of fresh water supply will be required for the nuclear installation design. The event is of equal or lesser damage potential than the events for which the NNI is planned to be designed.	Out	Although KNPS has a guaranteed supply of fresh water for the period of LTO, the drought experienced from 2015 to 2018 highlighted the need for alternative fresh water supply. Risk is however low.
External Fires	In	Mitigation against the occurrence of veld fires resulting in air pollution is included in nuclear installation design of ventilation systems. The event is therefore considered to be	Out	Mitigation against the occurrence of veld fires resulting in air pollution is included in nuclear installation design of ventilation systems.

External Event	New Nuclear Installation		Koeberg Nuclear Power Station	
	Screening Result	Comment	Screening Result	Comment
		of equal or lesser damage potential than the events for which the NNI is planned to be designed. However, site specific mitigation measures are required and until these measures are in place, the event is screened in.		
Aircraft Crash	Out (conditionally)	Confirm deterministic approach followed for future selected GEN III NNI for beyond design basis aircraft.	Out	Risk is considered low. Core damage frequency and large early release frequency within regulatory limits
Hazardous Materials –Land-Based Stationary and Transport Sources	Out (unconditionally but only for off-site hazardous materials. 'In' for on-site hazards until construction licence confirms screening status)	Hazardous material volumes and locations during NNI construction and their final storage during operation of the NNI have to be assessed in the next licensing phase.	Out	Hazardous materials are screened out due to screening distance.
Hazards from Nearby Shipping Routes	In	A ship transport accident has to be considered as a design basis external event for the purpose of the design of	Out	Event unlikely to occur

External Event	New Nuclear Installation		Koeberg Nuclear Power Station	
	Screening Result	Comment	Screening Result	Comment
		the NNI seawater intake and outlet structures as well as operating mitigation procedures.		
Loss of Off-Site Power	In	The site specific mean frequency and length of interruption to the main grid transmission lines has to be provided for the site when more detail on the grid, its interaction with the site and NNI design become available.	Out	The loss of off-site power is mitigated through emergency diesel mobile generators purchased following the eternal event review where the risk of an extended loss of off-site power was identified.
Electromagnetic Interference (other than solar storms)	Out (conditionally)	The event is of equal or lesser damage potential than the events for which the nuclear installation(s) is planned to be designed.	Out	The event is of equal or lesser damage potential than the events for which KNPS is designed.
Extra-Terrestrial Events including solar storms	Out	Event is less likely to happen.	Out	Event is less likely to happen.

CONTENTS

TABLES

APPENDICES

6 EVALUATION OF EXTERNAL EVENTS

6.1 Introduction

The National Nuclear Regulator (NNR) Regulations on Licensing of Sites for New Nuclear Installations (Department of Energy, 2011) define EEs as, *"events not associated with the operation of the nuclear installation(s) that could have an effect on the safety of the installation(s).*" The International Atomic Energy Agency (IAEA) (IAEA, 2019) similarly defines these events as events that originate either off the site or within the boundaries of the site but from sources that are not directly involved in the operational states of the nuclear installations.

Events external to a nuclear installation which could challenge nuclear safety have to be identified and evaluated for the site. The site characteristics and the design and operation engineered safety features of a nuclear installation must ensure acceptable nuclear safety in respect of external events (EEs) through compliance with regulatory safety criteria.

This chapter of the DSSR focuses on EEs (both naturally and man-made) important to the design and safety of the existing facility, Koeberg Nuclear Power Station (KNPS) and the proposed new nuclear power plant (NNI).

For the existing facility, the site characteristics including EEs are comprehensively investigated to identify changes in hazards that may potentially impact the current design and licensing basis (such as the SAR, design basis, etc.) of KNPS in support of the Period Safety Reviews as well as the Long Term Operation (LTO). Although EEs are identified and evaluated in the DSSR, the assessment of the expected impact of each hazard and the potential propagation mechanism and predicted effects on the installation does not form part of the scope of the DSSR. The DSSR does however provide a summary of those hazard that may require further attention in terms of the Koeberg design and licensing basis and the design consideration for NNI.

6.2 Purpose and Scope

The purpose of this chapter is to provide a summary of EEs from detailed information presented in ***Chapter 5*** (Site Characteristics) and to identify those EEs that may require further attention in the design and operation of the existing facility (KNPS).

For the proposed NNI, the main purpose is to summarise the information on EEs and to perform a preliminary screening of those events identified in ***Chapter 5*** against the Plant Parameter Envelope (PPE) criteria for NNI. This is the initial step in determining to what degree a NNI may be impacted by the identified hazard and to identify potential implications on the standard designs of the potential NNI against the PPE. The complete analysis of how EEs can interact with the SSCs of an NNI will be carried out in the next licensing phase involving the specific NNI design.

It is important to note that the PPE criteria were specifically developed for purposes of a nuclear installation site licence (NISL) for an NNI of GEN III PWR technology and do not apply to KNPS.

Considerations relating to the physical protection of the nuclear facilities against wilful actions by third parties are outside the scope of this chapter and are addressed in the relevant security documentation for the station, as such information is classified and cannot be presented in this SSR.

A separate screening exercise is done for KNPS purposes because of the difference in design basis and PPE between KNPS and a GEN III NNI.

6.3 Regulatory Framework

The regulatory requirements relevant for the evaluation of external events are stipulated in the following two documents:

- R.388, Safety Standards and Regulatory Practices (Department of Minerals and Energy, 2006);
- The Regulations on Licensing of Sites for New Nuclear Installations, No.R.927 (Department of Energy, 2011).

In terms of Regulations on Safety Standards and Regulatory Practices (SSRP) (Department of Minerals and Energy, 2006), section 3.4 requires that a installations having impact on radiation or nuclear safety must be design, built and operated in accordance with good engineering practice. Section 3.8 of the regulations requires that where a prior safety assessment or operation safety assessment has identified reasonable possibility of a nuclear accident, accident prevention and mitigation measures based on a principle of defence in depth must be established, implemented, and maintained.

Defence in depth is provided by an appropriate combination of specified systems and measures, one of which is "Adequate site selection and the incorporation of good design and engineering features providing safety margins, diversity and redundancy" (IAEA, 2015). The Regulations in (Department of Energy, 2011) that are specifically relevant to EEs included in ***Chapter 6*** are:

"4(5) Natural phenomena and potential man-made hazards must be appropriately accounted for in the design of the new nuclear installation(s), and that adequate emergency plans and nuclear security measures can be developed."

"5(3) The characteristics of the site relevant to the design assessment, risk and dose calculations, including inter alia:

(a) external events;

(b) meteorological data;

(c) land use;

(d) population demographics;

(e) regional development;"

6.4 Regulatory Position Papers, Guides and International Practice

The NNR documents relevant to the analysis of site-specific external events are as follows:

- NNR Position Paper PP-0009 - Authorisations for Nuclear Installations, Rev 0 (NNR, 2012). It defines siting as the process of selecting a suitable site for a nuclear installation(s), including appropriate assessment of site characteristics/hazards and definition of the related site parameter envelope. The external hazards must be appropriately characterised to address all safety issues and the site parameter envelope has to be adequately quantified considering the impact and risk to the public from all nuclear installations planned on the site and in the vicinity of the site.
- NNR Position Paper PP-0014 - Considerations of External Events for New Nuclear Installations (NNR, 2014). The purpose of this document is to outline considerations for conducting site investigations for evaluation of

hazards related to external events. It discusses the derivation of target safety goals which are required when establishing the design basis parameters for the design of nuclear installations against external events using the performance-goal based approach. It clarifies the NNR position on the selection of design basis hazard levels applicable to new nuclear installations.

- NNR Interim Guidance RG-0011 for the Siting of Nuclear Facilities (NNR, 2016). This document provides guidance on the implementation of the regulatory requirements as contained in the draft General Nuclear Safety Regulations, the draft Specific Nuclear Safety Regulations for Nuclear Facilities and the draft Nuclear Security Regulations as it pertains to the siting of nuclear facilities (these regulations have not been published yet but are available to be referenced in respect of specific regulations in them).

Relevant international standards and recommendations for the identification, categorisation and analyses of external events consulted include but is not limited to the following:

- International Atomic Energy Agency (IAEA) Specific Safety Requirements No. SSR-1, Site Evaluation for Nuclear Installations (IAEA, 2019):
    - Potential external hazards associated with natural phenomena, human induced events and human activities that could affect the region shall be identified through a screening process.

The compliance for the various EEs external event technical input and results against guidelines and regulations are provided in the ***Chapter 5*** sections.

6.5 Approach to the Screening of External Events

The two main categories of external events are:

- of natural origin, e.g. geological, meteorological, hydrological events affecting the nuclear installation.;
- of human-induced origin, e.g. industrial and transportation accident affecting the nuclear installation.

The hazard parameters characterising the external events are evaluated, e.g. mean wind speeds at different annual probabilities or the peak pressure from an hazardous material explosion. Expected changes in external hazards during the lifetime of the nuclear installation(s) are taken into account (e.g. climate change), based on current knowledge and understanding of the site characteristics and the sources of external events.

The objective of the screening is to identify those EEs that may have an impact on the suitability of the site for the construction, licensing and operation of a new NNI. The screening also identifies those EEs for which the design of the NNI will need to be checked or special considerations made in terms of the design and safe operation of the installation. The information can be used to support the safety analysis for for design basis external events and beyond design basis external events.

A graded approach is applied in identifying the hazard. The EEs screened and evaluated are based on the list of EEs included in (Eskom, 2023). These EEs were selected based on consideration of a comprehensive list of EEs included in ***Appendix 6-C: Additional Information on External Events and Screening***

The site specific information for each EE is summarised based on the detailed information in the relevant sections of ***Chapter 5***.

The EEs relevant to the site and nuclear safety were identified using the following main steps:

- establish a comprehensive list of EEs that require consideration in the siting and design of the power plant; identify any external hazards unique to the site and add potential events that can arise from these hazards to the list of EEs; assess available data collected on the natural aspects of the site, e.g. geology, meteorology, oceanography and identify natural hazards; collect all relevant data (site specific and generic) in order to identify human induced events, phenomena and mechanisms associated with potential stationary[1] and mobile[2] sources of hazardous materials, industries and other human activities;

- perform an initial screening of the EEs and identify those relevant to the site (e.g. an avalanche is not relevant to the site); EEs not relevant to the site are screened out;
- evaluate EEs not screened out; evaluate means the process of determining hazard parameter values as a function of return periods/annual probability of exceedance for natural events or annual occurrence frequencies for human induced external events/accidents;
- for NNI and existing facilities, compare the EEs to determine:

  – the suitability of the site; EEs may be screened out using the criteria in ***Section 6.7***.

  – identify those EEs for which the nuclear installation design will need to be checked/confirmed;

  – identify those EEs for which special consideration will need to be taken and/or design mitigation implemented on the site; EEs screened in.

For new NNI, the potential impact on the design is assessed against the PPE, whereas for existing facilities, the potential impact is assessed (where necessary) against the existing design basis of the licensed facility. Information on EEs screened out is not discarded and will be used when the NNI specific design is assessed against NNR deterministic and risk licensing criteria during the next licensing phase. A major part of the process of licensing of an NNI is the safety analysis of the specific design that has to account for EEs screened in. It involves the application of methods of deterministic and probabilistic analysis. It establishes and confirms the design basis for the items important to safety and demonstrates that the design can meet the prescribed and acceptable limits for radiation doses and releases for each plant condition category (normal operation, anticipated operational occurrences and accidents), and that defence in depth has been achieved. Both the deterministic and probabilistic safety analysis

[1]Sources of external human induced events, for which the location of the initiating mechanism (explosion centre, point of release of explosive or toxic gases) is fixed, such as chemical plants, oil refineries, storage depots and other nuclear facilities at the same site **(IAEA, 2023)**.

[2]Sources of external human induced events, for which the location of the initiating mechanism is not totally constrained, such as any means of transport for hazardous materials or potential projectiles (by road, rail, waterways, air, pipelines). In such cases, an accidental explosion or a release of hazardous material may occur anywhere along a road or other way or pipeline **(IAEA, 2023)**.

processes will require the definition of a set of Postulated Initiating Events (PIEs) which includes EEs.

Although EEs are identified and evaluated in the DSSR, The DSSR does however provide a summary of those hazard that may require further attention in terms of the Koeberg design and licensing basis and the design consideration for NNI.

For KNPS, the information on EEs is used to assess if there are changes to the existing design basis. The assessment of the impact of the changes to each hazard and the potential propagation mechanism and predicted effects on the installation does not form part of the scope of the DSSR.

6.6 Approach to the Evaluation of External Events

6.6.1 External Events of Natural Origin

EEs are evaluated by analysis of available data for the site and determining event frequency statistics. These statistics are return periods and annual probabilities of exceedance of hazard parameter values characteristic of the EE severity, e.g. wind speed, or depth of flooding. The statistical data were prepared as part of ***Chapter 5***. Data are provided for very low return periods for some of the natural hazard parameters (return periods of 1E08 years). There is, however, general agreement that the uncertainty in the data for natural hazards may prevent reasonable prediction of events for frequencies lower than one in 1E04 years (IAEA, 2006). The target frequency for the design basis EEs (DBEEs) of the proposed NNI will be decided with due consideration of the NNR position paper on EEs for new nuclear installations (NNR, 2014). It must be noted that the return period of up to 1E08 years does not necessarily imply that the plant design should be assessed against such a return frequency. The requirements relevant to the design of nuclear power plants are established in SSR-2/1 (IAEA SSR-2/1 , 2016).

Where possible, investigation of EEs considered the return periods of hazard parameter values and the duration of exposure of the nuclear installation to the hazard considering the lifetime of the installation.

Return period is defined as the average time between consecutive events of the same or greater severity. A given event of return period, T, is generally assumed equally likely to occur any year, thus the probability of that event being exceeded in any one year is 1/T. The annual probability of exceedance, P, of an event is the reciprocal of the return period of that event (i.e., P ~ 1/T). For an event with return period, T, and annual probability of exceedance, P, the exceedance probability, P_E, over design life, n years, is calculated as follows (U.S. DOE, 2012):

$$P_E = 1- (1-P)^n$$

$$= 1-(1-1/T)^n$$

$$\approx 1-e^{-n/T}$$

P_E and P vary from 0 to 1, and n and T are expressed in years.

As an example, consider a typical design life of 60 years and a 24-hour rain event with a return period of 100 years. In this case, the annual probability of exceeding e.g. 192 mm rain in 24 hours is 45 per cent. This calculation can be repeated for the final NNI design to be selected for the site and its safety assessment, should its design life be different to 60 years, e.g. 80 years.

6.6.2 Human-induced External Events

Human-induced EEs are considered accidental events (e.g. oil spills and hazardous material explosions). Two methods are used to evaluate human induced events:

- The EE can be assessed deterministically by evaluating the consequences should the event take place. An example is an explosion as a result of hazardous materials at industrial facilities at a fixed distance from the nuclear installation and the resulting pressure pulse as a function of distance. A screening distance value (SDV) for such an event can then be calculated beyond which no damage to the nuclear installation will occur. If there is no hazardous installation located inside this distance, the event can be screened out.
- When the concept of SDV cannot be applied, an event can be evaluated probabilistically by determining the annual occurrence frequency, e.g. an accidental aircraft crash or a ship accident (oil spill) that could impact the cooling function of the installation. A screening probability value (SPV) can then be applied.

6.7 Screening Criteria

Screening in respect of EEs for was carried out in DSSR Rev. 0 on the basis of (ANS, 2007). The criteria are listed together with the corresponding numbered NNR criteria in (NNR, 2014) and written in italic:

- Criterion 1 - the design basis event is of equal or lesser damage potential than the similar hazard for which the plant has been for.

  (2) A phenomenon which in itself has no significant impact on the operation of a nuclear power plant and its safety assessment.
- Criterion 2 - the event cannot occur close enough to the installation to affect it.

  (*4) in case of NNI, locate the nuclear power plant sufficiently distant from the postulated phenomenon to mitigate its effects.*
- Criterion 3 - the event is included in the definition of another event.

  (5) A phenomenon which is included or enveloped by design for another phenomenon. For example, storm surge and seiche are included the probable maximum tsunami[3]*; toxic gas is included in pipeline accident or industrial or military facility accident.*
- Criterion 4 - the event has a significantly low mean frequency of occurrence when considering regulatory target safety goals, taking into account the uncertainties in the estimates, where available data permit.

  (3) A phenomenon which by itself has a probability of occurrence less than the 10^{-8} per year (event sequence frequency).

- Criterion 5 - the event is slowly developing and it can be demonstrated that there is sufficient time for measures to eliminate it or to provide adequate response. *(1) A phenomenon which occurs slowly or with adequate warning with respect to the time required to take appropriate protective action*.

The potential evolution of a hazard during the lifetime of the installation was also considered in the screening of EEs for the site. Examples are the anticipated evolution of human activity around the site and climate change (e.g. effect on sea level rise).

[3] **Note that lake flooding is not applicable to NNIs at coastal sites such as Duynefontyn.**

Hazards shall be considered in designing the layout of the plant and in determining the postulated initiating events and generated loadings for use in the design of relevant items important to safety for the plant. Screening criteria are applied with caution during the assessment of the suitability of the site for a NNI since the layout and detailed design of the installation(s) to be built are not available at this stage. Some events can be screened out *unconditionally* and should not require additional consideration as a potential DBEE. There are events that are screened out conditional to confirmation when assessing the detailed nuclear installation design. A screening status is therefore assigned to each event as follows:

- screened ***out unconditionally*** (e.g. on the basis of an SDV*);*
- screened ***out conditionally*** (a measure of uncertainty exists, and design confirmation required);
- ***screened in*** (design mitigation is required or the site is potentially excluded; also refer to ***Section 6.8***).

The NNR introduced the concept of Target Safety Goal (TSG) (NNR, 2014) which can be used to establish design basis parameters for the design of nuclear installation(s) against external events such as non-seismic events (seismic events have a specified PPE aligned with internationally accepted return periods). In order to meet the core damage frequency design basis Safety Goal limit with sufficient margin, the licensee needs to aim for a more conservative Target Safety Goal as follows:

- TSG_{CDF} = 5E-6 pa,

To meet the Large Early Release Frequency (LERF) Safety Goal, the licensee needs to aim for a more conservative Target Safety Goal of:

- TSG_{LERF} <1E-06 pa.

It could also be used to calculate the combination of the design factors and the mean hazard exceedance probability value required to achieve a set safety goal subject to NNR acceptance.

When it is not possible to relate a safety goal to an EE hazard parameter exceedance probability (for example when the risk equation for the event sequence does not exist) then the following applies. The design basis parameter value is obtained from the hazard curve by making a conservative assumption that the exceedance probability is at least equal to the safety goal for design basis events (1E-05/y) plus margin, and therefore 5E-06/y. However, the interim guide on safety assessment of nuclear facilities (RG-0019) (NNR, 2016) categorizes events with an occurrence frequency equal to or greater than 10E-5 per year as a Design Base Condition.

An event screened out in terms of design basis considerations for the proposed NNI may still require detailed consideration in the assessment of the NNI in scenarios related to normal operation, anticipated operational occurrences, design basis and beyond design basis events in particular when combinations of events are assessed, even if the EEs individually meet the PPE limiting values. This information will also be required when performing probabilistic safety analysis (PSA) of the detail design of the installation. Examples of screening criteria used in PSA analyses of a specific design are listed in ***Table 6-1*** (ANS, 2007).

Table 6-1: PSA Screening Criteria

Screening Criterion No.	Description
1	The current DBEE has a mean frequency $<10^{-5}$/y, and the mean value of the conditional core damage probability (CCDP) is assessed to be $<10^{-1}$.
2	The core damage frequency, calculated using a bounding or demonstrably conservative analysis, has a mean frequency $<10^{-6}$/y.
3	Screen out events of which the frequency is so low that elimination of the event will not modify the risk profile.
4	The risk contribution of the event is minor and acceptable.
5	A bounding analysis of the core damage frequency/fuel damage frequency due to the external event yields a result $< 10^{-9}$ per year.

6.8 Site Exclusion Criteria

Exclusion criteria represent requirements that, if not satisfied by site conditions, would preclude a site licence for greenfield sites or the potential termination of an operating licence for a site with an existing NI. They are used to eliminate sites based on consideration of go/no-go situations (EPRI, 2015).

A site is excluded when design solutions cannot be found for EEs screened in, i.e., a nuclear installation design basis will not meet NNR principal safety criteria and Eskom PPE criteria. The exclusion of a site includes results of measurement against evaluation requirements in (IAEA, 2019) and which are the following:

- Where reliable evidence of capable faults that has the potential to challenge the safety of the nuclear installation in terms of ground motion and/or fault displacement hazards and for which no practicable engineering solution is available.
- The presence of features that can cause permanent ground displacement such as fault displacement and settlement or subsidence, swelling soils and shale, or other hazards including underground cavities, landslides, or periodic flooding that may make engineering design difficult and may require extensive additional investigations.
- The potential for soil liquefaction is found to be unacceptable unless practicable engineering solutions are demonstrated to be available.
- Hazards due to volcanic activity that have the potential to affect the safety of the nuclear installation and for which no practicable engineering solutions are available.
- Extreme and rare meteorological hazards: Extreme meteorological hazards and their possible combinations that have the potential to affect the safety of the nuclear installation and for which no practicable solution is available.
- Hazards due to flooding, considering natural and human induced events including their possible combinations, with the potential to affect the safety of the nuclear installation and for which no practicable solution is available.
- Other natural phenomena that are specific to the region and which have the potential to affect the safety of the nuclear installation unless practicable engineering solutions exist.
- Activities that involve the handling, processing, transport and storage of chemicals having the potential for explosions or for the production of gas clouds capable of deflagration or detonation that take place in the site vicinity and for which there are no practicable solutions available.
- If the effects of release of flammable, explosive, asphyxiant, toxic, corrosive or radioactive materials store, processed, transported and otherwise dealt with in the site region would produce an unacceptable hazard for which no practicable solution is available.

- If there are installations in the site region that may give rise to missiles of any type that could affect the safety of the nuclear installation and the effects of these occurrences would produce an unacceptable hazard and if no practicable solution is available.
- The potential for accidental aircraft crash hazards is unacceptable and if no practicable solutions are available.

6.9 External Events Evaluation and the Eskom PPE

The evaluation of the EEs and their screening status are reported in ***Sections 6.10*** to ***6.12***. The PPE values specified by Eskom (Eskom, 2023) are included in Appendix 6-D.

6.10 Events of Natural Origin

6.10.1 Geological Events

6.10.1.1 Earthquake Induced Ground Shaking and Surface Faulting

Seismic hazard assessments for the Koeberg/Duynefontyn site were performed in the 1970s and ‘80s as part of the siting, design and licensing of the Koeberg Nuclear Power Station (Dames & Moore, 1981). These studies established the seismic design basis for the site; namely a standard US design spectrum shape anchored to a peak ground acceleration (PGA) of 0.3g. Subsequent studies (Council for Geoscience, 2004) confirmed the validity of Koeberg seismic design basis.

The geological, seismological and geotechnical studies performed as part of the KNPS studies found no indications of surface rupture associated with the Duynefontyn site (Settler, 1999). Subsequent studies (Council for Geoscience, 2004) also failed to locate evidence for surface rupture, or tectonic structures that could result in surface rupture. If Eskom should construct an NNI on the site, confirmatory bedrock mapping will be performed to confirm that the probability of surface rupture is as low as indicated by the earlier studies.

Considering advances and knowledge and understanding of EEs and changes to regulatory requirements, Eskom performed confirmatory studies which included a Probabilistic Seismic Hazard Analysis (PSHA), performed in accordance with the enhanced Senior Seismic Hazard Analysis Committee (SSHAC) level 2 guidelines to evaluate the overall seismic impact on the plant (Council for

Geoscience, 2024). The SSHAC study results shows the design basis spectrum is at 0,36 g as opposed to the original 0.3g.

Koeberg also conducted an Interim Seismic evaluation. This evaluation can be considered unaffected by the results of the SSHAC studies in so far as the exceedance at higher frequency is concerned.

For the existing facility, additional work may be required to assess the impact. This may include seismic PSA and Seismic Margin Assessment.

The new spectrum needs to be considered in the design of the new NNI and confirmatory bedrock mapping need to be performed before construction to confirm that the probability of surface rupture is as low as indicated by the earlier studies.

Screening Status: In for both KNPS and NNI

6.10.1.2 Volcanism

Volcanic events are infrequent, relative to most other natural events that can affect the safety and performance of a nuclear installation. Some volcanoes have erupted after lying dormant for thousands of years, or even longer. As a general guide, volcanoes that have erupted during the past 10 000 years are usually considered active (IAEA, 2012). The preliminary information and the initial assessment of the potential volcanism in the site region (see ***Section 5.13***, Geology) indicate that volcanism occurred in the region more than 10 million years ago.

Volcanic hazards arise from phenomena that have broad ranges of physical characteristics. Volcanoes located hundreds of kilometres from a site can cause hazardous phenomena, such as tephra fallout and tsunamis, which may adversely affect the safety and performance of a nuclear installation. The scope of ***Section 5.9*** (Oceanography and Coastal Engineering) included the hazard due to volcanoes beyond the site vicinity. Volcanoes formed part of a preliminary source characterisation model that was developed for use in screening of possible tsunami sources that could potentially lead to consequential flooding of the Duynefontyn site. The following potential tsunamigenic sources were evaluated:

- far-field earthquake (teleseismic subduction-zone) sources;

- far-field volcanogenic sources;
- near-field fault sources;
- submarine slumps/slides directly adjacent to site and on the continental slope.

The focus in respect of volcanoes was on edifice or flank-collapse resulting in a tsunami risk which is addressed under Section 6.10.4. The results have shown that risk associated with volcanic flank collapse is less than 1E-5.

Screening status: Out for both KNPS and NNI

6.10.1.3 Groundwater Level and Quality

6.10.1.3.1 Aquifers

A thorough understanding of the groundwater at the site and its potential effects on the foundations of the NNI has been obtained through the detailed site groundwater investigations (***Section 5.11***, Geohydrology). These show that there are two aquifers present: an upper intergranular, unconfined Sandveld Aquifer and an underlying semi-confined, fractured rock Malmesbury Group Aquifer. The former is a productive aquifer comprising an upper sand layer grading into sand with shell fragments and then a lower pebbly-sand grading into gravels. The latter comprises interbedded phyllites and impure sandstones, with an upper weathered zone comprising of clay.

6.10.1.3.2 Water levels

Depth to groundwater in the Sandveld Aquifer at the illustrative footprint for the NNI varies between *c*.2 and 4 m below ground level (bgl). The overall average water level variation in this aquifer is *c*.1 m.

Distinct high rainfall events in August 2008, December 2009, June 2013, and August 2013 show individual peaks in water level rise indicating high rainfall events will affect water levels on site and indicate a rapid response to recharge, as would be expected in areas with a shallow unconfined water table. The average wet-dry season water level variation is *c*.0.6 m.

It is predicted that global warming will cause a future increase in sea levels worldwide. Modelling of potential sea level rise at the site has indicated a possible rise in sea level of about 2.0 m by 2100, with an additional 15 per cent added for regional variation giving 2.3 m. The results of a modelling scenario which assumes long-term steady state sea level rise (to 2.3 m) and one year of high rainfall (of *c*.1 494 mm/a, based on the 1E-08/y probability), indicates that groundwater levels at the site could rise to a maximum of 4 to 5 m above current levels. This would bring the groundwater in many of the lower-lying parts of the site to within 1 m of ground surface, thus increasing the potential for local flooding. However, it is assumed that the nuclear terrace for NNI will be raised above the natural ground level to safeguard against such flooding and, *inter alia*, flooding by tsunamis, storm surges and abnormally high tides.

In the Malmesbury Aquifer, a maximum variation of *c*.1.5 m in groundwater level over the 12 years of monitoring has been recorded. Seasonal wet-dry water level variation, however, is on average *c*.0.5 m. Depth to groundwater varies between 0.70 and 5.50 m bgl with an average maximum variation of c.1.30 m between the highest and lowest levels recorded. Depth to groundwater at the illustrative new nuclear installation footprint varies between *c*.0.70 and *c*.3.40 m bgl with a maximum variation of *c*.1.30 m between the highest and lowest levels.

6.10.1.3.3 Water Quality

Down-hole EC and pH profile logs in the Sandveld Aquifer indicate values of 86 to 195 mS/m and 7.1 to 7.6, respectively, i.e., low to moderate salinity and neutral to slightly alkaline. Chemical analyses of samples from this aquifer, between May 2008 and May 2020, over thirteen monitoring rounds, at the proposed nuclear power plant footprint show a dominant NaCl character and a mixture of NaCl and $Ca(HCO_3)_2$ character, typical of coastal aquifers. The Langelier Saturation Indices vary from 0.21 to 0.32, indicating that this groundwater is likely to cause scaling (some minor coating). Sulfate corrodes ordinary concrete when present in concentrations >200 mg/ℓ. The measurement results ranged from 44 to 77 mg/ℓ and the corrosion risk to foundations is therefore considered to be low.

The Larson-Skold corrosion indices for mild steel for groundwater sampled from boreholes in the Sandveld Aquifer range from 1.4 to 5.8, with a median of 2.6, which indicates that a tendency towards high corrosion rates should be expected.

The Malmesbury Aquifer shows chemical characteristics that are NaCl type and acidic to neutral pH. Langelier Saturation Indices for this aquifer vary from -1 to 0.46, indicating that the groundwater is likely to cause mild scaling. Sulfate concentrations range between 1.8 and 77 mg/ℓ. The Larson-Skold indices range between 3.6 to 144.8 (median of 5.1) which indicates that this water will be highly corrosive to steel components.

Given these indices and the coastal environment, use of corrosion resistant materials must be considered in a NNI design.

Groundwater level and quality monitoring has not shown any anomalous or concerning trends that could affect nuclear safety, apart from the need to cater for corrosive conditions in any construction below the water table. Groundwater is not anticipated to present aggressiveness risks to concrete, but corrosion risk to steel is high.

Screening status: In for NNI and Out (conditionally for KNPS)
Of no safety significance but need to take into consideration during construction and operation of an NNI. For KNPS, the effect of groundwater on the soil/cement base-mat at KNPS is monitored as part of a groundwater protection programme.

6.10.2 Geotechnical Events

6.10.2.1 Screening and Evaluation of Geotechnical Events

The final assessment of geotechnical events is dependent on engineering solutions and the specific nuclear installation design to demonstrate compliance with PPE and an acceptable design basis. The geotechnical events that were investigated and to be considered are discussed here.

6.10.2.2 Collapse, Subsurface Movement or Uplift of the Site Surface

The two main sources of collapse, subsurface movement or uplift of the site surface that need to be considered (IAEA, 2019), are:

- natural induced phenomena (e.g., caverns, quarries and karst formations);
- human induced phenomena (e.g., mines, boreholes/water wells and oil wells).

As presented in ***Section 5.15***, the site is underlain by Quaternary-age soils overlying rocks of the Tygerberg Formation of the Malmesbury Group. The bedrock is characterised by steeply dipping, interlaminated and bedded successions of greywackes, siltstones, and mudstones with a dominant strike north-northwest-south-southeast. These formations do not possess any physical attributes that could result in the natural development of subsurface voids (e.g., caves) and karst features (which develop in limestone/dolomite). Drilling programmes carried out on the site have not encountered any voids or karst features that could pose external hazards to the site.

The geotechnical profile presented in ***Section 5.15*** (Geotechnical Characterisation), ***Subsection 5.15.8.2***, lists the following features, which could be potentially hazardous to an NNI:

- previous use of the site (e.g. mining activities);
- gas pockets, and swelling rocks[4];
- zones of weakness or discontinuities in crystalline rocks;
- indicators of potential cavities and susceptibility to ground collapse in the context of:
  - sinks, sink ponds, caves and caverns;
  - sinking streams;
  - historical ground subsidence;
  - natural bridges;
  - surface depressions;
  - springs;
  - rock types such as limestone, dolomite, gypsum, anhydrite, halite, terra rossa soils, lavas, weakly cemented clastic rocks, coal or ores;
  - non-conformities in soluble rocks.

Information gathered to date from historical investigations and through intrusive investigations carried out for this SSR indicate that none of the above features are present on the site. To confirm this statement in the proposed NNI footprint area, the pre-operational and operational stages of the geotechnical investigation will specifically investigate the occurrence of these features on localised foundation footprints. There is, however, certainty that the features mentioned in the above two bullet points are not features characteristic of the Malmesbury rocks.

[4] However, interbedded shales are commonly encountered in the profile and these rocks are sometimes prone to weathering down to expansive clays

In addition, as the NNI is planned to be founded on (or in) bedrock (see ***Section 5.15***), no subsidence, collapse or uplift is anticipated at the site during the lifetime of the facility as minimum values of unconfined compressive strengths of the rocks measured at the site exceed the minimum required bearing capacity of the PPE (Eskom, 2023). Since foundations of any future nuclear facility on the site will be on bedrock level, excavations will be through overburden sand, hence no blasting or drilling will be required during excavation.

Once the position of any future nuclear installation is finalised, additional geotechnical investigations will be required through both intrusive (drilling) investigations and through detailed mapping of the exposed bedrock surface as was done for KNPS.

Mining activities within 16 km of the site, i.e., the site vicinity (see ***Section 5.7***, nearby Transportation, Industrial and Military Facilities, ***Subsection 5.7.9.4***) were considered to identify potential sources of human induced events. The site evaluation concluded that the only quarry situated within the site vicinity, located on the Ou Skip Road, east of Melkbosstrand (3.4 km south-southeast of the site, see ***Drawing D-5.7.6*** in ***Section 5.7***), is no longer operational. Beyond the site vicinity, additional quarries, sand mines and brickfields were identified. The identified quarries and sand mines have relatively small operations. These operations also tend to change location as sand and stone reserves at a particular locality are exhausted and new source become known. The occurrence of these activities therefore needs to be monitored over the lifetime of the nuclear installation(s).

Production boreholes/wells would have to be sited close to the NNI to have any possible effects due to drawdown of groundwater levels based on yield testing carried out on the site (***Subsection 5.11.6.2***). The Aquarius and Witzand wellfields are the closest groundwater abstraction areas to the site. Hydrographs of water level measurements in boreholes dating back to 1985 show no indication of significantly declining water levels. It is therefore apparent that groundwater levels have not been negatively impacted by abstraction from these two wellfields (***Subsection 5.11.9***).

There are no currently identified oil/gas fields or exploration areas in the site region.

Based on the current information about the site and the region, no collapse, subsurface movement, or uplift of the site surface, due to caverns, karst formations, mining, production boreholes and oil wells, is expected to occur during the lifetime of the NNI or the KNPS.

Screening status: Out for both KNPS and NNI

Criterion 1 - the event is of equal or lesser damage potential than the events for which the NNI is planned to be designed.

Criterion 2 - the event cannot occur close enough to the NNI to affect it.

6.10.2.3 Soil Liquefaction

Liquefaction is a phenomenon in which the strength and stiffness of a soil is reduced by earthquake shaking or other rapid (dynamic) loading. Liquefaction can occur most commonly in saturated sandy and silty soils. It is a consequence of a significant decrease in effective overburden pressure, i.e., the force between the soil particles decreases significantly because of an increase in pore pressure caused by e.g., an earthquake. A more technical definition is the sudden loss of shear strength in saturated, cohesionless soils induced by groundwater elevations and earthquake induced vibratory ground motion. Significant damage can occur to civil structures supported on soils that liquefy and liquefaction presents significant risks to slope stability. Liquefaction is not permitted on the nuclear installation terrace. The site is disqualified if liquefaction cannot be dealt with by engineering design.

It is important to note that the site is underlain by an intergranular aquifer dominated by poorly graded aeolian sand that exhibits erratic soil consistency in places and considering the seismic hazard (peak ground acceleration of 0.4 g and an earthquake magnitude of $M_{6.5}$ event) the potential for liquefaction exists across vast tracts of the site (see ***Subsection 5.15.6.6***). Current site data and analysis of these data lead to the following conclusions (see ***Subsection 5.15.13.4***):

- Wide distributions of soils investigated on the site have a high liquefaction potential with a notable exclusion being the KNPS nuclear island under which liquefaction potential was engineered out using cement stabilised soil when KNPS was constructed.
- Liquefaction risks relate to:
  - construction on the site potentially altering the groundwater table at the existing KNPS and changing the current liquefaction risks at that site;

   – construction of new installation(s) at the site.

- Liquefaction risks can be mitigated through robust dewatering systems and carefully designed soil improvement measures that has proved successful with the development of KNPS.

Screening status: In for NNI and out for KNPS

Liquefaction risks at the new NNI footprint to be considered in the design of the NNI. For KNPS, liquefaction potential is already considered in the design of the plant and monitored performance of the cement stabilised raft under KNPS indicates very good performance that screens liquefaction risk out for KNPS.

6.10.2.4 Slope Instability

Slope instability is a phenomenon resulting from steep slopes, high groundwater, and/or vibratory ground motion but not related to surface faulting. Slope instability can result in landslides and general earth movements that could affect the safe operation of the NNI. It could also hinder emergency response. Slope instability is not permitted at the site and must be dealt with by engineering design.

As presented in ***Subsection 5.15.7***, the site geotechnical profile consists of bedrock overlain by predominantly cohesionless aeolian sands that have an average thickness of 21 m. There is also an intergranular aquifer found near surface. Since the NNI is envisaged to be founded on (or in) bedrock, there is a possibility that approximately 21 m deep cut excavations will be required to reach the founding level. These cuts will require dewatering and stabilisation during construction of the NNI. The soils will also need to be battered back to safe angles considered to be in the region of 18° and will need to be devoid of groundwater before any confidence in slope stability for new nuclear installations can be argued.

Based on the current site data, sufficient detail exists to suggest that development of new nuclear installation(s) on the site will not present safety related challenges that cannot be mitigated by sound engineering.

Screening status: Out for KNPS and conditionally for NNI (to be considered during design and construction phase of NNI).

Criterion 1 - the event is of equal or lesser damage potential than the events for which the NNI is planned to be designed.

6.10.2.5 Behaviour of Foundation Materials

A minimum bearing capacity is required of the load bearing foundation materials to support the load exerted by nuclear installation plant structures. These loads will be determined during the detailed design of the NNI.

Extensive investigation of the site bedrock through field and laboratory investigations revealed that the site is underlain by steeply dipping (75˚), interlaminated and bedded successions of greywackes, siltstones, and mudstones with a dominant strike north-northwest-south-southeast (see ***Sections 5.13*** and ***5.15***). Inherent in these alternating successions is variability in weathering profile and thus rock bearing capacity. The PPE indicates that a minimum bearing capacity of approximately 720 kPa is required. The minimum unconfined compressive strength measured in the site rocks is 850 kPa, and the mean is approximately 77 MPa indicating that worst case scenario bearing strength of the rocks meets the PPE requirement, and the mean case exceeds this by orders of magnitude. Comparison of the general foundation soil characteristics requirements for an NNI and the currently available data for the site (see ***Table 6-2***) dictate building the nuclear installation foundations on (or in) the site bedrock.

Table 6-2: Soil Parameter Values

Soil	Parameter Values[5]	Site Values (see ***Section 5.15***)
Average allowable static soil bearing capacity	Greater than or equal to 8 600 lb/ft^2 (412 kPa) over the footprint of the nuclear island at its excavation depth. Minimum = 718.2 kPa under the nuclear island as per the PPE	Soils will not have bearing capacity >200 kPa even with mechanical ground improvements – desired bearing capacity in excess of this in soils will require cement stabilisation.

[5]**AP1000**

Soil	Parameter Values[5]	Site Values (see *Section 5.15*)
Average allowable static rock bearing capacity	Minimum = 718.2 kPa under the nuclear island as per the PPE	Bearing capacity in rocks will vary laterally because of the dipping sedimentary deposits. Bearing capacity ranges from 0.85 MPa to close to 409 MPa (mean 77 MPa)
Maximum allowable dynamic bearing capacity for normal plus safe shutdown earthquake (SSE)	Greater than or equal to 35 000 lb/ft2 (1.7 MPa) at the edge of the nuclear island at its excavation depth. PPE: ≥2 872.8 kPa at the edge of the nuclear island at its excavation depth	To be defined
Lateral variability	Soils supporting the nuclear island should not have extreme variations in subgrade stiffness. Case 1: For a layer with a low strain shear wave velocity greater than or equal to 2 500 ft/s (762 m/s), the layer should have approximately uniform thickness, should have a dip not greater than a value to be defined in a next phase of investigations, and should have less than 20% variation in the shear wave velocity from the average velocity in any layer. Case 2: For a layer with a low strain shear wave velocity less than 2 500 ft/s (762 m/s), the layer should have approximately uniform thickness, should have a dip	Lateral variability in shear wave velocity in excess of these values is a function of the rock weathering profile in the steeply dipping (70o) rock strata. Lateral variability is to be assessed when the foundation excavations are completed, and the bedrock exposed. Variability across the steeply dipping geological formations and/or transitions on site will be in excess of these values and spanning geological contacts and/or transitions zones is to be avoided. Should geological contacts and/or transition zones be avoided and weathered material removed from the founding strata, Case 1 has a higher probability of materialising and lateral variability in excess of 20% has a low probability of occurring.

Soil	Parameter Values[5]	Site Values (see ***Section 5.15***)
	not greater than 20º, and should have less than 10% variation in the shear wave velocity from the average velocity in any layer.	
Shear wave velocity liquefaction potential	Greater than or equal to 1 000 ft/sec (304.8 m/s) based on low-strain, best-estimate soil properties over the footprint of the nuclear island at its excavation depth. PPE: 304.8 m/s	The site soils have a mean Vs = 350 m/s ±130m/s. The variability inherent in the VS results in widespread liquefaction potential across the site that requires sound engineering design as was done for KNPS

Adequate bearing capacity of the founding rocks at the site does not present as much of a design challenge as the variability of these materials and the implications on differential bearing capacity. In the pre-construction stage, this variability will be explored in greater detail, i.e., upon exposure and mapping of the founding materials once overburden sands are removed – as was done for the KNPS.

Design of the foundations to accommodate variability exposed at this stage in the NNI project will not be unduly onerous based on the information gathered to date. It is unlikely to expect any safety related design challenges should the NNI foundation design be approached in a similar manner to that done at the KNPS.

***Screening status: Out for KNPS and Out conditionally for NNI*.**

Criterion 1 - the event is of equal or lesser damage potential than the events for which the NNI is planned to be designed.

To be taken into consideration during design of new NNI.

6.10.3 Meteorological Events

6.10.3.1 Evaluation of Main Meteorological Hazard Parameters

In accordance with international recommendations (IAEA, 2019) two main types of meteorological phenomena and events need to be evaluated in the site evaluation stage, i.e., extreme values of meteorological hazard parameters and rare meteorological phenomena, as follows (see ***Section 5.8***, Meteorology):

- extreme values of meteorological parameters (measurable) such as air temperature and wind speed that characterise the meteorological or climatological environment - These parameters are measured routinely over a network of fixed stations by international, national, local, or private meteorological services. These measurements are usually normalised (such as data collected on wind speed, which are normalised to a given height). The extreme parameter values and the annual probabilities of being exceeded are derived from the measurements.
- rare meteorological phenomena that occur infrequently (immeasurable)- At any particular station, the instruments used for routine measurements would rarely register characteristics of these phenomena. Rare meteorological phenomena, which are highly complex, are usually scaled in terms of their intensity. These intensity values may be expressed in terms of either a qualitative characteristic such as damage or a quantitative physical parameter such as wind speed.

All measurements and studies of meteorological conditions that have been performed for this SSR are presented and discussed in detail in ***Section 5.8***.

Results of meteorological investigations and measurements indicate that the site can potentially experience severe weather in the form of thunderstorms, hail, hurricane force winds and possibly tornadoes. Many of the severe storms occurring in the Western Cape are compound, producing various potential combinations of hail, wind, tornado, lightning and flash flooding. Damaging winds associated with severe thunderstorms include tornadoes, downbursts (macrobursts or microbursts), straight-line winds, gust fronts and derechoes[6].

The site region is not on a hurricane track or adjacent to a warm ocean. Therefore it is not expected that the site will experience a hurricane, or at least there is a very low probability. Tropical cyclones are generated in areas, where the ocean surface temperature is greater than 27°C and between latitudes 5°S to 30°S. The site is located at approximately 33°S and is therefore not subject to tropical cyclones.

The site is however said to experience hurricane force winds. Hurricane force winds refer to a wind speed scale described by the Beaufort Scale as winds with speeds above 118 km/h (32.8 m/s). This wind speed (as a gust) has been exceeded 5 times (1986, 1987, 1993, 1994 and 2022) over the 40-year monitoring period at the site. The hourly average has never exceeded this speed for the 40-year monitoring period. The highest gust of 38.8 m/s occurred during May 1987.

Hurricane force winds were not considered in the Koeberg Site Safety Report Rev. 0. The KNPS design basis wind for Class I buildings is 62.5 m/s (maximum 3 s gust) and for non-safety related buildings is 38.3 m/s (maximum mean hourly velocity) (**Appendix 6-F**). The actual measured extreme wind speeds at the site over the 40-year period have not exceeded the design basis wind speeds for Koeberg buildings. The IAEA Specific Safety Guide No. SSG-18 (IAEA, 2011), recommends using the 3 s gust wind speed at 10 m above the ground that has a 1 per cent annual frequency of exceedance (100 year mean recurrence interval) to specify wind loads. The Koeberg design basis wind speed (3 s gust) for Class I buildings at 62.5 m/s is only exceeded at a return period of 1E04 years and for non-safety related buildings at 38.8 m/s (maximum mean hourly velocity) at a return period of between 1E05 and 1E06 years.

Results of the meteorological evaluation investigations also indicate an increase in tornado activity within an 80 km radius from the site since 1987. Whilst climate change may have contributed to increases in tornado frequencies, it may also

[6] The term ‘derecho’ is used to describe larger scale straight-line winds advancing very quickly ahead of a well organised, long-lasting squall line or a large-scale multiple cell storm (refer to ***Section 5.8***)

simply be that the reporting of tornadoes has increased due to population spread as well as the associated damage to property. Tornadoes were not considered in the Koeberg Site Safety Report Rev. 0.

The tornado frequencies per severity is given in ***Table 6.4****Error! Reference source not found.* below. The results indicate that EF2 tornadoes have an expected probability above 1E-07 per year and EF3 tornadoes well below 1E-07 per year. Using the EF scale, the estimated maximum tornado wind speeds (3 s gust estimates) are between 61 m/s and 75 m/s.

Rainfall measurements at the site over the 40-year monitoring period indicates that the highest hourly, 24-hourly, monthly, and annual precipitation was 23.6 mm, 70.0 mm, 162.4 mm and 640.4 mm, respectively. The Koeberg design basis rainfall for safety related buildings is 200 mm/hr. The Koeberg design basis rainfall for safety related buildings has never been exceeded, even for a 24-hour storm.

The freeze-thaw phenomenon is not considered an issue at the site. Freeze-thaw occurs when concrete (or rocks) is saturated with water and the temperature drops, freezing the water molecules. The frozen water expands 9 per cent of its original volume. Whilst there are many theories (Guo, et al., 2022) as to the damage mechanisms in concrete, the simple view Is that the increase in volume produces increased pressure in the pores of the concrete. Tiny cracks will form where this pressure exceeds the tensile strength of the concrete. Increased frequency of freeze-thaw cycles will result in more stress on the concrete structure. However, besides the frequency of freeze–thaw cycles, the frost intensity should also play an important role. The frost intensity describes how long and to what extent the temperature falls below the 0°C transition. According to (Walder & Hallet , 1985), most of the damage potential can be assumed for a temperature of -10°C.

However, this temperature range has not been observed at the Duynefontyn site with the recorded lowest hourly average of 3.2°C. The 10 000-year return period projects a temperature below 0°C, i.e. -0.5°C. Even the projected 100 000 000-year return period estimate of -6.0 ± 3.4°C does not reach -10°C. The possibility of freeze-thaw from frozen water in the pores is therefore not likely at the site; estimated to be 1 in 10 000 years chance, and hence freezing thaw phenomenon is not an issue.

Additionally, regarding the possibility of ice occurring in the sea surrounding the site, the lowest seawater temperature measured in all the data sets described in ***Section 5.9*** is 8.12°C, and an extreme value analysis of the minimum measured temperatures at Site C (-3m msl) was above 0°C at an exceedance of 1x10-8 per year. On this basis ice is not anticipated to form in the sea at the site.

Table 6-3 and ***Table 6-4*** list the main results from ***Section 5.8*****.** Design basis and extreme values are based on the maximum values measured at the site.

Table 6-3: Meteorological Events and Hazard Parameter Data

Meteorological Parameter		Baseline	Climate Change Projections (Including 95% Confidence Intervals)			
			2044	2064	2110	2130
Annual Average		4.1	4.2 ± 0.2	4.3 ± 0.2	4.4 ± 0.2	4.5 -0.3+0.2
Hourly Maximum Wind Speed [m/s] (10 m above site ground level)	Extreme Observed & Projected	17.2	17.4 ±0.3	17.5 ±0.3	17.7 ±0.3	17.9 ±0.3
	10 Year Return	16.9 ± 1.0	17.3 ± 1.0	17.6 ± 1.0	18.3 ± 1.0	18.7 ± 1.0
	100 Year Return	21.6 ± 1.5	22.1 ± 1.5	22.5 ± 1.5	23.4 ± 1.5	23.9 ± 1.5
	1 000 Year Return	26.3 ± 2.2	26.9 ± 2.2	27.3 ± 2.2	28.4 ± 2.2	29.0 ± 2.2
	10 000 Year Return	30.9 ± 2.8	31.6 ± 2.8	32.1 ± 2.8	33.4 ± 2.8	34.1 ± 2.8
	100 000 Year Return	35.5 ± 3.5	36.4 ± 3.5	36.9 ± 3.5	38.4 ± 3.5	39.2 ± 3.5
	1 000 000 Year Return	40.2 ± 4.2	41.1 ± 4.2	41.7 ± 4.2	43.4 ± 4.2	44.3 ± 4.2
	10 000 000 Year Return	44.8 ± 4.8	45.8 ± 4.8	46.5 ± 4.8	48.4 ± 4.8	49.4 ± 4.8
	100 000 000 Year Return	49.4 ± 5.5	50.5 ± 5.5	51.3 ± 5.5	53.4 ± 5.5	54.5 ± 5.5
Wind peaks (**gusts**) [m/s] (10 m above site ground level)	Extreme Observed & Projected	38.8	39.2 -0.6+0.5	39.4± 0.6	40.0 ± 0.7	40.3 ± 0.7
	10 Year Return	33.8 ± 2.7	34.1 ± 2.7	34.2 ± 2.7	34.8 ± 2.7	35.1 ± 2.7
	100 Year Return	43.3 ± 4.8	43.7 ± 4.8	43.9 ± 4.8	44.6 ± 4.8	45.0 ± 4.8
	1 000 Year Return	52.7 ± 6.8	53.2 ± 6.8	53.4 ± 6.8	54.3 ± 6.8	54.8 ± 6.8
	10 000 Year Return	62.0 ± 8.9	62.6 ± 8.9	62.9 ± 8.9	64.0 ± 8.9	64.5 ± 8.9
	100 000 Year Return	71.4 ± 11.0	72.1 ± 11.0	72.4 ± 11.0	73.6 ± 11.0	74.2 ± 11.0
	1 000 000 Year Return	80.8 ± 13.1	81.5 ± 13.1	81.9 ± 13.1	83.3 ± 13.1	84.0 ± 13.1

Meteorological Parameter		Baseline	Climate Change Projections (Including 95% Confidence Intervals)			
			2044	2064	2110	2130
	10 000 000 Year Return	90.1 ± 15.2	90.9 ± 15.2	91.4 ± 15.2	92.9 ± 15.2	93.7 ± 15.2
	100 000 000 Year Return	99.5 ± 17.3	100.4 ± 17.3	100.9 ± 17.3	102.6 ± 17.3	103.4 ± 17.3
Ambient temperature [°C]	Mean daily maximum dry bulb temperature	20.1	21.1 -0.4+0.5	21.8 -0.4+0.5	23.7 -0.4+0.5	24.7 -0.4+0.5
	- coincident wet bulb temperature (a)	16.0	18.0 -0.3+0.1	18.3 -0.4+0.2	19.1 -0.5+0.2	19.4 -0.7+0.2
	Mean daily maximum wet bulb temperature (a)	16.2	18.2 -0.2+0.2	18.5 -0.2+0.4	19.3 -0.2+0.6	19.7 -0.3+0.6
	Extreme Observed & Projected dry-bulb maximum	38.8	39.8 -0.5+0.4	40.5 -0.5+0.4	42.4 -0.5+0.4	43.5 -0.5+0.4
	10 Year Return	37.5 ± 0.9	40.3 ± 1.8	41.1 ± 1.8	43.4 ± 2.0	44.5 ± 2.0
	100 Year Return	40.4 ± 2.0	42.6 ± 2.7	43.4 ± 2.8	45.6 ± 2.9	46.8 ± 3.0
	1 000 Year Return	43.3 ± 3.2	44.9 ± 3.7	45.7 ± 3.8	47.9 ± 3.9	49.1 ± 4.0
	10 000 Year Return	46.2 ± 4.3	47.1 ± 4.7	48.0 ± 4.8	50.2 ± 4.9	51.3 ± 4.9
	100 000 Year Return	49.1 ± 5.5	49.4 ± 5.7	50.2 ± 5.8	52.4 ± 5.9	53.6 ± 5.9
	1 000 000 Year Return	52.0 ± 6.7	51.7 ± 6.7	52.5 ± 6.8	54.7 ± 6.9	55.9 ± 6.9
	10 000 000 Year Return	54.9 ± 7.9	53.9 ± 7.7	54.7 ± 7.7	57.0 ± 7.9	58.1 ± 7.9
	100 000 000 Year Return	57.8 ± 9.0	56.2 ± 8.7	57.0 ± 8.7	59.2 ± 8.9	60.4 ± 8.9
	Maximum temperature of 3-hour duration (b)	37.0 Corresponding Wet Bulb Temperature 19.0	37.9 -0.5+0.3	38.6 -0.5+0.4	40.5 -0.6+0.5	41.4 -0.8+0.5

Meteorological Parameter		Baseline	Climate Change Projections (Including 95% Confidence Intervals)			
			2044	2064	2110	2130
	Maximum temperature of 6-hour duration (b)	36.1 Corresponding Wet Bulb Temperature 18.9	37.0 -0.5+0.3	37.7 -0.5+0.4	39.6 -0.6+0.5	40.5 -0.8+0.5
	Maximum temperature of 7-day duration (b)	18.5 Corresponding Wet Bulb Temperature 15.5	19.4 -0.5+0.3	20.1 -0.5+0.4	22.0 -0.6+0.5	22.9 -0.8+0.5
	Mean daily minimum dry bulb temperature	13.1	13.8 -0.3+0.3	14.2 -0.3+0.3	15.4 -0.3+0.3	16.1 -0.2+0.3
	- coincident wet bulb temperature (a)	11.5	12.9 -0.2+0.1	13.1 -0.2+0.1	13.7 -0.4+0.2	14.0 -0.5+0.2
	Mean daily minimum wet bulb temperature (a)	11.0	12.4 -0.1+0.2	12.6 -0.1+0.2	13.1 -0.2+0.4	13.4 -0.2+0.5
	Extreme Observed & Projected dry-bulb minimum	3.0	3.9 -0.5+0.4	4.6 -0.5+0.4	6.5 -0.7+0.6	7.5 -0.8+0.7
	10 Year Return	3.5 ± 0.5	3.4 ± 0.8	4.1 ± 0.8	5.8 ± 0.9	6.7 ± 0.9
	100 Year Return	1.6 ± 1.0	2.0 ± 1.2	2.7 ± 1.2	4.4 ± 1.3	5.3 ± 1.3
	1 000 Year Return	-0.2 ± 1.5	0.7 ± 1.6	1.3 ± 1.7	3.0 ± 1.7	3.9 ± 1.7
	10 000 Year Return	-2.1 ± 2.0	-0.7 ± 2.1	-0.1 ± 2.1	1.6 ± 2.1	2.5 ± 2.2
	100 000 Year Return	-3.9 ± 2.5	-2.1 ± 2.5	-1.5 ± 2.5	0.2 ± 2.6	1.1 ± 2.6
	1 000 000 Year Return	-5.8 ± 3.0	-3.5 ± 2.9	-2.9 ± 3.0	-1.2 ± 3.0	-0.2 ± 3.0

Meteorological Parameter		Baseline	Climate Change Projections (Including 95% Confidence Intervals)			
			2044	2064	2110	2130
	10 000 000 Year Return	-7.6 ± 3.5	-4.9 ± 3.4	-4.3 ± 3.4	-2.6 ± 3.5	-1.6 ± 3.5
	100 000 000 Year Return	-9.5 ± 4.0	-6.3 ± 3.8	-5.7 ± 3.8	-4.0 ± 3.9	-3.0 ± 3.9
	Minimum temperature of 3-hour duration (b)	4.5 Corresponding Wet Bulb Temperature 3.6	5.4 -0.5+0.3	6.1 -0.5+0.4	8.0 -0.6+0.5	8.9 -0.8+0.5
	Minimum temperature of 6-hour duration (b)	4.8 Corresponding Wet Bulb Temperature 4.0	5.7 -0.5+0.3	6.4 -0.5+0.4	8.3 -0.6+0.5	9.2 -0.8+0.5
	Minimum temperature of 7-day duration (b)	14.0 Corresponding Wet Bulb Temperature 12.1	14.9 -0.5+0.3	15.6 -0.5+0.4	17.5 -0.6+0.5	18.4 -0.8+0.5
Rainfall [mm]	Average Annual Total	372.4	318.3 -8.8+8.4	300.3 -1.7+12.5	254.7 -1.9+5.5	229.6 -1.1+0.6
	Extreme Annual Total	640.4	Projections indicate reduction. Worst-case assumption assumes same as baseline			
	Annual Re-occurrences:					
	10 Year Return	471.1 ± 45.3	Projections indicate reduction. Worst-case assumption assumes same as baseline			
	100 Year Return	611.9 ± 85.7				
	1 000 Year Return	750.1 ± 127.0				
	10 000 Year Return	888.1 ± 168.7				
	100 000 Year Return	1026.1 ± 210.5				

Meteorological Parameter		Baseline	Climate Change Projections (Including 95% Confidence Intervals) 2044	2064	2110	2130
	1 000 000 Year Return	1164.1 ± 252.4				
	10 000 000 Year Return	1302.1 ± 294.4				
	100 000 000 Year Return	1440.1 ± 336.4				
	Extreme 24-hour Storm	70	Projections indicate reduction. Worst-case assumption assumes same as baseline			
	24-Hour Re-occurrences:					
	10 Year Return	49.0 ± 7.3	Projections indicate reduction. Worst-case assumption assumes same as baseline			
	100 Year Return	69.0 ± 12.8				
	1 000 Year Return	88.6 ± 18.3				
	10 000 Year Return	108.1 ± 23.7				
	100 000 Year Return	127.7 ± 29.2				
	1 000 000 Year Return	147.2 ± 34.7				
	10 000 000 Year Return	166.7 ± 40.2				
	100 000 000 Year Return	186.3 ± 45.7				
	Extreme 1-hour Storm	23.6	Insufficient data to make projection. Assume same as baseline			
Mean Sea Level Atmospheric pressure [hPa]	Daily Minimum	910.6 (September)	Not available	Not available	Not available	Not available
	Daily Maximum	1040.0 (July)	Not available	Not available	Not available	Not available
	Extreme Lower (Hourly)	932.5	932.3 -0.3+0.2	932.1 -0.4+0.3	931.7 -0.3+0.4	930.7 -0.4+0.3
	Mean Annual	1016.2	1015.9 -0.3+0.3	1015.7 -0.3+0.4	1015.3 -0.4+0.3	1015.0 -0.4+0.4
	Extreme Upper (Hourly)	1046.9	1046.9 -0.0+0.1	1046.9 -0.0+0.0	1046.9 -0.0+0.0	1046.9 -0.0+0.0
Notes:						

Meteorological Parameter	Baseline	Climate Change Projections (Including 95% Confidence Intervals)			
		2044	2064	2110	2130

(a) Wet-bulb temperature projections are not part of the primary meteorological variables provided by the climate change mode used in the analyses. The projections provided in the table are based on using the daily minimum, mean and maximum temperature projected increases and assuming ±25% variation in the corresponding moisture content.
(b) Temperatures of 3-hour, 6-hour and 7-day durations assumed projected temperature increases as per the climate change model.

Table 6-4: Additional Meteorological Events and Hazard Parameter Data

Meteorological Parameter			Value			
Tornadoes	Tornado Probability (EF - Enhanced Fujita Scale)	Based on 116-year database 1905 -2020	All(2)	1.0×10^{-5} per year per km²		
			EF0	7.0×10^{-6} per year per km²		
			EF1	2.4×10^{-6} per year per km²		
			EF2	5.6×10^{-7} per year per km²		
			EF3	1.0×10^{-8} per year per km²		
			EF4	$<1.0 \times 10^{-8}$ per year per km²		
		Based on 34-year database 1987 -2020 (1)	All(2)	2.2×10^{-5} per year per km²		
			EF0	1.7×10^{-5} per year per km²		
			EF1	5.2×10^{-6} per year per km²		
			EF2	1.2×10^{-6} per year per km²		
			EF3	2.2×10^{-8} per year per km²		
			EF4	$<2.2 \times 10^{-8}$ per year per km²		
	10^{-7} per year wind speed: - maximum wind speed - maximum translational - maximum rotational		75.0 m/s 15.0 m/s 60.0 m/s			
			Lower Quartile	Upper Quartile	Median	Average
	Path Width [m]:					

Meteorological Parameter		Value			
	EF0 tornado (70% to 74% probability)	22.9	68.6	45.7	54.9
	EF1 tornado (23% to 24% probability)	68.6	182.9	91.4	163.8
	EF2 tornado (5% to 6% probability)	137.2	402.3	228.6	344.1
	EF3 tornado (<0.01% probability)	339.5	1005.8	548.6	736.3
	Path Length [km]				
	EF0 tornado (70% to 74% probability)	0.29	2.7	0.8	2.27
	EF1 tornado (23% to 24% probability)	1.77	9.33	4.4	7.1
	EF2 tornado (5% to 6% probability)	4.53	19.25	10	14.3
	EF3 tornado (<0.01% probability)	12.38	36.34	23	29.1
	Pressure drop for 10^{-7} per year wind speed	40 hPa			
	Maximum rate of pressure drop for 10^{-7} per year wind speed	13 hPa/s			
Atmospheric Turbulence (Delta-T Method) (120-m Tower)	Convective (A)	1.55%			
	Unstable (B)	2.02%			
	Moderately Unstable (C)	3.28%			
	Neutral (D)	33.86%			
	Moderately Stable (E)	37.44%			
	Stable (F)	16.54%			
	Very Stable (G)	5.30%			
Prolonged Inversions	Likelihood	Annual	22%		

Meteorological Parameter		Value	
		Summer	14%
		Winter	30%
Snowfall (3)	Average	0.0 mm/h	
	Maximum load	0.0 N/m³	
Lightning	Flashes/year/km²	0.3 flashes/year/km² (range 0.2 to 1.6)	
	Average strokes per flash	13.75	
	Maximum strokes per flash	25	
	Average peak current	25 kA	
	Highest peak current	166 kA	
Thunder	No. days with thunder	7.0 days/year	
Hail	No. days with hail	1.0 days/year	
Frost	No. days with frost	0 days/year	
Fog	No. days with fog	60 days/year	
Relative humidity	Summer (relative humidity at 37 ºC, dry bulb)	14.6%	
	Winter (relative humidity at -25 ºC, dry bulb)	91.1% at lowest temperatures Assume 100% at -25ºC	
Solar Radiation	Lowest daily total	8.3 MJ/m^2.day (June)	
	Highest daily total	30.9 MJ/m^2.day (December)	
Penman Evapotranspiration	Monthly Total Minimum	76.3 mm (June)	

Meteorological Parameter		Value	
	Monthly Total Maximum	237.0 mm (December)	
Corrosivity	Rate in 1st year	Carbon steel	85.8 µm/year
		Zinc	3.4 µm/year
		Copper	1.9 µm/year
		Aluminium	1.2 µm/year
	Average rate over 20 years	Carbon steel	20.0 µm/year
		Zinc	1.9 µm/year
		Copper	0.7 µm/year
		Aluminium	0.5 µm/year

Notes:

(1) Tornado activity has increased since 1987 within an 80 km radius from the site. Whilst climate change may have contributed to increases in tornado frequencies, it may also simply be that the reporting of tornadoes has increased due to population spread as well as the associated damage to property.

(1) The “All” tornado entry combines all frequencies from EF0 to EF4 in the table.

(2) This reflects current observation; however extreme minimum temperatures (excluding climate change projections indicate temperatures well below freeze point for water and may result in the occurrence of snow at the site

Screening status: Out (Conditionally) for KNPS and Out for NNI

All meteorological parameters, excluding extreme winds - hurricane force winds and tornadoes have been screened out for KNPS. Hurricane force winds and tornadoes have a low frequency of occurrence but mitigation may be required for missiles resulting from these events)

For NNI all meteorological parameters have been screened out.

Criterion 1 - the event is of equal or lesser damage potential than the events for which the NNI is planned to be designed.
Criterion 4 - the event has a significantly low mean frequency of occurrence when considering regulatory target safety goals, taking into account the uncertainties in the estimates, where available data permit.

6.10.3.2 Electromagnetic Interference from Lightning Strikes

The main source of potential electromagnetic interference at the NNI is lightning. The severity of lightning strikes at the site is listed in ***Table 6-4***.

Design of nuclear installations includes standard protection requirements for lightning hazards and PPE parameters are provided (Eskom, 2023). Lightning can typically cause partial or complete loss of offsite power, which is the main impact of lightning.

Screening status: Out for KNPS and Out Conditionally for NNI
Criterion 1 - the event is of equal or lesser damage potential than the events for which the NNI is planned to be designed.

6.10.3.3 Other Extreme Meteorological Events

Extreme events such as tropical cyclones, ice and ice cover, blizzards and drought are discussed in ***Section 5.8***. These events are screened out because of the meteorological data presented in ***Table 6-3*** and ***Table 6-4*** and the fact that the sea serves as a heat sink. Nuclear installations located on rivers, for example, have to consider drought as an external event. In ***Subsection 6.10.6.2*** it is stated that ice is not anticipated to form in the sea at the site and the minimum cooling water intake temperature of -0.5°C will be met.

As presented in ***Table 6-3***, strong winds can occur at the site, and hence large exposed sandy areas could cause windblown dust. The vegetation found on the site and off-site in the dominant wind direction (southeast), acts as a natural mitigation measure. The nuclear installation design will have to consider this effect, but it is expected that mitigation against abrasive dust should be simple to accommodate in the design, as is done at many other coastal sites.

According to the IAEA (IAEA, 2011), the frequency of dust storms and sandstorms can be identified through hourly weather observations when visibility is 10 kilometres or less, the wind speed exceeds a threshold value (i.e., 7.5 m/s), and relative humidity is below a threshold value (i.e. less than 70 per cent).

The IAEA (IAEA, 2011) recommends the results of the assessment to be expressed as total dust or sand loading (mg/m^3), duration (h), and average dust or sand loading (mg/m^3) for the historic dust storm or sandstorm that had the largest calculated time integrated dust or sand loading.

The highest dust loading during the monitoring period occurred from 9h00 to 22h00 on 17 December 2020. The time integrated dust loading for this period was calculated to be 64.9 $mg\text{-}h/m^3$ and the duration, 14 hours. The average dust concentration during this period was 4.63 mg/m^3. The average wind speed for the 14-hour period was 9.8 m/s which occurred from the south, with maximum gusts up to 17.3 m/s, maximum 10-minute average wind speeds up to 12.6 m/s and maximum hourly average wind speed of 9.9 m/s. Based on the observed frequency of dust events, January, February and November are the months most likely to experience dust storms, whereas May to August are the months least likely to experience dust storms.

The NNI design will have to consider this effect, but it is expected that mitigation against abrasive dust should be simple to accommodate in the design, as is done at many other coastal sites, including KNPS.

Screening status: Out for both KNPS and NNI

6.10.4 Hydrological Events involving the Sea

6.10.4.1 Introduction

The results of the extensive studies in ***Section 5.9*** on hydrological events involving the sea are summarised below. The studies covered the following hazards:

- flooding from the sea;
- extreme low water levels;
- thermal plume dispersion and recirculation;
- extreme seawater temperatures;
- sedimentation and scour;
- erosion from the sea;
- landslide into water.

This screening status for hydrological events involving the sea is supported by the information on uncertainties and future work described in ***Section 5.9*** and quoted as follows (references are provided in ***Section 5.9***).

In line with Eskom's external hazards requirements and the NNR defined risk categories the external hazards have been quantified for the following exceedance probabilities: 1E-02, 1E-04, 1E-05, 1E-06, 1E-07 and 1E-08 y^{-1}. This has been done by performing extreme value analysis on datasets which have a maximum duration of 42 y. Recent IAEA guidance is that hazards cannot be estimated with sufficient accuracy for return periods more than three to four times the length of the sample period. This implies that return periods longer than approximately 168 y or equivalently exceedance probabilities less than 6E-03 y^{-1} need to be interpreted with caution. In the case of datasets with shorter durations, the accuracy will reduce proportionally.

The conceptual seawater cooling intakes and outfalls which have been developed and modelled for the DSSR will need to be refined in the future based on an engineering feasibility study. Marine geotechnical surveys and additional numerical modelling will be required as part of future engineering design studies of the intake and outfall structures.

Based on available information, meteorite impact tsunamis is screened out as the event is considered to be lower than 1E-5 exceedance probability.

Screening status: In for NNI and out for KNPS

6.10.4.2 Flooding from the Sea

Flooding from the sea due to the following was assessed:

- storm wave run-up combined with sea level rise, high tides, positive storm surge, wave set-up and basin seiche;
- tsunami run-up combined with sea level rise, high tides and positive storm surge.

The best estimate results are presented in ***Table 6-5*** for levels above mean sea level (amsl) and distance from a baseline value.

Table 6-5: Flooding from the Sea

Source of Flooding	Exceedance Probability (y^{-1})	KNPS Max Vertical Run-up Level (m amsl) 2021	KNPS Max Vertical Run-up Level (m amsl) 2064	KNPS Max Horizontal Inundation Distance (m from Baseline[(a)]) 2021	KNPS Max Horizontal Inundation Distance (m from Baseline[(a)]) 2064	NNI Max Vertical Run-up Level (m amsl) 2021	NNI Max Vertical Run-up Level (m amsl) 2064	NNI Max Vertical Run-up Level (m amsl) 2130	NNI Max Horizontal Inundation Distance (m from Baseline[(b)]) 2021	NNI Max Horizontal Inundation Distance (m from Baseline[(b)]) 2064	NNI Max Horizontal Inundation Distance (m from Baseline[(b)]) 2130
Storm Waves	10^{-2}	6.55	6.53	104	127	6.38	6.66	9.38	79	160	328
Storm Waves	10^{-4}	7.85	7.67	145	186	8.97	9.87	12.41	125	210	345
Storm Waves	10^{-5}	8.69	8.33	156	222	9.10	10.35	13.36	177	257	365
Storm Waves	10^{-6}	9.54	9.00	168	258	9.23	10.83	14.31	229	305	385
Storm Waves	10^{-7}	10.13	10.41	207	321	10.11	12.03	15.52	259	321	406
Storm Waves	10^{-8}	10.72	11.83	246	383	10.98	13.24	16.73	288	336	427
Tsunami: Distant earthquakes	(c)	6.05	6.81	137	162	6.67	7.22	8.95	80	169	333
Tsunami: Volcanic flank collapse	(c)	11.82	13.95	382	399	12.71	13.93	15.82	384	399	553
Tsunami: Local submarine landslides	(c)	6.80	7.04	143	175	6.80	8.19	10.08	123	184	333
Probable Maximum Tsunami (PMT)	(d)	11.82	13.95	382	399	12.71	13.93	15.82	384	399	553

Notes: a) KNPS the baseline is parallel to the terrace and seaward of the intakes. b) At the NNI the baseline corresponds to the present-day +2 m msl contour.
c) Maximum for each tsunami source type. d) Maximum for all tsunami source types

Tsunami

The updated tsunami hazard assessment considered all probable sources, i.e., nearfield and far field sources. The results show that the Probable Maximum Tsunami (PMT) run-up and inundation are governed by the volcanic flank collapse tsunamis which indicate flooding of the KNPS nuclear terrace level located at approximately +8 m msl. No other tsunamigenic sources, including distant earthquakes and local submarine landslide sources, result in run-up above the KNPS nuclear terrace level, even including climate change to 2064.

Current estimates for PMT are +11.82 m (2021) increasing to 13.95 m (2064) considering climate change. The volcanic flank collapse risk comes from Tristan da Cunha, a volcanic island located approximately 3 000 km west of the Cape and that had a flank collapse between 6 000 and 35 000 years ago.

A focussed palaeotsunami field investigation of sites that are judged to be favourable for recording tsunami deposits near Duynefontyn, was carried out with the aim to identify and assess the magnitude of any recent prehistoric tsunamis. No evidence supporting palaeotsunamis, including the volcanic flank collapse tsunami from Tristan da Cunha island was identified by the field investigation.

However, the onshore geological record is of relatively short duration and incomplete even for the late Pleistocene (~3000 – 11 ka) given that for much of that time, sea level was below present level and tsunami deposits likely would be eroded during multiple sea level fluctuations, including the most recent post-glacial transgression from the Late Glacial Maximum (20-21 ka).

In light of the limitations outlined above, the results of the study do not preclude the possibility of events, including the volcanic flank collapse, already considered in the updated DSSR.

A Probabilistic Tsunami Hazard Analysis (PTHA) was commissioned to quantify the frequency of exceeding the +8 m msl terrace level, various inundation depths on the terrace, as well as the uncertainty distribution related to these frequencies. Results of the PTHA have shown that the probability of flooding the terrace is less than 1E-5 based on best estimate for the current scenario and projection to 2064.

Storm Wave Run-up

Results from the oceanography study indicates that the likelihood of a storm wave run-up breaching the KNPS terrace has increased. While the original terrace design height was based on a 1E-06 yr^{-1} return frequency, the latest data indicate the return frequency of exceeding the terrace level at +8 m msl now lies between 1E-04 yr^{-1} and 1E-06 yr^{-1}, however these locations are north and south of the nuclear terrace. Only at 1E-08 y^{-1} does the wave run-up flood the terrace adjacent to the reactor buildings. Therefore, the likelihood of a storm wave run-up exceeding the terrace level at KNPS and impacting the facility is considered low.

The PPE for the NNI states that the terrace height must be such that the terrace is elevated above design basis flooding hazards. These results show the maximum flood level is +16.7 m msl, due to an extreme 1E-08 y^{-1} wave storm in 2130 at the NPS site. The maximum horizontal inundation is 553 m due to the PMT in 2130. The inundation extends into the estimated position of the NNI for the PMT in all years.

For wave storms the inundation does not reach the position of the NNI in 2021 and 2064, however in 2130 the position of the NNI is reached for exceedances of 1E-02 y^{-1} and lower.

For the NNI, the SSCs will need to be placed above these maximum flood levels and landward of the maximum inundation, or alternatively protective structures such as revetments and wave walls will need to be placed in front of the SSCs.

Screening: ***In for NNI and Out (conditionally) for KNPS***

To be considered in the design of the proposed NNI. For KNPS, further analysis was carried out and the results have shown that the risk is lower than 1E-5.

6.10.4.3 Extreme Low Water Levels

Extreme low water levels at the cooling water intakes can occur due to:

- storm wave drawdown combined with low tides, negative storm surge and basin seiche; or
- tsunami drawdown combined with low tides and negative storm surge.

The best estimate extreme low water levels at the KNPS cooling water intake pumps inside the intake basin, and at the -20 m and -30 m msl depths opposite the NNI, corresponding to possible tunnel intake locations, are presented in ***Table 6-6***.

Table 6-6: Extreme Low Water Levels

Source of Drawdown	Exceedance Probability	KNPS		NNI								
		Minimum vertical drawdown level at pumps		Minimum vertical drawdown level at pumps[a]			Minimum vertical drawdown at -20 m msl			Minimum vertical drawdown at -30 m msl		
	(y^{-1})	(m msl)		(m msl)			(m msl)			(m msl)		
		2021	2064	2021	2064	2130	2021	2064	2130	2021	2064	2130
Storm Waves	10^{-2}	-1.10	-1.11	-1.10	-1.11	-1.13	-3.55	-3.47	-3.47	-4.87	-4.79	-5.27
Storm Waves	10^{-4}	-1.42	-1.39	-1.42	-1.39	-1.45	-3.66	-3.81	-3.85	-5.39	-5.44	-5.55
Storm Waves	10^{-5}	-1.53	-1.54	-1.53	-1.54	-1.62	-3.74	-3.86	-3.93	-5.76	-6.04	-6.17
Storm Waves	10^{-6}	-1.64	-1.69	-1.64	-1.69	-1.80	-3.83	-3.90	-4.01	-6.14	-6.64	-6.79
Storm Waves	10^{-7}	-1.79	-1.83	-1.79	-1.83	-1.95	-1.79	-3.94	-4.00	-4.03	-6.41	-6.61
Storm Waves	10^{-8}	-1.94	-1.97	-1.94	-1.97	-2.09	-4.04	-4.10	-4.05	-6.68	-6.58	-6.82
Tsunami: Distant earthquakes	(b)	-2.26	-2.26	-2.26	-2.26	-2.23	-4.96	-5.04	-5.19	-3.90	-3.87	-3.81
Tsunami: Volcanic flank collapse	(b)	-1.83	-1.81	-1.83	-1.81	-1.77	-7.18	-7.16	-7.18	-6.64	-6.65	-6.51
Tsunami: Local submarine landslides	(b)	-2.12	-2.12	-2.12	-2.12	-2.14	-5.35	-5.36	-5.40	-4.69	-4.70	-4.73
Probable Maximum Tsunami (PMT)	(c)	-2.26	-2.26	-2.26	-2.26	-2.23	-7.18	-7.16	-7.18	-6.64	-6.65	-6.51

Notes: a) Assuming a basin intake with similar geometry to KNPS. b) Minimum level for each tsunami source type. c) Minimum level for all tsunami source types.

For the existing KNPS basin, the Essential Service Water System (SEC) pumphouse is designed to accommodate a minimum short duration water level of -2.5 m msl under normal operating conditions. If the sea level drops below -3.5 m msl no water would reach the pumps. At KNPS, the results show that the lowest water level is -2.3 m msl, which is driven by the PMT. The KNPS pumps will thus continue to operate for all events assessed.

If a basin intake with similar geometry to KNPS is selected for the NNI, then the intake should accommodate a minimum water level of -2.3 m msl.

If a tunnel intake in a depth of -20 m msl is selected for the NNI, then the intake should accommodate a minimum water level of -7.2 m msl, which is driven by the PMT.

If a tunnel intake in a depth of -30 m msl is selected for the NNI, then the intake should accommodate a minimum water level of -6.8 m msl, which is driven by the 1E-08 y^{-1} storm event.

Screening: Out for KNPS

In for NNI – to be considered in the proposed NNI design.

6.10.4.4 Thermal Plume Dispersion and Recirculation

It is proposed that the NNI will be cooled using a once-through seawater cooling system. Four different conceptual layouts described in ***Section 5.9*** for the seawater cooling intake and outfall system have been developed and thermal plume dispersion modelling has been performed to demonstrate the technical feasibility of the site:

- Layout 0: Existing KNPS intake basin and outfall channel;
- Layout 1: Short tunnel intakes and outfalls;
- Layout 2: Long tunnel intakes and outfalls;
- Layout 3: Basin intake and tunnel outfalls;
- Layout 4: Basin intake and rubble-mound outfall structure.

The PPE for the NNI specifies that the maximum ΔT of the re-circulated cooling water between the discharge and the intake should be less than 1.5°C. The maximum ΔT of the re-circulated water at the KNPS is not specified.

The modelled recirculation ΔTs at the KNPS intake and at the NNI intake are presented in ***Table 6-7***.

Table 6-7: Recirculation at KNPS Intake and NNI Intake

Case	ΔT at KNPS Intake (°C)			ΔT at NNI Intake (°C)		
	50th Percentile	95th Percentile	99th Percentile	50th Percentile	95th Percentile	99th Percentile
KNPS (2108 MWe)	0.35	1.80	2.40	-	-	-
KNPS + NNPS (2500 MWe) Layout 1	0.71	2.01	2.57	0.13	0.71	1.33
KNPS + NNPS (2500 MWe) Layout 2	0.48	1.79	2.41	0.03	0.48	0.92
KNPS + NNPS (2500 MWe) Layout 3	0.47	1.73	2.17	0.17	0.85	1.10
KNPS + NNPS (2500 MWe) Layout 4	0.98	2.17	2.81	0.69	2.04	2.69
KNPS + NNPS (4000 MWe) Layout 1	0.89	2.11	2.69	0.08	0.70	1.17
KNPS + NNPS (4000 MWe) Layout 2	0.60	1.83	2.44	0.05	0.50	0.94
KNPS + NNPS (4000 MWe) Layout 3	0.70	1.80	2.27	0.36	1.22	1.48

KNPS + NNPS (4000 MWe) Layout 4	1.38	2.49	3.02	1.19	2.62	3.24

The results show that the 99th percentile ΔT at the existing KNPS intake is 2.4°C. The NNI generally increase the ΔT at the existing KNPS intake, with Layout 4 resulting in the largest increase (+0.6°C for the 99th percentile), while Layout 3 had the least impact.

At the NNI intake, Layouts 1 to 3 meet the ΔT of 1.5°C for the 99th percentile. Layout 4 has a 99th percentile ΔT of 2.7 and 3.2°C for power outputs of 2 500 and 4 000 MW_e, respectively.

6.10.4.5 Extreme Seawater Temperatures

The PPE specifies a maximum cooling water intake temperature for the NNI of 30°C. For the existing KNPS a shut-down of the reactor will be necessary if the intake temperature exceeds 23°C (has been changed to 25°C but evaluation was done for design basis of 23°). The maximum seawater temperature at the cooling water intakes will depend on:

- the intake and outfall layout, the power output and resultant ΔT due to recirculation from the outfall to the intake;
- the extreme maximum background seawater temperature at the intake location and climate change.

The best estimate return period in years to exceed 23°C at the KNPS intake and the best estimate annual probability to exceed 30°C at the NNI intake are presented in ***Table 6-8***.

Table 6-8: Extreme Maximum Seawater Temperatures at the Intakes (Including Recirculation)

Case	Best Estimate Return Period to Exceed 23°C at KNPS Intake[(a)] (y)			Best Estimate Probability to Exceed 30°C at NNI Intake (y^{-1})		
	2021	2044	2064	2021	2064	2130
KNPS (2108 MWe) Layout 0	98	56	35	-	-	-
KNPS + NNPS (2500 MWe) Layout 1	56	32	20	1.0E-05	2.8E-05	1.3E-04
KNPS + NNPS (2500 MWe) Layout 2	71	40	25	3.4E-06	9.1E-06	4.1E-05
KNPS + NNPS (2500 MWe) Layout 3	73	42	26	8.5E-06	2.3E-05	1.0E-04
KNPS + NNPS (2500 MWe) Layout 4	51	29	18	1.5E-05	4.0E-05	1.8E-04
KNPS + NNPS (4000 MWe) Layout 1	44	25	15	1.1E-05	2.8E-05	1.3E-04
KNPS + NNPS (4000 MWe) Layout 2	65	37	23	3.6E-06	9.6E-06	4.4E-05
KNPS + NNPS (4000 MWe) Layout 3	61	35	21	8.5E-06	2.3E-05	1.0E-04
KNPS + NNPS (4000 MWe) Layout 4	29	17	10	3.1E-05	8.2E-05	3.8E-04
Note: (a) Expressed as the return period for convenience, where return period = 1/exceedance probability						

Without the NNI, the best estimate return period to exceed 23°C at the KNPS intake is 98 y for the year 2021 and 35 y for the year 2064.

In all cases the addition of the NNI reduces the return period to exceed 23°C at the KNPS intake. Layout 4 with a 4 000 MW_e power station has the largest impact on the KNPS, with the 23°C threshold reducing to a 29 y return period for the year 2021 and a 10 y return period for the year 2064. Layout 4 will thus increase the probability of a shut-down of the KNPS reactors due to high seawater temperatures.

At the NNI intakes, the higher maximum specified intake temperature of 30°C, combined with lower recirculation ΔT's results in significantly lower exceedance probabilities of between 3.4×10^{-6} and 3.8×10^{-4} y^{-1}, with the latter for Layout 4 with the 4 000 MW_e power station in 2130. These exceedance probabilities indicate that the intake seawater temperatures will need to be considered in the design of the cooling system for the NNI.

Screening: Out for KNPS and In for NNI

Seawater temperature to be considered in the design of NNI.

6.10.4.6 Sedimentation and Scour

Sediment transport modelling was carried out to assess the sedimentation in the KNPS intake basin entrance and scour around coastal structures during extreme storm and tsunami events. The best estimate maximum scour depth below the seabed and maximum bed level in the intake basin is presented in ***Table 6-9***.

Table 6-9: Sedimentation and Scour at the KNPS Intake Basin due to Storms

Source	Exceedance Probability	Maximum Bed Level in Intake Basin Entrance[(a)]	Maximum Scour Adjacent to Structures[(b)]
	y^{-1}	(m msl)	(m)
Storm waves	10^{-2}	-2.7	-6.1
Storm waves	10^{-4}	-2.7	-6.4
Storm waves	10^{-5}	-2.7	-6.8
Storm waves	10^{-6}	-2.7	-7.3
Storm waves	10^{-7}	-2.6	-7.5
Storm waves	10^{-4}	-2.5	-7.8
Tsunami	Not applicable	-2.7	-3.5

Notes:
(a) Measured as the shallowest point along the deepest flow path between the intakes and the sea. The initial maximum bed level was -2.68 m msl.
(b) Defined as the depth below the existing seabed.

Under extreme storm conditions scour exceeding -5 m is predicted at the roundhead and along the outside of the southern trunk of the KNPS breakwater. The effect of this on the stability of the breakwater requires additional investigation. The design of any similar coastal structures for the NNI should account for similar levels of scour.

Storm-induced sedimentation is not predicted to close off the intake basin and seawater will be able to enter the intake basin. Regular maintenance dredging is however required to remove the annual sedimentation in the KNPS intake basin of approximately 132 000 m^3/y, which may increase after extreme storm events. Less than 0.3 m of tsunami-induced sedimentation is predicted in front of the KNPS pumphouses and the intake basin is not closed off by sedimentation during the modelled extreme tsunami event. These results would also apply should an intake basin with the same geometry be selected for the NNI. The annual maintenance dredging would however increase with increasing intake seawater flow rate.

For Layouts 1 and 2 (refer to ***Section 5.9***) the proposed seawater intake is a tunnel extending to approximately -20 and -30 m msl water depth respectively, with the intake opening positioned 3 to 5 m above the seabed. Modelling was performed to estimate the volume of sand drawn into the intakes which will have to be removed from the proposed landside intake basin. The results presented in ***Table 6-10*** are conservatively based on the suspended sediment concentrations 1 m above seabed.

Table 6-10: Sand Volume Drawn into Cooling Water Intake Tunnels

Exceedance Probability (y^{-1})	Case	Units	2500 MWe		4000 MWe	
			Layout 1 (Intake at -20 m msl)	Layout 2 (Intake at -30 m msl)	Layout 1 (Intake at -20 m msl)	Layout 2 (Intake at -30 m msl)
-	Operational Conditions	m^3/y	1 400	380	2 200	610
10^{-2}	Storm event	m^3/event	6 300	2 100	10 000	3 400
10^{-4}	Storm event	m^3/event	55 000	17 000	88 000	27 000
10^{-5}	Storm event	m^3/event	91 000	32 000	150 000	51 000
10^{-6}	Storm event	m^3/event	150 000	60 000	240 000	96 000
10^{-7}	Storm event	m^3/event	220 000	110 000	360 000	170 000
10^{-8}	Storm event	m^3/event	330 000	180 000	530 000	290 000

For operational conditions the volume of sand drawn into the tunnel intakes which will have to be removed from the proposed landside intake basins is less than 2 200 m^3/y. This is significantly less than the average maintenance dredging volume of the existing KNPS intake basin of approximately 132 000 m^3/y.

A maintenance dredging programme will be required to prevent excessive sedimentation in the basin and to keep a sufficient buffer for storm events.

For extreme storm events the sand volume increases significantly and the 10^{-6} storm event results in similar sand volumes over the 4.1-day storm event as the annual maintenance dredging at KNPS. The intake basin will need to accommodate these sediment volumes without blocking the pumps.

The shallower intake in -20 m msl depth results in a threefold increase in sand volumes compared to the intake in -30 m msl. This increase will need to be considered in the detailed engineering and costing of the intakes.

Screening: Out for KNPS and In for NNI

6.10.4.7 Erosion from the Sea

The hazard of future coastline erosion has been studied in ***Section 5.9*** for the proposed KNPS long term operation and an NNI. The coastline stability was evaluated by measuring the horizontal distance from the baseline to the most landward extent where any erosion or accretion were observed on the profiles. The model was run for extreme storms with exceedance probabilities of 1E-02, 1E-04, 1E-06 and 1E-08 y^{-1}. The model was run for the following dates to include the effect of climate change on waves, water levels and coastline stability:

- 2021 – present day;
- 2064 – end of decommissioning period for KNPS.

The results are summarised in ***Table 6-11***. The results shows that coastline erosion increases over time due to long-term coastline trends, sea level rise and larger waves and thus posing a risk to the breakwater and outfall structures when the erosion line reaches the root of these structures. In 2021 the erosion line south of KNPS reaches the root of the revetment protecting the outfall structure at 1E-02 y^{-1}. The predicted long-term accretion south of KNPS reduces the risk to the outfall structure by 2064. In 2021 it is predicted that the erosion line north of KNPS reaches the root of the northern breakwater at 1E-08 y^{-1}, with this probability increasing to 1E-02 y^{-1} by 2064.

The maximum coastline erosion occurred on the northern side of the site, except for the 1E-08 y^{-1} storm where the dune ridge was breached south of KNPS, the probability which is considered to be low. At 1E-02 y and 10E-04 y^{-1}, it can be concluded that the rate of erosion as a result of sea level rise will not pose an immediate risk of damage to the KNPS breakwater and intake structures. Although the 1E-08 y^{-1} event might result in a significant impact on the structures since the erosion will be beyond the area where the structures are, the risk is considered to be low due to a lower return frequency.

The predicted erosion does not reach the estimated position of the NNI for 2021 and 2064. For 2130 the southern section the NNI are eroded for all exceedance probabilities modelled. It will thus be necessary to move the position of the NNI landward, or to design appropriate coastal protection such as revetments.

Table 6-11: Maximum Coastline Erosion Adjacent to KNPS and in Front of NNI

Exceedance Probability	Total Coastline Erosion Adjacent to KNPS		Total Coastline Erosion in Front of NNI		
(y^{-1})	(m from Baseline[a])		(m from Baseline[b])		
	2021	2064	2021	2064	2130
10^{-2}	-59	-145	-96	-178	-346
10^{-4}	-74	-159	-96	-178	-346
10^{-5}	-80	-167	-107	-180	-350
10^{-6}	-87	-175	-143	-182	-354
10^{-7}	-181	-182	-143	-185	-356
10^{-8}	-286	-306	-157	-195	-358

Note:
(a) At KNPS the baseline is parallel to the terrace and seaward of the intakes.
(b) At the NNPS the baseline corresponds to the present-day +2 m msl contour.

Screening: In for NNI and Out (conditionally) KNPS

Coastline erosion is identified as a significant hazard that will need to be considered in the design of the NNI. For KNPS, the hazard is slow in developing such that it can be demonstrated that there is sufficient time to eliminate the source of the threat or provide an adequate response. However, the hazard should be monitored for KNPS to ensure appropriate actions are taken to prevent potential damage to the structures.

6.10.4.8 Landslide into Water

The site is on flat terrain therefore there is no hazard posed by landslides.

6.10.5 Biological Phenomena and Related Events

Blockage of intakes and biofouling is briefly discussed in ***Section 5.9***. It is concluded, based on the KNPS and worldwide experience that the NNI intakes could be designed to cope with the marine species found at the site and to minimise the risk of complete blockage of the intake.

Section 5.3 provides further supporting information. Chlorine or other biocides should be used to keep the cooling system free of marine growth.

The impacts of marine biota on the proposed NNI, as is the case for the existing KNPS, stem from entrainment of marine organisms and settlement of sessile organisms in the intake pipes, resulting in a potential blockage and loss of cooling water supply:

- Jellyfish and planktonic forms of comb-jellies are known to cause blocking of power station cooling systems when they reach high densities. Three notable jellyfish ingress events have been recorded since KNPS commenced operation in the 1980s, viz. in February 1997, June 1999 and May 2005. In all three cases, massive ingress of jellyfish into the inlet basin significantly affected normal operations of the nuclear installation.
- Considering the noticeable increase in jellyfish along the South African West Coast since the 1970s, the probability of entrainment of high densities of these organisms into the cooling water system of a proposed NNI in this area appears to be increasing. Evidence supporting global increases in jellyfish in response to climate change remains inconclusive.
- Floating kelp can also potentially block water intakes and may be dislodged during storm events. There are nearshore kelp beds in the area.
- Colonisation by sessile organisms, such as mussels and barnacles, may result in the fouling of cooling pipes.

A risk assessment of a loss of adequate cooling water from the sea because of marine organisms is considered fraught with uncertainties. It is therefore prudent to confirm that design and management measures will be adequate in respect of the ultimate heat sink when the nuclear installation design becomes available since auxiliary cooling towers may be included as part of the cooling function.

The site should be no different to other sites when considering the hazards from terrestrial fauna and flora. Protection against rodents, for example, will require the same protection measures as being applied at other hazardous facilities. Ventilation systems, for example, need to be designed to prevent invasion by insects etc.

It is important to note that the safety function of an ultimate heat sink for the NNI may be provided by auxiliary cooling towers. This design feature must be taken into consideration assessing the risk of a loss of ultimate heat sink.

Screening status: Out (conditionally)

Criterion 1 - the event is of equal or lesser damage potential than the events for which the NNI is planned to be designed.

The potential impact of marine organisms on the cooling water supply can be dealt with through appropriate design and management measures.

6.10.6 External Flooding from Terrestrial Sources

International experience shows (IAEA, 2023) that apart from flooding from the sea, there are other flooding scenarios that have to be considered. These scenarios could induce a transient in water level at the site resulting in static effects (water weight) and dynamic loads on the NNI (also refer to ***Section 6.10.1.3.2***, Water levels). Operational experience from existing nuclear installations provides evidence for external flood induced events in which the functionality of safety related equipment has been impaired. Most of these are related to insufficient measures for site protection, to poor maintenance of the drainage systems and to effects of ice on river sites. Much evidence has also been recorded recently on leakage from nuclear installations, essentially through poor sealing in structural joints or cable conduits and inspection openings. The provisions for such events are mainly design related, but attention should be paid to the possibility of the groundwater table rising as a consequence of a flood, as its maximum level is a design basis for the NNI (IAEA, 2021).

6.10.6.1 Failure of Human-Made Water Retaining Structures

Hydrological and seismic events, as well as faulty operation, can result in the failure of water retaining structures. There are two dams in the Lower Berg River Catchment (Misverstand Dam and Voëlvlei Dam) located more than 50 km northeast of the site. However, they fall within a different watershed and therefore do not drain towards the site and hence pose no hazard (see ***Section 5.10***, Hydrology and Hydraulics).

No other large dams are being planned in the vicinity of the site in the medium and long term. There are a few small and minor farm dams east of the site but failure of a farm dam upstream of the site is not considered a hazard to the NNI since these dams are small with approximate dam wall heights of not more than 5 m. The NNI is furthermore protected from these human-made dams by large sand dunes.

Screening status: Out (unconditionally)
Criterion 2 - the event cannot occur close enough to the NNI to affect it.

6.10.6.2 Changes in the Natural Channel for a River (Including River Diversions)

International experience has shown that an analysis of the integrity of all dams along the path to the site should be performed and, unless non-failure can be established, failure should be postulated and the floods resulting from all assumed dam failures should be routed to the site (IAEA, 2021).

The Modder River lies to the north of the site and falls into a different catchment area approximately 23 km from the site. On this basis no flooding hazard from this river is expected at the NNI. The Salt River lies to the south of the site and falls into a different catchment approximately 6 km from the site and therefore is not a flooding hazard. There are a few minor streams traversing the site and north and south of the site, the catchments of which are very small, giving small run-off peaks and hence low flood levels. These levels are not expected to pose a hazard but this will have to be confirmed when the NNI site elevation is defined.

Furthermore, based on the expected design life of the NNI of 60 years, the probability of a 1E-06 event occurring during this design life is only 0.0060 per cent, which is very low.

From a regional assessment of the area surrounding the NNI it was established that the rivers within a 5 km buffer are small with relatively small catchments. This in turn gives low flood peaks and low water levels in rivers. Local storm water control measures at the NNI and substations need to be designed to handle up to a 1E-06/y event.

Infrastructure flooding risk as a result of ice slides does not exist since temperatures in the area are well above freezing point, which has been established from meteorological data in the nuclear installation area (see ***Section 5.8***).

Screening status: Out (unconditionally).
Criterion 1 - the event is of equal or lesser damage potential than the events for which the NNI is planned to be designed.
Criterion 2 - the event cannot occur close enough to the NNI to affect it.

6.10.6.3 Waterspouts

This phenomenon is enveloped by the information provided in ***Subsection 6.10.3.3***.

Screening status: Out for both KNPS and NNI
Criterion 3 - the event is included in the definition of another event.

6.10.6.4 Snow Melt

As reported in ***Section 5.8***, snow is unlikely to occur in the site region and hence will be unlikely to lead to flooding, e.g., rising of upstream water level due to stream obstructions.

Screening status: Out for both KNPS and NNI
Criterion 3 - the event is included in the definition of another event. Criterion 4 - the event has a significantly low mean frequency of occurrence when considering regulatory target safety goals, considering the uncertainties in the estimates, where available data permit.

6.10.7 On-site Hydrology Aspects

The on-site hydrology aspects are discussed in ***Section 5.10.*** There are drainage lines and ponding areas on the site (and thus potentially within the nuclear installation footprint), and a flood hazard assessment has been performed. The following preliminary conclusions for the regional safety consequence assessment were made:

The catchments on site have a low run-off coefficient due to high infiltration as a result of sandy soils and moderate vegetation. Due to the topography and locality of the NNI, the run-off from external catchments potentially impacting the site is relatively small (size of catchments less than 4.0 km^2) and the flood water levels are controlled by the backup from the extreme sea water levels.

There also are no perennial watercourses close to the site and the closest major watercourse is the Diep River approximately 15 – 20 km located in a different quaternary catchment. The majority of run-off occurs along drainage lines and temporarily ponds within the low-lying areas between the dunes during a storm event.

Surrounding ponding areas are expected to have a low/medium/high impact on the nuclear installation safety based on the current site location as the temporary ponding could cause low lying infrastructure associated with the nuclear installation(s) to be flooded. Wetland depressions within the dunefields can contain significant volumes of water, depending on the seasonal rains. These are depressions that occur in an otherwise sloped terrain. The wetlands and other water retaining structures located on the site in future will be assessed against the specific nuclear installation design when it becomes available.

From a site safety perspective, the site is not located along any major watercourses which could potentially impact the site during extreme external flood events. A conservative approach was adopted throughout the study and considered a combination of extreme events occurring simultaneously resulting in a low probability of occurrence. The flood levels are impacted by the extreme downstream water levels from the ocean rather than water levels generated by surface water run-off from the minor catchments.

With the appropriate remedial measures in place, the safety consequence (Hazard x Vulnerability) is low, and the site is suitable for the development of a NNI (***Section 5.10***). The final footprint for the NNI would need to be located above the 1E-04, 1E-06 and 1E-08 annual probability of exceedance (95^{th} percentile) flood levels.

Screening status: In (conditionally) for NNI and Out for KNPS

The recommended platform levels for the NNI would need to be considered during the detailed design phase.

6.10.8 Loss of Freshwater Supply

The water supply (non-cooling) characteristics presented in ***<u>Section 5.12</u>*** (Water Supply) show that the freshwater requirements could vary between 69 and 100 ℓ/s during normal and peak operation. This is for an NNI to supply an initial 13 200 MW_{th}.

The loss of freshwater supply could have an influence on reactor systems, for example Service Water System and Component Cooling Water System. A design specification for stored water volume to compensate for a loss of fresh water supply will be required for the nuclear installation design. The on-site stored water will negate the effects of a loss of off-site fresh water supply and the event is screened out.

Screening status: Out for KNPS. Must be confirmed for NNI in a later licensing stage.

Criterion 1 - the event is of equal or lesser damage potential than the events for which the NNI is planned to be designed.

6.10.9 External Fires

External fires are fires occurring outside the nuclear installation site boundary, e.g. forest/veld fires and oil spills at sea. Potential hazards posed by external fires are a loss of offsite power (LOOP), forced isolation of the installation's ventilation and a potential impact on control room habitability. Protection against fires is achieved by minimising the probability of a fire and providing barriers against external fires. A fire of external origin must not prevent the performance of safety functions.

Fynbos, which is highly fire-prone, covers a significant part of the site. Alien vegetation which is also fire-prone, covers some land adjacent to the site. Extensive veld fires have occurred in the past in the vicinity as well as inside the Koeberg nature reserve. Existing management of the site vegetation that is exercised in respect of the KNPS shall have to be reviewed to ensure that it also caters for an NNI.

Examples of mitigation against the effects of a fire included in nuclear installation design are:

- ventilation system can be protected by isolation of the systems from outside air by means of dampers with reliance on alternative systems to accomplish the functions of the ventilation system;
- adequate supply of air to all diesel generators required to perform necessary safety functions - Segregation in respect of air intakes and distance between intakes are some preventative measures.
- safety related instrumentation and control systems vulnerable to smoke and dust have to be environmentally qualified.
- placement of equipment that depends on air to be away from site boundaries

Screening status: Out for KNPS and In for NNI
Mitigation against the occurrence of veld fires resulting in air pollution is included in nuclear installation design of ventilation systems. The event is therefore considered to be of equal or lesser damage potential than the events for which the NNI is planned to be designed.

6.11 Human-induced External Events

6.11.1 Accidental Aircraft Crash

6.11.1.1 International Practice and Regulatory Requirements

The NNR requires a design-specific assessment of the effects on an NNI of the impact of a large, commercial or military aircraft (NNR, 2014). It must be designed to withstand the impact of a design basis aircraft crash without loss of any safety function.

In many cases probabilistic screening was the only approach formerly used for accidental aircraft crash, but countries are increasingly examining the crash consequences, partly in response to the possibility of malevolent human actions. Double containment and certain layouts of some advanced nuclear installation designs to reduce above ground vertical profiles, offer advantages in the resistance of malevolent EEs, which cannot be probabilistically defined (EPRI, 2011). Some countries therefore follow a deterministic approach for an aircraft impact evaluation. The reference load case may be identified without explicit reference to an aircraft type or to an occurrence frequency. This is the case in the USA where applicants for design certification of new nuclear installations are subject to 10 CFR 50.150 (U.S. NRC, 2009) and must make the complete aircraft impact assessment available for US NRC inspection. The impact of a large commercial aircraft is considered a beyond-design-basis event by the US NRC. It is required that applicants for nuclear installation design certification perform an aircraft impact assessment of the effects on the NNI of a large, commercial aircraft. An applicant has to "*identify and incorporate into the design those design features and functional capabilities to show that, with reduced use of operator actions: (i) The reactor core remains cooled, or the containment remains intact; and (ii) spent fuel cooling or spent fuel pool integrity is maintained".*

6.11.1.2 An Aircraft Crash

The methodology and results of annual aircraft crash rates assessment for the site is presented in (Necsa, 2023). The crash rates are calculated per unit site area and are independent of the dimensions of existing or planned plant buildings located or planned on the site. The effects on the NNI are to be determined when a specific design is made available in the next licensing phase. The crash rates are determined for the following aviation categories and associated sub-categories:

a) Civil Aviation:

- commercial aviation
- general aviation:
  - fixed-wing aircraft;
  - rotary wing aircraft (helicopters).

b) Military Aviation:

- large fixed-wing aircraft;
- small fixed-wing aircraft;
- rotary wing aircraft (helicopters).

For each aviation category the annual aircraft crash rate is determined by considering airfield-related events from nearby airports (landing and take-off activities), in-flight events (directly over or in the immediate proximity of the site), and background crash rates (random crash rate within South Africa). It presents the current expected and future projected annual aircraft crash rate for the aviation categories. The current expected annual aircraft crash rate per km^2 for the site are provided in

Table 6-12 and ***Table 6-13***.

Table 6-12: Duynefontyn current expected annual aircraft crash rate

Aviation Category			Estimated Crash Rate (/yr /km²)
Civil Aviation	Commercial Aviation		7.46E-07
	General aviation	Fixed-wing	4.98E-05
		Helicopters	9.34E-07
Military Aviation	Large		1.53E-07
	Small		2.37E-07
	Helicopters		2.92E-05

Table 6-13: Duynefontyn site future projected annual aircraft crash rate

Aviation Category			Estimated Crash Rate (/yr /km²)
Civil Aviation	Commercial Aviation		2.33E-06
	General Aviation	Fixed-wing	4.79E-05
		Helicopters	3.27E-07
Military Aviation	Large		5.91E-05
	Small		1.02E-04
	Helicopters		6.69E-06

6.11.1.3 Conclusions

The current expected annual aircraft crash rate study shows that fixed wing civil aviation and military helicopters have occurrence frequencies greater than 1E-06 per year per km^2. The risk to the site is however considered low as the immediate airspace above the site is a registered restricted flying area (FAR36). The area covers a footprint with a 4.63 km radius with centre at 33°41’00S and 18°26’50E excluding areas east of the R27 road. The restricted area extends from ground level to 610 m above mean sea level (above MSL). To the east of the site is a danger area (FAD 200A) from ground level to 610 m above MSL, and north-east of the site is a danger area (FAD 200B) from ground level to 1 220 m above MSL.

For an NNI aircraft crash is included as a standard event with specific load functions in the design basis of the reference nuclear installations, irrespective of aircraft crash frequency considerations. Both the Westinghouse AP1000 and the Areva EPR reactors, for example, which are included as reference nuclear installations for the site, have designs that have been approved by the US NRC. Their designs are certified as being able to withstand the impact of a large commercial aircraft and include the following safety features (US NRC, 2011):

- performing the cooling function with reduced use of operator action;
- intact containment: “(1) will not be perforated by the impact of a large, commercial aircraft; and (2) will maintain ultimate pressure capability, given a core damage event until effective mitigation strategies can be implemented. Effective mitigation strategies are those that provide, for an

indefinite period of time, sufficient cooling to the damaged core or containment to limit temperature and pressure challenges below the ultimate pressure capability of the containment.";

- spent fuel pool (SFP) integrity: "The "SFP integrity" criterion in 10 CFR 50.150(a)(1) is satisfied if the impact of a large commercial aircraft on the SFP wall or support structures would not result in leakage through the SFP liner below the required minimum water level of the pool.".

Screening status: Out (conditionally for NNI) and Out for KNPS

Confirm deterministic approach followed for GEN III NNI for beyond design basis aircraft.
For KNPS risk is considered low due to restricted flying area above the site and the 1E-5 probability.

6.11.2 Hazardous Materials – Land-Based Stationary and Transport Sources, Harbours and Shipping Lanes

6.11.2.1 Hazardous Material Inventories and Screening Distance Values

The main hazard assessment study is reported in (MHR, 2022) and is based on information in ***Section 5.7***. The scope and requirements for the study involved the following:

- conduct consequence analysis for hazardous material storage, transportation and processes in the site vicinity and calculate the screening distance values (SDV)[7] for hazardous materials identified that have potential to impact KNPS and a future NNI;
- conduct a risk assessment inside the SDVs to evaluate hazards such as explosion pressure waves, toxic, corrosive or combustible gas releases and external fires;
- include a transport route quantitative analysis to assess the extent of the road transportation hazards from flammable, explosive and toxic materials.

[7] Screening distance value (SDV): The distance from a nuclear facility beyond which, for screening purposes, potential sources of a particular type of external event can be ignored.

The results of the report and conclusions reached in respect of the hazardous materials considered are included in (MHR, 2022).

The MHR study is supported by another study that included information more relevant to hazardous materials used as examples of GEN III NNI (PSI, 2022).

A summary information in the two reports' information with specific reference to the NNI and KNPS follows.

6.11.2.2 Consideration of hazardous material aspects in NNPS designs

6.11.2.2.1 On-site Hazardous Materials

The storage and use of non-nuclear hazardous materials on a site are important elements of the safety assessments of an NNI. Explosions and the accidental release of asphyxiating and toxic gases can potentially result in interacting events that compromise the function of SSCs important to nuclear safety. Most of the information relevant to on-site hazards requires knowledge of the lay-out of an NNI on site since distance, orientation of structures and meteorological conditions are determining factors.

Results of earlier hazardous material studies in the KNPS Safety Analysis Report (SAR) and External Event Safety Review (EESR) following the Fukushima accident are discussed in (PSI, 2022).

An overview is provided in the following two sub-sections of the design safety features claimed by the EPR and AP1000 NNIs in respect of hazardous materials.

6.11.2.2.2 AP1000

The AP1000 NNI design provides for protection from explosions outside of the nuclear island (Westinghouse, 2018). Any smoke or toxic gases that penetrate the AP1000 site boundary are considered in the context of internal or external hazards. The AP1000 plant main control room is designed to provide isolation from toxic smoke and gases generated on-site. The main control room is pressurised to a positive pressure using compressed air for a period of 72 hours which prevent toxic gases from entering.

The AP1000 design has been developed in accordance with US NRC Regulatory Guide 1.91 (U.S. NRC, 2013) which defines the safe distance from an explosion as the point at which the blast wave overpressure is limited to approximately 7 kPa (70 mbar); below this value no significant damage would be expected. (This is a higher value, for example, than 5 kPa specified for KNPS).

For those sources of flammable material, present outside the nuclear island which can form an explosive atmosphere, analysis has been performed to determine the distance from the centre of the vapour cloud explosion (VCE) by which point the blast overpressure would have dropped to 7 kPa.

The civil/structural design criteria define the overpressure resistance requirement for the external walls of the nuclear island as 34 kPa. The external walls of the nuclear auxiliary building are composed of nominally 0.6 m thick reinforced concrete walls. Similarly, the containment shield building (which envelops the reactor containment building) is constructed from two external 19 mm thick steel plates infilled with concrete, giving an overall thickness of 0.91 m.

Based on the standard plant layout, the assessments of explosions originating from the bulk hydrogen storage and other chemicals conclude that the blast overpressure would not exceed the 7 kPa threshold at the nuclear island exterior walls. The safety Class 1 SSCs within the nuclear island would therefore be unaffected by the postulated explosions and would continue to deliver their safety functions.

The examples of assessments of AP1000 hazardous materials are representative of the hazard assessments that have to be presented as part of safety case for an NNI to be constructed on the site. Specific design measures are described to reduce hazardous materials risks and include maximising the distances between the plant gas system, standby diesel fuel oil system, and the nuclear island, for example. These design lay-out features minimise the effects from a catastrophic loss of a bulk container of liquefied gas. Pipework are routed away from areas where safety important SSCs are present or where personnel are involved in safety-related operations. Hazardous materials involved in the operation of the AP1000 include the following and it is expected that these materials are common to PWR type NNIs:

- hydrogen;
- carbon dioxide;

- nitrogen;
- boric acid;
- lithium hydroxide;
- hydrazine;
- sodium hydroxide;
- diesel oil;
- trisodium phosphate (TSP);
- hydrogen peroxide;
- bottled gases;
- chemical inhibitors;
- refrigerant gases.

An overview is provided in (PSI, 2022) of the hazardous and storage safety aspects associated with on-site bulk storage of toxic, corrosive, asphyxiating and flammable materials used in the operation of the AP1000.

6.11.2.2.3 The EPR reactor

The safety design of the EPR includes similar consideration as described for the AP1000. The EPR development took external hazards into consideration at the NNI design stage consistent with internal events or internal hazards, i.e. to determine if EEs can act as interacting events that can contribute to the core damage frequency (CDF). The objective of the design provisions against external hazards is to ensure that the safety functions performed by the safety classified SSCs which are required to bring the plant in the safe shutdown state, are not affected by these hazards. Design provisions were made as necessary to limit the consequential failures of SSCs which could be sources of internal events or internal hazards (EDF, 2011).

The design includes extensive detail on the safety of the main control room against radiological and toxic gases. Design considerations include protection that may be achieved by geographical separation of the required systems or components against hazards which have localised effects such as chemical spills and explosions. Protection is justified by analysis of the consequences of a failure of unprotected equipment on a probabilistic basis.

EPR design verification for a construction licence has to be carried out in respect of explosions which require site specific information. The objective of the design verification is to evaluate, for each accident scenario, the safe distance similar to an SDV, beyond which a potential explosion/spill will not threaten any basic safety function, because the consequential pressure wave/impact on safety related SSCs has to be lower than the design load case. This evaluation assumes worst case meteorological conditions for the explosive gas cloud drift before the explosion or migration of the chemical/s involved. Where this deterministic approach does not allow the risk from external explosion to be excluded, a probabilistic assessment is carried out.

6.11.2.3 Conclusions

All hazardous installations and transportation of flammable, explosive and toxic materials further than the SDV equal to 10 km derived for the site, were excluded from the study (MHR, 2022). The SDV for various installations were developed from the results of a consequence analyses and these would be considered "safe" and would not affect the operation of the nuclear facilities on the site. Using the derived SDV, potential human-induced hazards were excluded from the study when their respective distances from the site were greater than the derived SDV.

Recent data on the Witzands water-treatment works, which is situated approximately 5.7 km north of Duynefontyn in (MHR, 2022) concludes that the biggest chlorine cylinder used at the facility is a 70 kg unit with a total of 19 cylinders and a full release would not affect the site.

Rail transportation distances exceeded the SDV and thus would not impact the site.

The main road transport routes are outside the respective SDV for hazardous chemicals being transported on these roads, except for chlorine and sulphur dioxide. A probabilistic assessment in (MHR, 2022) concluded that a screening probability equal to 1.0 E-07/y fatalities is complied with.

The hazardous materials stored at the KNPS and proposed inventories of the new NNI to be stored at the site could potentially have impacts on each other during large accidental releases. Central storage of hazardous materials for KNPS and new NNI that may require large volumes should be avoided. ***Chapter 3*** includes a statement that no KNPS safety related systems or equipment will be shared or cross-connected with the new nuclear installation(s). Centralised storage of hazardous material, should it be considered for KNPS and a new NII, may pose higher risks than decentralised storage areas.

Hazardous materials will be used during the construction of a NII on the site. Risks posed to KNPS should be investigated when the nature and extent of these future activities have been defined.

The Port of Cape Town, the Port of Saldanha Bay and the shipping lanes are beyond the calculated SDV for the worst-case catastrophic event. The risk of ship accident nearer to the site than the shipping lanes is included in ***Section 6.11.3***.

The design safety features of a selected NNI in respect of on-site hazardous materials will have to be confirmed during a licensing stage following a NISL, taking into consideration the specific NNI lay-out on the site and site specific EEs. It must be verified that the selected design provide assurance that the functions which are needed to achieve the primary safety objectives are not compromised by events resulting from external hazards that include human induced on-site EEs.

It is recommended in (MHR, 2022) that Eskom can prevent future hazardous installation developments that could pose a threat to the site by using the Occupational Health and Safety Act 85 of 1993 and the Major Hazard Installation Regulations.

Screening status:

- ***Out unconditionally but only for off-site hazardous materials***.

  Criterion 2 - the event cannot occur close enough to the NNI to affect it.

- ***In for on-site assessments***

  Hazardous material volumes and locations during NNI construction and their final storage during operation of the NNI and KNPS have to be assessed in the next licensing phase for NNI.

6.11.3 Hazards from Nearby Sea Shipping Routes

The site is situated adjacent to the main traffic routes for vessels moving from both south-to-north and north-to-south rounding the tip of Africa. The site is situated on a significant shipping route and bulk carriers constitute the majority of the traffic, followed by container vessels, oil tankers and general cargo vessels. For example, the evaluation of shipping lanes determined that significant volumes (109.7 × 10^6 t) of crude oil was transported past the site during 2019 (***Section 5.7*** Nearby transportation, Industrial and Military Facilities). This volume has however decreased significantly since the peak period in 1997 when 630.0 × 10^6 t passed around the South African coastline. A total of 118 004 vessels (bulk carrier, cargo, contain and tanker ships) past the site during 2020. A ship accident could for example result in an oil spill, release of hazardous gases and damage to cooling water intake structures. Three ships have sunk/grounded in the site vicinity and an additional eight accidents were recorded in the site region for the period 1994 to 2018. Five significant oil spills have occurred in the site region for the same period.

Oil entrained in the cooling water intake system would be taken up into the condenser, foul the inside of the tubes resulting in the deterioration of heat transfer. Ships can stray from mandatory shipping lanes and approach the area where the cooling water intake structure is located and potentially damage this structure. Oil tankers, for example, categorised as Ultra Large Crude Carriers can have a draft that exceeds 30 m and could damage submerged cooling water intakes if they accidently run aground.

Hazardous Material	Quantity	Location	Distance and Direction	SDV Criterion	SDV Distance	Impacts on Site
Petroleum	14 000 ℓ	KNPS	-	Explosion 2 kPa	645 m	No
	90 ℓ	Melkbosstrand NSRI	5.8 km S	Explosion 2 kPa	-	No
	92 000 ℓ	Caltex, Melkbosstrand	6.0 km S	Explosion 2 kPa	645 m	No
	69 000 ℓ	Sasol, Melkbosstrand	6.2 km SSE	Explosion 2 kPa	645 m	No
	92 000 ℓ	Total, Melkbosstrand	6.9 km SSE	Explosion 2 kPa	645 m	No

Hazardous Material	Quantity	Location	Distance and Direction	SDV Criterion	SDV Distance	Impacts on Site
	400 ℓ	Wesfleur WWTW	9.0 km NNE	Explosion 2 kPa	645 m	No
Diesel	274 000 ℓ	KNPS	-	Explosion 2 kPa	645 m	No
	23 000 ℓ	Caltex, Melkbosstrand	6.0 km S	Explosion 2 kPa	645 m	No
	23 000 ℓ	Sasol, Melkbosstrand	6.2 km SSE	Explosion 2 kPa	645 m	No
	46 000 ℓ	Total, Melkbosstrand	6.9 km SSE	Explosion 2 kPa	645 m	No
	16 000 ℓ	Apollo Bricks	7.6 km NE	Explosion 2 kPa	645 m	No
	59 400 000 ℓ	Ankerlig OCGT	9.8 km NNE	Explosion 2 kPa	645 m	No
LPG	18 kg	NSRI, Melkbosstrand	5.8 km S	BLEVE 2 kPa	41 m	No
	18 kg	Caltex, Melkbosstrand	6.0 km S	BLEVE 2 kPa	41 m	No
	40 000 kg	Sasol, Melkbosstrand	6.2 km SSE	BLEVE 2 kPa	645 m	No
	2 000 kg	Total, Melkbosstrand	6.9 SSE	BLEVE 2 kPa	645 m	No
Oxygen	11.5 kg	KNPS	-	Catastrophic Failure	28 m	No
Acetylene	8.5 kg	KNPS	-	Explosion	47 m	No
Carbon Dioxide Gas	31.3 kg	KNPS	-	Catastrophic Failure	28 m	No
Liquid Carbon Dioxide	31.1 kg	KNPS	-	Catastrophic Failure	28 m	No
Nitrogen	11.0 kg	KNPS	-	Catastrophic Failure	28 m	No

Hazardous Material	Quantity	Location	Distance and Direction	SDV Criterion	SDV Distance	Impacts on Site
Propane Butane	48 kg	KNPS	-	BLEVE 2 kPa	41 m	No
Helium	1.51 kg	KNPS	-	Catastrophic Failure	23 m	No
Nitrogen-oxide	31.3 kg	KNPS	-	Catastrophic Failure	32 m	No
Air Dry	8.5 kg	KNPS	-	Catastrophic Failure	-	No
Argon UHP	17.4 kg	KNPS	-	Catastrophic Failure	23 m	No
Argon High Purity	3.5 kg	KNPS	-	Catastrophic Failure	23 m	No
Argonmethane	Unknown	KNPS	-	Catastrophic Failure		No
Hydrogen (3%)/Nitrogen (97%)	60.0 ℓ	KNPS	-	Catastrophic Failure	27 m	No
Hydrogen (10%)/Nitrogen (90%)	60.0 ℓ	KNPS	-	Catastrophic Failure	27 m	No
Hydrogen (100%)	4 x 550 m3	KNPS	On Site	Catastrophic Failure	538 m	1.0E-6
Hydrogen (100%)	27 x 14x 1,93 m3	KNPS	On Site	Catastrophic Failure	138 m	1.0E-6
Technical Air	8.5 kg	KNPS	-	Catastrophic Failure	-	No
Helium, instrument grade	10.0 ℓ	KNPS	-	Catastrophic Failure	23 m	No
Hydrogen, instrument grade	10.0 ℓ	KNPS	-	Catastrophic Failure	17 m	No
Ammonia	3 000 kg	KNPS	-	Catastrophic Failure	156 m	No

Hazardous Material	Quantity	Location	Distance and Direction	SDV Criterion	SDV Distance	Impacts on Site
Caustic	23 227 kg	KNPS	-	Catastrophic Failure	7 m	No
Sulphuric Acid	47 603 kg	KNPS	-	Catastrophic Failure	7 m	No
Sulphuric Acid	18 – 20 t	Witzands WTW	5.73 km N	Sulphuric Acid	7 m	No
Coal	860 t	Apollo Bricks	7.6 km NE	-	-	No
Oil	1 260 ℓ	Apollo Bricks	7.6 km NE	-	-	No
Chlorine	70.0 ℓ	KNPS	-	Catastrophic Failure	222 m	No
	1 500 kg	Witzands WTW	5.73 km N	Catastrophic Failure	222 m	No
	400 kg	Melkbosstrand WWTW	4.9 km SE	Catastrophic Failure	222 m	No
	400 kg	Wesfleur WWTW	9.00 km NNE	Catastrophic Failure	222 m	No
Propane	22.4 m3	Ankerlig OCGT	9.8 km NNE	BLEVE	645 m	No
Un-organic fertiliser	813 t	Farms in the site vicinity	8.4 km NE	Explosion 2 kPa	312 m	No
Organic fertilizer	586 t	Farms in the site vicinity	8.4 km NE	Explosion 2 kPa	312 m	No
Chlorine Road Tankers	8 400 kg	R27 Road	2.3 km E	Catastrophic Failure	2970 m	1.0E-9
Sulphur Dioxide Road Tankers	15 t / Day	R27 Road	2.3 km E	Catastrophic Failure	3850 m	1.0E-10
Petrol and Diesel Road Tankers	560 m3 /Year	KNPS	On Site	Catastrophic Failure	On Site	1.0E-9

Appendix 6-B describes a methodology to conservatively estimate the annual frequency of a ship accident that could have an impact on the site. It shows a fairly high frequency which is supported by actual oil spills that have occurred in the vicinity of the site. Examples of events that affected KNPS to varying degrees by oil at sea are described in (Moldan, 2008) and include the following:

• *Afrikaner* – sank after striking Whale Rock, south of Robben Island in 1994. Koeberg and surrounding beaches were oil affected for about one month;

• *Apollo Sea* – sank after leaving Saldanha harbour in June 1994 – Koeberg was affected by oil for about one month;

• *VLCC Tochal* – A bulk carrier with a large hole in the bow limped around the peninsula into False Bay for repairs and affected parts of the western coastline intermittently for a few weeks.

• *Treasure* – An iron ore carrier sank 10 km due west of Koeberg in June 2000, and oil affected Koeberg and its beaches.

• *Seli 1* – ran aground in Table Bay (Dolphin Beach) on 7 September 2009, and has on at least two occasions threatened Koeberg with releases of oil.

A ship accident will not necessarily result in a threat to safety related SSCs. Wind direction and emergency response actions, for example, will lower the annual occurrence frequency of an actual impact on the cooling water intake structures and the heat sink safety function. The site specific oil spill risk assessment in (Moldan, 2008) describes design options and mitigation measures. The potential consequences of an oil spill were also assessed as part of a safety re-assessment for the KNPS (Eskom, 2011). The aim of the assessment was to determine KNPS's robustness to handle a potential oil spill. The conclusion reached was that it is unlikely that an oil spill off the west coast of South Africa will lead to a safety cliff edge effect with regard to nuclear reactor core cooling.

Screening status: In for the NNI and Out for KNPS.

A ship transport accident has to be considered as a DBEE for the purpose of the design of the NNI seawater intake and outlet structures as well as operating mitigation procedures.

6.11.4 Loss of Off-Site Power

A loss of off-site power (LOOP) event is considered to be a total loss of external power supplies to the site. International experience and especially the recent events at Fukushima show that the LOOP together with the failure of on-site backup systems can have severe consequences. The site specific mean frequency and length of interruption to the main grid transmission lines has to be provided for the site when more detail on the grid, its interaction with the site and NNPS design become available. The European Utility Requirements (EUR) describes LOOP events applicable to the French grid and data is presented in ***Table 6-14***. Examples of load follow and grid requirements are those for the standard design of the EPR (EUR, 2001):

- minimum short-circuit power of the main grid: 5 000 MWA;
- minimum short-circuit power of the stand by offsite grid:

– 110 kV: 2 000 MWA;

– 225kV: 3 000 MWA.

A LOOP should be assumed coincident with any extreme external event (e.g. extreme flood) if a direct or indirect causal relationship cannot be excluded (IAEA, 2003). For EEs that could result in an unplanned turbine trip or reactor trip that would increase the potential for grid instability, a coincident LOOP is normally postulated for purposes of design basis analysis.

Table 6-14: Examples of Loss of Off-site Power Parameters for a PWR

Event	Mean Time for Grid to Recover	Estimated Annual Frequency	Comment
Short time LOOP	0.5 h	5×10^{-2}	Short time LOOP corresponds to most frequent grid failures, with a short recovery time.
Medium time LOOP	24.0 h	2×10^{-4}	Medium time LOOP corresponds to switchgear accidents, being a common cause for both normal and auxiliary line power supply failure.

Event	Mean Time for Grid to Recover	Estimated Annual Frequency	Comment
Long time LOOP	192.0 h	1×10^{-3}	Long time LOOP is composed of less frequent grid faults between the plant and the transformer and off-line accidents due to climatic causes in the vicinity of the plant, both associated with a long recovery time.

Eskom has completed a safety re-assessment as part of the External Event Review of KNPS that focussed on EEs following Fukushima-Daiichi nuclear accident. The safety re-assessment included LOOP. The insights gained by KNPS provide valuable reference information when considering an NNI design in a future NIL to site/construct. The safety re-assessment is documented in an interim safety re-assessment report, number EERT-11-013 (Eskom, 2016). The report contains an assessment of the robustness of the KNPS design to maintain its safety functions when challenged by hazards beyond the design basis for the plant. Vulnerabilities and proposals for nuclear safety improvements were identified. Some of the specific EE scenarios that have been considered are:

- LOOP;
- station black-out (SBO), defined as a LOOP and a loss of all the EDGs;
- total station black-out, defined as an SBO with the additional loss of the station black-out diesels (LLS);
- loss of ultimate heat sink (LUHS) (i.e. loss of sea water cooling);
- combined loss of ultimate heat sink and station black-out.

The focus of the LOOP study (Eskom, 2011) was on the ability of the plant to survive a prolonged loss of external support for up to 14 days. This duration is based on insights from the Fukushima accident, the relative isolation of KNPS from support institutions, and the perceived ability of disaster management to cope with both the direct impact of the external event on the community and the evolving events at KNPS.

Screening status: In for NNI and Out for KNPS

For KNPS the risk is mitigated through mobile emergency diesel generators purchased following the external event review.

6.11.5 Electromagnetic Interference (other than solar storms)

Potential sources of electromagnetic interference that could cause malfunction in or damage to safety related equipment or instrumentation have to be identified. ***Section 5.7*** (***Subsection 5.7.15.1***) describes the electromagnetic infrastructure in the site vicinity. If such interference is possible, protective measures should be allowed for in the design of the plant.

Operational experience from the nuclear industry indicates that the interference can be initiated by both on-site (high voltage switch gears, portable telephones, portable electronic devices and computers) and off-site (radio interference and telephone network) sources (IAEA, 2021). Design of safety systems normally includes qualification in terms of potential electromagnetic environments and the Eskom set of reference NNI represents the latest nuclear technology.

Screened status: Out (conditionally) for NNI and (unconditionally) for KNPS.

Screening Criteria: Criterion 1 - the event is of equal or lesser damage potential than the events for which the nuclear installation(s) is planned to be designed.

For KNPS the event is dealt with in the design and operation of the facility as well as the security protocols.

6.12 Extra-Terrestrial Events

It is assumed that the event and frequency at the site of events of this nature, e.g. asteroids, and meteors, is beyond the design basis. These events, in accordance with EUR requirements for Light Water Reactor (LWR) Nuclear Power Plants (EUR, 2001), should not be considered in the design. However, an exception is the occurrence of extreme space weather events such as a solar storm.

Screening status: Out for both KNPS and NNI

6.13 Combination of External Events

6.13.1 Introduction to identifying combinations of external events

The IAEA Expert Mission to Fukushima in June 2011 states in their report that severe long-term combinations of EEs should be adequately covered in design and operations of a nuclear installation (IAEA, 2011). The Fukushima Dai-ichi NNI survived the earthquake of a magnitude that caused ground motion beyond the design basis of some NNI structures. It was the subsequent tsunami that resulted in a severe accident progressing into a BDBA.

Lessons learnt from the Fukushima Dai-ichi accident have been taken into account in the design of GEN III NNIs. External event reviews and so-called stress tests have also been carried out to identify potential weaknesses in currently operating NNIs should extreme EEs be experienced, also for KNPS (Eskom, 2015). The insights obtained from the stress tests are used to strengthen the design and improve response to design extension conditions beyond the design basis. The following example is provided of an NNI that had to demonstrate inclusion of lessons learned and resulting design consideration following the Fukushima Dai-ichi accident. It is accepted that the NNR will request similar evidence from a future vendor during a licensing stage subsequent to a NISL.

The UK Office for Nuclear Regulation (UK ONR) raised an issue with EDF and AREVA during the generic design assessment (GDA) of the EPR NPS (also referred to as UK EPR™) (UK HSE, 2013). This GDA issue requested evidence how lessons learnt from the events at Fukushima were accounted for. The approach taken by EDF and AREVA was to review the robustness of the UK EPR™ design against severe external events and, where appropriate, to identify and develop potential design enhancements recognising developments in other EPR™ projects and wider international initiatives. EDF and AREVA provided reports covering:

- review of UK EPR™ robustness against seismic and external flooding events;
- review of UK EPR™ ability to withstand loss of power and cooling;
- review of UK EPR™ severe accident management arrangements to mitigate the consequences of such events;
- summary of how the recommendations from the Chief Inspector’s report have been addressed for the UK EPR™;
- a description of the enhancements identified from EDF and AREVA’s post Fukushima reviews;
- work undertaken to address other GDA issues that identified design changes which improve the robustness of EPR™ against extreme events;
- a new Pre-Construction Environment Report sub-chapter dealing with post Fukushima reviews.

From their reviews EDF and AREVA identified design change proposals for GDA that the regulator accepted provide the following:

- improved flood protection for emergency electrical supplies (both AC and DC);

- extension of the capability and autonomy of emergency electrical supplies (both AC and DC);
- identification of connection points for proposed mobile diesel generators;
- addition of Spent Fuel Pool (SFP) instrumentation into the severe accident management Control and Instrumentation (C&I) systems;
- provision of connections to enable delivery of water via mobile pumps for SFP make-up and containment pressure control.

6.13.2 An approach to assess combinations of EEs

Appendix 6-C includes a comprehensive list of EEs posing potential hazards to an NPS, some of which have been identified for the site and described in earlier sections. The list which was produced by the University of Vienna and co-funded by European Commission (Decker, 2017) resulted in the identification of 577 possible correlations between individual EEs and 82 combinations of mutually exclusive EEs (hazards from EEs which cannot apply to an NPS at the same time). Correlations discriminate between:

1) Causally connected EEs (cause-effect relation) where one EE (e.g., liquefaction) may be caused by another EE hazard (e.g., earthquake); or where one EE (e.g., high wind) is a prerequisite for a correlated EE (e.g., storm surge). The identified causal links are not commutative.
2) Associated EEs (“contemporary” EEs) which are probable to occur at the same time due to a common root cause (e.g., drought and high temperature).
3) EEs that occur contemporaneously by random coincidence. Such combinations cannot include EEs which are mutually exclusive (e.g., high temperature and surface ice).

An example of a combination of mutually exclusive EEs, i.e. an implausible combination, is to experience a veld fire challenging the off-site power lines while a tropical cyclone accompanied by severe rain is in progress. Combinations should also be credible. The term credible implies that the likelihood of the combination is not insignificantly small. The likelihood a combination of the simultaneous occurrence of a tsunami and aircraft crash is deemed not credible.

The identification of plausible and credible combinations of events is carried out by using an EE combination matrix as is illustrated in ***Appendix 6-E***.

The main purpose of such a matrix is to facilitate a systematic and iterative process to either screen out combinations or to identify combinations of events for further assessment. It requires that each combination has to be interrogated in a systematic manner, using expert opinion, published literature and studies on EEs and prior assessments of single EE (e.g., aircraft crash study for KNPS), if available. Events initially screened out based on an assessment of single event considerations may have to be included in the matrix. The matrix provides an auditable trail of the combination selection process, e.g. the combination of {Organic Material in Intake Basin Sea Water} and {High Sea Water Temperature} and {LUHS (loss of ultimate heat sink)}. It has the purpose of answering the question whether there is a correlation between jellyfish and sea water temperature and whether it can increase the likelihood of a deteriorating heat sink function provided by the sea.

6.13.3 Combined events probabilistically assessed for the Duynefontyn site

6.13.3.1 Site probabilistic assessment of combined events

Limited but safety important combined event probabilistic assessment was performed for flooding events taking into account extreme meteorological and tsunami events (see ***Section 6.10.4*** and ***Section 5.9***). From all of the potential flooding hazards the most severe and relevant hazards for the nuclear installation(s) at the site were combined to obtain the maximum and minimum water levels at the site. The maximum water levels are required for the flooding risk assessment, while the minimum water levels are related to the exposure of the cooling water intake.

6.13.3.2 KNPS External Event Review

A KNPS report on external hazards and combinations was compiled as part of the KNPS External Event Review Initiative (EERI) (Eskom, 2015). Its purpose was '*to identify those external hazards and assess to a required detail of risk for KNPS*'. The report deals with the identification and screening of what is defined as '*plausible EEs that require stress tests*'. A comprehensive list of potential hazards applicable to nuclear installations was developed of which some correspond to those identified and evaluated in this chapter, ***Chapter 6***.

Screening criteria were used in the KNPS external event review (EER) to eliminate implausible external hazards that do not pose any risk to KNPS and to identify a list of plausible EE hazards that should be assessed. The document further identified plausible combinations of EE hazards that require assessment. These combinations include additional consequential hazards or induced failures, correlated hazards, and plausible coincidental hazards. Consequential hazards are additional hazards that are induced by the initial hazard, and include the initiation of additional off-site hazards, or additional failures induced on the plant that could result in explosion, fire, flooding and chemical releases that could further exacerbate plant failures or inhibit the mitigation of the initial hazards. Correlated hazards are defined as hazards that do or can occur simultaneously. An example is high winds, lightning, extreme precipitation and hail, all of which could occur simultaneously in a severe thunderstorm. Finally, co-incident hazards are independent events that occur either often enough, or for a prolonged duration such that the chances of them occurring simultaneously is not incredible.

6.14 Monitoring

The process of site evaluation continues throughout the lifetime of the nuclear installation(s), from siting through nuclear installation design, construction, operation to decommissioning. Therefore, characteristics of the natural and human induced hazards, as well as demographic, meteorological and hydrological conditions of relevance to the nuclear installation(s) at the site will be monitored over the lifetime of the facility (see ***Section 5.2***). Key parameters related to external hazards are identified in ***Sections 5.7*** to ***5.15*** and are being monitored as part of this SSR.

The preliminary external hazard identification and event evaluation for the site presented in this chapter have identified a relevant selection of hazards and events. Periodic review of this selection of events, in terms of completeness and detail on the hazard parameters, is required.

6.15 Management of Uncertainties

The management system to update information and manage uncertainties in data collected for ***Chapter 5*** also applies to the information in ***Chapter 6***. The main approaches adopted for management of uncertainties associated with EEs identified are:

- use of best and most reliable sources of data for the site;
- use of relevant data for the site region;
- continuation with the monitoring activities and where necessary expanding the scope of the programme;
- update of this SSR at regular intervals in line with the requirements as contained in the siting regulations;
- application of a conservative approach;
- use of experience from other similar facilities and best international standards and recommendations.

Specific consideration has to be given to the evolving nature of human activities and which could develop into significant external hazards. It is difficult to predict the future developments around the proposed nuclear installation(s) at the site, especially the establishment of specialised industries supporting the nuclear installation. Of concern are installations that may have impacts beyond the site boundary. In accordance with the Occupational Health and Safety Act, Act No. 1993, any installation that poses a risk to both the workers and the public is classified as a Major Hazard Installation (MHI) and is required to comply with legislation. With use of the MHI regulation, Eskom can prevent future hazardous installations from being erected within a distance that may pose a risk to the nuclear installation(s).

6.16 Regulatory Compliance and Management System

Specialist studies followed the interim guidance provided by the NNR (NNR, 2016) and the NNR position paper on external events (NNR, 2014). Compliance to NNR requirements and guidance are included in ***Chapter 2 and Chapter 5 Sections***. The specialists who carried out studies followed a quality assurance programme that was established to control the effectiveness of the execution of these investigations, the data analysis and the formulation of conclusions on the site acceptability. This conforms to the overall management system for this SSR (***Chapter 10***, Management System).

Full compliance with the regulations on licensing of sites requires a design specific PSA for NNI, which will only be possible when the final nuclear installation design information is available.

6.17 Conclusions

EEs addressed in this chapter are either:

- screened out unconditionally as the demand from the event on the nuclear installation(s) at the site is less than that specified in the PPE or the current KNPS design basis;
- screened out on condition that the screening status be confirmed when the specific design is selected for NNI or ongoing studies such as bedrock mapping at the NNI footprint is performed;
- screened in as specific checks will be required in the design qualification of the NNI on the site and/or design mitigating action taken to ensure the LTO of KNPS.

The site characterisation assessments have identified changes in the hazards relating to seismic, flooding from tsunami, coastline erosion and wind speeds. Coastline erosion, and wind speeds were found to be low risk hazards to the Koeberg site. The assessment revealed that the probable maximum tsunami (PMT) run-up and inundation are governed by the volcanic flank collapse tsunamis. Further analysis were carried out and the results have shown that the risk is lower than 1E-5.

Relating to the seismic hazard, SSHAC studies were conducted, and the results show that the design basis spectrum is at 0.36g as opposed to the original KNPS design of 0.3g. The interim Seismic Evaluation conducted by Eskom can be considered unaffected by the SSHAC results, hence the conclusions of the Interim Seismic evaluation that provides reasonable assurance that the KNPS units are sufficiently robust to shut down safety and cope with significant seismic event and loss of AC power, remain valid.

Based on the information presented in ***Chapters 5*** and ***6*** it is concluded that the site is suitable to accommodate an NNI and for the continued operation of the KNPS.

A summary of the screening status of EEs is provided in ***Table 6-15***.

Table 6-15: External Events Screening

External Event	New Nuclear Installation		Koeberg Nuclear Power Station	
	Screening Result	**Comment**	**Screening Result**	**Comment**
Earthquake Induced Ground Shaking and Surface Faulting	In	SSHAC studies completed. Seismic PSA to be completed.	In	SSHAC results shows a slight increase in the PGA value from 0.3 to 0.36. Seismic PSA to be completed.
Volcanism	Out	Volcanic flank collapse a potential tsunamigenic source (screened in under flooding from the sea)	Out	Volcanic flank collapse a potential tsunamigenic source (screened in under flooding from the sea).
Groundwater Level	In	Groundwater levels at the new build site could rise to a maximum of 4 to 5 m above current levels. This would bring the groundwater in many of the lower-lying parts of the site to within 1 m (and higher) of ground surface, thus increasing the potential for local flooding. To be considered during the design of the NNI	Out (conditionally)	Not of safety significance but need to be monitored for the LTO operational period. Monitored as part of the groundwater monitoring programme.
Water Quality	In	Corrosion risk to foundations is	Out (conditionally)	Not of safety significance however a

External Event	New Nuclear Installation		Koeberg Nuclear Power Station	
	Screening Result	Comment	Screening Result	Comment
		considered to be low. Mild/carbon steel high corrosion rates should be expected. Because of the coastal environment, use of corrosion resistant materials must be considered in the NNI design.		groundwater protection programme is being implemented to monitor corrosion risk to the foundations for the LTO operational period.
Collapse, Subsurface Movement or Uplift of the Site Surface	Out	The event is of equal or lesser damage potential than the events for which the NNI is planned to be designed.	Out	The event is of equal or lesser damage potential than the events for which the plant is designed. Incorporated into the design.
Soil Liquefaction	In	Liquefaction risks to be taken into consideration in design and construction of a new nuclear installation(s). Same method could be used as was used for KNPS to eliminate liquefaction potential.	Out	Liquefaction potential was eliminated for the KNPS nuclear island using cement stabilised soils during construction.
Slope Instability	Out (conditionally).	The event is of equal or lesser damage potential than the events for which the NNI is planned to be designed. To be considered during construction of NNI.	Out	The event is of equal or lesser damage potential than the events for which the KNPS is designed. Incorporated into the design.
Behaviour of Foundation Materials	Out (conditionally).	The event is of equal or lesser damage potential than the events for which the NNI is planned to be designed.	Out	Not applicable to KNPS

External Event	New Nuclear Installation		Koeberg Nuclear Power Station	
	Screening Result	**Comment**	**Screening Result**	**Comment**
Meteorological events: - wind field parameters, including wind speeds and gusts - air temperature, including dry- and wet-bulb temperatures - rainfall - lightning - blizzards - barometric pressure - corrosivity potential - tornadoes - atmospheric turbulence - prolonged inversions - snowfall - lightning - thunder - hail - frost - fog - relative humidity	Out	The event is of equal or lesser damage potential than the events for which the NNI is planned to be designed. The event has a significantly low mean frequency of occurrence when considering regulatory target safety goals, taking into account the uncertainties in the estimates, where available data permit.	Out (conditionally)	F3-F4 does not occur on the site Hurricane force winds and tornadoes were not considered in the original design for KNPS. Events have very low frequency of occurrence.

External Event	New Nuclear Installation		Koeberg Nuclear Power Station	
	Screening Result	Comment	Screening Result	Comment
- solar radiation - evapotranspiration				
Hydrological events: - flooding from the sea; - extreme low water levels; - thermal plume dispersion and recirculation; - extreme seawater temperatures; - sedimentation and scour; - erosion from the sea; - landslide into water	In	Tsunami risk and storm-surge are significant hazards that must be considered in the design of the NNI. Terrace to be located above the PMT. Coastline erosion is identified as a significant hazard that will need to be taken into account in the design of the NNI.	Out (conditionally)	Although the Tsunami risk resulting from a volcanic flank collapse indicate a Probable Maximum Tsunami (PMT) higher than the current terrace level, further analyses have shown that the frequency is lower than 1E-5 which does not affect the design of the plant. Coastline erosion is evolving very slow and it is monitored as part of the engineering programme.
Biological Phenomena and Related Events	Out (conditionally)	The event is of equal or lesser damage potential than the events for which the NNI is planned to be designed. NNI intakes could be designed to cope with the marine species found at the site and to minimise the risk of complete	Out (conditionally)	The potential impact of marine organisms on the cooling water supply can be dealt with through appropriate design and management measures. Monitoring required. Eskom has developed process and

External Event	New Nuclear Installation		Koeberg Nuclear Power Station	
	Screening Result	Comment	Screening Result	Comment
		blockage of the intake. It has to be confirmed that design and management measures will be adequate in respect of the ultimate heat sink when the NNI becomes available.		procedures to deal with this phenomenon.
External Flooding from Terrestrial Sources: - failure of human-made water retaining structures (e.g. dams) - changes in the natural channel for a river (including river diversions) - waterspouts - snow melt	Out	The event cannot occur close enough to the NNI to affect it. The event is included in the definition of another event.	Out	The average vulnerability and safety consequences are low.
On-site hydrology aspects (e.g. surrounding ponding areas)	In	The recommended terrace and other platform levels for the nuclear installation(s) would need to be considered during the detailed design phase.	Out	The majority of run-off occurs along drainage lines and temporary ponds within the low-lying areas.
Loss of Freshwater Supply	Out (conditionally)	A design specification for stored water volume to compensate for a loss of fresh	Out	Although KNPS has a guaranteed supply of fresh water for the period of

External Event	New Nuclear Installation		Koeberg Nuclear Power Station	
	Screening Result	Comment	Screening Result	Comment
		water supply will be required for the nuclear installation design. The event is of equal or lesser damage potential than the events for which the NNI is planned to be designed.		LTO, the drought experienced from 2015 to 2018 highlighted the need for alternative fresh water supply. Risk is however low.
External Fires	In	Mitigation against the occurrence of veld fires resulting in air pollution is included in nuclear installation design of ventilation systems. The event is therefore considered to be of equal or lesser damage potential than the events for which the NNI is planned to be designed. However, site specific mitigation measures are required and until these measures are in place, the event is screened in.	Out	Mitigation against the occurrence of veld fires resulting in air pollution is included in nuclear installation design of ventilation systems.
Aircraft Crash	Out (conditionally)	Confirm deterministic approach followed for future selected GEN III NNI for beyond design basis aircraft.	Out	Risk is considered low. Core damage frequency and large early release frequency within regulatory limits
Hazardous Materials –Land-Based Stationary and Transport Sources	Out (unconditionally	Hazardous material volumes and locations during NNI construction and	Out	Hazardous materials are screened out due to screening distance.

External Event	New Nuclear Installation		Koeberg Nuclear Power Station	
	Screening Result	Comment	Screening Result	Comment
	but only for off-site hazardous materials. 'In' for on-site hazards until construction licence confirms screening status)	their final storage during operation of the NNI have to be assessed in the next licensing phase.		
Hazards from Nearby Shipping Routes	In	A ship transport accident has to be considered as a design basis external event for the purpose of the design of the NNI seawater intake and outlet structures as well as operating mitigation procedures.	Out	Event unlikely to occur
Loss of Off-Site Power	In	The site specific mean frequency and length of interruption to the main grid transmission lines has to be provided for the site when more detail on the grid, its interaction with the site and NNI design become available.	Out	The loss of off-site power is mitigated through emergency diesel mobile generators purchased following the eternal event review where the risk of an extended loss of off-site power was identified.
Electromagnetic Interference (other	Out (conditionally)	The event is of equal or lesser damage	Out	The event is of equal or lesser

External Event	New Nuclear Installation		Koeberg Nuclear Power Station	
	Screening Result	Comment	Screening Result	Comment
than solar storms)		potential than the events for which the nuclear installation(s) is planned to be designed.		damage potential than the events for which KNPS is designed.
Extra-Terrestrial Events including solar storms	Out	Event is less likely to happen.	Out	Event is less likely to happen.

6.18 References

1. ALCADIA, 2006. Probabilistic Evaluation of the Risk of an Oil Spill Reaching the Heat Sink Intake Channel of the Koeberg Nuclear Power Plant. Technical Note No. 05-075/12.XXX), s.l.: s.n.
2. ANS, 2007. American National Standards Institute ANSI/ANS 58.21: External Events PRA Methodology, Illinois: American Nuclear Society.
3. Council for Geoscience, 2004. Eskom's Coastal Nuclear Sites: Site-Specific Seisic Design Baselines. Ref 2004-0188, Pretoria: Council for Geoscience.
4. Council for Geoscience, 2024. Enhanced SSHAC Level 2 Probabilistic Seismic Hazard Analysis for the Duynefontyn nuclear site, Pretoria: Council for Geoscienc.
5. Dames & Moore, 1981. Seismic Design Requirement, Koeberg Nuclear Power Station. Job no 9629-041-45, Johannesburg: Dames and Moore.
6. Decker, K. B. H., 2017. Advanced Safety Assessment Methodologies: extended PSA. List of external hazards to be considered in ASAMPSA_E. Technical report ASAMPSA_E /WP21/D21.2/2017-41. Reference IRSN PSN-RES/SAG/2017-00011, Vienna: EURATOM.
7. Department of Energy, 2011. The Regulations on Licensing of Sites for New Nuclear Installations, 2010. Government Gazette 34735, Pretoria: Government Gazette.
8. Department of Minerals and Energy, 2006. R.388: Regulations in Terms of Section 36, Read with Section 47 of the National Nuclear Regulator Act, 1999 (Act No. 47 of 1999), on Safety Standards and Regulatory Practices. Government Gazette 28755, Pretoria: Department of Minerals and Energy.
9. EDF, 2011. UK EPR Pre-Construction Safety Report PCSR-Sub-chapter 13.1 – External Hazard Protection UKEPR-0002-131 Issue 04, s.l., s.l.: AREVA NP & EDF SA.
10. EPRI, 2011. Identification of External Hazards for Analysis in Probabilistic Risk Assessment, Palo Alto: Electric Power Research Institute.

11. EPRI, 2015. Site Selection and Evaluation Criteria for an Early Site Permit Application. Siting Guide 1006878. Final Report, Cocord: Electric Power Research Institute.

12. Eskom, 2011. Interim Safety Re-Assessment: Oil Spill Hazard report. Report No. EERT-11-022 Revision 0, Cape Town: Eskom.

13. Eskom, 2011. Loss of Off-Site Power: EERT-11-26 Rev 0, Cape Town: Eskom.

14. Eskom, 2015. External Hazard Screening Assessment: Individual Hazards and Combinations Ref No. EERT-12-0221-RPT Rev 1., Cape Town: Eskom.

15. Eskom, 2015. Solar Storm Hazard Report EERT-12-010-RPT, Cape Town: Eskom.

16. Eskom, 2016. Koeberg External Events Safety Reassessment Report EERT-11-013 Rev 5, Cape Town: Eskom.

17. Eskom, 2023. Eskom Standard: Nuclear Engineering Plant Parameter Envelope Doc I.D NSIP03179, Cape Town: Eskom.

18. EUR, 2001. European Utility Requirements for LWR Nuclear Power Plants. Rev C, State 07., s.l.: European Utility Requirements Organisation.

19. Guo, J. et al., 2022. Damage Mechanism and Modeling of Concrete in Freeze–Thaw Cycles: A Review.. Buildings 2022, Volume 12, p. 1317.

20. IAEA SSR-2/1 , 2016. Safety of Nuclear Power Plants: Design, Vienna: IAEA.

21. IAEA, 2003. IAEA-TECDOC-1341. Extreme external events in the design and assessment of nuclear power plants, Vienna: International Atomic Energy Agency.

22. IAEA, 2006. IAEA TECDOC 1487. Advanced Nuclear Plant Design Options to Cope with External Events, Vienna: International Atomic Energy Agency.

23. IAEA, 2011. IAEA International Fact Finding Expert Mission of Nuclear Accident Following the Great East Japan Earthquake and Tsunami. Preliminary Summary, Vienna: International Atomic Energy Agency.

24. IAEA, 2011. Meteorological and Hydrological Hazards in SIte Evaluation for Nuclear Installations, Safety Standard Series, Specific Safety Guide No. SSG-18, Vienna: International Atomic Energy Agency.

25. IAEA, 2012. IAEA Safety Standards, Specific Safety Guide No. SSG-21. Volcanic Hazards in Site Evaluation for Nuclear Installations, Vienna: International Atomic Energy Agency.

26. IAEA, 2015. Site Survey and Site Selection for Nuclear Installlation, Vienna: Internation Atomic Energy Agency.

27. IAEA, 2019. IAEA SSR-1: Site Evaluation for Nuclear Installations, Vienna: International Atomic Energy Agency.

28. IAEA, 2021. IAEA Specific Safety Guide No. SSG 68, Design of Nuclear Installations Against External Events Excluding Earthquakes, Vienna: International Atomic Energy Agency.

29. IAEA, 2021. IAEA Specific Safety Guide No. SSG-68, Design of Nuclear Installations Against External Events Excluding Earthquakes, Vienna: International Atomic Energy Agency.

30. MHR, 2022. Risk Assessment for the Fire, Explosion and Toxic Vapour Cloud Impacts of Human-Induced Events from Transportation, Civil and Industrial Facilities at Duynefontyn, Cape Town: MHR Consultants.

31. Moldan, A., 2008. Oil Spill Impact Assessment Conducted for the Duynefontein Site, Cape Town: s.n.

32. Necsa, 2023. Report LSA-SRK2021-REP-0001 Rev02: Annual Aircraft Crash Rate for the Duynefontyn Site, Pretoria: Necsa.

33. NNR, 2012. PP-0009: Authorisations for Nuclear Installations. Rev 0. Centurion., Pretoria: National Nuclear Regulator.

34. NNR, 2014. NNR Position Paper PP-0014: Considerations of External Events for New Nuclear Installations. Rev 0., Centurion: National Nuclear Regulator.

35. NNR, 2014. PP-0014: Considerations of External Events for New Nuclear Installations. Rev 0 (Draft). Centurion., Pretoria: National Nuclear Regulator.

36. NNR, 2016. Interim Guidance on Safety Assessment of Nuclear Facilities (RG-0019) Rev 0, Pretoria: NNR.

37. NNR, 2016. NNR RG-0011 Interim Guidance for the Siting of Nuclear Facilities, Pretoria: National Nuclear Regulator.

38. PSI, 2022. Duynefontyn Site Safety Report Update: External Events and On-site Hazardous Materials, Cape Town: PSI Risk Consultants CC.

39. PSI, 2022. Suynefontyn Site Safety Report Update: External Events resIting from On-site Hazardous Materials, Cape Town: SRK Consulting.

40. Settler, E. G. G. K. A., 1999. A Summary of the Conclusions Reached on the Geophysical and Seismological Investigations for the Koeberg Nuclear Power Station During the Period July to August 1999. Report No. 1999-0159, Cape Town: Eskom.

41. Suyi Li, Q. M. X. Q., 2012. An Overview of Maritime Waterway Quantitative Risk Assessment Models National University of Singapore, Singapore: Risk Analysis. Vol.32 No 3 2012.

42. Thevik, H. S. E. F. T., 2010. A Method for Assessing the Risk of Sea Transportation: Numerical Examples for the Oslofjord, s.l.: s.n.

43. U.S. DOE, 2012. DOE-STD-1020-2002: Standard Natural Phenomena Hazards Analysis and Design Criteria for Facilities, Washington: U.S. Department of Energy.

44. U.S. NRC, 2009. US Nuclear Regulatory Commission Regulations. 10 CFR 50.150 Aircraft Impact Assessment. (74 FR 28112) , Washington DC: U.S. Nuclear Regulatory Commission.

45. U.S. NRC, 2013. Regulatory Guide 1.91: Evaluations of Explosions Postulated to Occur at Nearby Facilities and on Transportation Routes near Nuclear Power Plants. Regulatory Guide 1.191, Rev 2, Washington DC: U.S. Nuclear Regulatory Commission.

46. UK HSE, 2013. Generic Design Assessment –UK Health and Safety Executive - Office for Nuclear Regulation Report ONR-GDA-AR-12-025 Rev 0, s.l.: UK Health and Safety Executive.

47. US NRC, 2011. NUREG-1793: Final Safety Evaluation Report Related to Certification of the AP1000 Standard Design, Washington DC: US Nuclear Regulatory Commission..

48. Walder, J. & Hallet , B., 1985. A theoretical model of the fracture of rock during freezing. Geol Soc Am Bull , Volume 96, p. 336–346.

49. Westinghouse, 2018. UK pre-construction safety report Westinghouse Electric Company LLC.2016. AP1000 Pre-Construction Safety Report Report. UKP-GW-793, Revision 1 , s.l.: Westinghouse Electric Company LLC.

REDACTED

REDACTED

Appendix 6-B: An Estimate of a Ship Accident Frequency in the Vicinity of the Duynefontyn site

A ship accident occurrence frequency can be estimated using ship traffic data in the vicinity of the site to determine whether it has to be considered as a DBEE for an NNPS. The result of the frequency calculation that follows indicates that a ship accident has to be included as a DBEE in the safety analysis for an NNPS on the site. A PSA will require the most recent shipping information when a NNP safety analysis is done for a NIL to site/construct.

Ship accident risk analysis typically involves assessment of the following accident types (Thevik, 2010):

- collision - The frequency of inter-ship powered collisions at a given geographical location is estimated by considering close quarters encounters. A probability of a collision for each encounter provides the collision frequency. This probability is related to a number of factors including the visibility conditions and the extent of internal and external vigilance.
- powered grounding - The frequency of powered groundings that result from marine traffic lanes located in close proximity to the shoreline or shallow water is calculated. It is mainly based on a failure to make a critical course change.
- drift grounding - It is assumed that drift grounding occurs when a ship loses the ability to navigate, due to steering or engine failure, and is subsequently forced onto the shoreline through the action of wind or current. Fault tree analysis can be used to determine the frequency of propulsion and steering system breakdown. Probabilities for self-repair and rescue by anchoring or tug assistance within given time limits are taken into account.
- structural failure - The frequency of such accidents is calculated by applying an accident frequency factor per vessel hour at sea while underway. The frequency factor applied takes account of the severity of the sea conditions.
- fire and explosion - The frequency of such an accident is controlled by the number of vessel miles travelled. A frequency factor is derived from the historical data.

These methods calculate accident frequencies as the product of two terms and expressed by the following equation:

Accidents per Area and per Year
=
Number of Accident Type per Area and per Year
×
Probability of Accident per Critical Situation ………Equation 6.1

A ship accident probability was estimated for an impact area near the site. Information on global shipping accidents was gathered and combined with South African ship traffic statistics. The site is situated adjacent to the main traffic routes for vessels moving from both south-to-north and north-to-south rounding the tip of Africa. *Equation 6.1* is adapted in order to make use of global ship accident data listed in ***Table 6B.1***, ***Table 6B-2*** and ***Table 6B-3*** (Suyi Li, 2012) and South African ship traffic data in ***Section 5.7***.

Table 6B-1: Lloyd's maritime information services ship casualty database

Ship type	Fire and Explosion Frequencies (Number of Accidents per Ship-Hour)
Tankers	4.08×10^{-7}
Bulk ships	3.43×10^{-7}
General cargo ships	2.65×10^{-7}
Ferries	3.51×10^{-7}

Table 6B-2: Estimated annual frequency per ship of initiating events for container ships worldwide (International Maritime Organisation data 1990 to 2007)

Initial Event	Frequency of Accident (per ship-year)
Collision	1.61×10^{-2}
Contact	3.72×10^{-3}
Grounding	7.49×10^{-3}
Fire	3.65×10^{-3}
Explosion	1.90×10^{-3}
Heavy weather	2.64×10^{-3}
Non-accidental structural failure:	
Double Hull (DH) ships	1.93×10^{-3}
All ships	5.74×10^{-3}

Table 6B-3: Estimated annual frequency per ship of initiating events for container ships

Estimated Annual Frequency per Ship of Initiating Events for Various Ship Types							
	Single Hull Oil Tanker	Double Hull Oil Tanker	Oil / Chemical Tanker	Chemical Tanker	LPG Tanker	Bulk Carrier	LNG Carrier
Collision	9.90×10^{-3}	8.60×10^{-3}	4.30×10^{-2}	9.40×10^{-3}	2.20×10^{-2}	1.90×10^{-2}	6.70×10^{-3}
Contact	4.90×10^{-3}	3.10×10^{-3}	1.20×10^{-2}	4.60×10^{-3}	3.00×10^{-3}	1.10×10^{-2}	2.80×10^{-3}
Fire/Explosion Explosion	3.70×10^{-3}	1.10×10^{-3}	1.10×10^{-2}	4.50×10^{-3}	4.30×10^{-3}	2.90×10^{-3}	3.50×10^{-3}

The frequency of ship accidents in the impact area is estimated using the following conservative assumptions:

- The area at sea where ship accidents could result in accidents and potentially impact on the nuclear site is assumed to be a semi-circle of 50 km radius and includes the transverse ship traffic paths at the site. Section 5.7 reports that the minimum distance that traversing tankers, which do not call at the Port of Cape Town, can pass to the site is some 96 km summer (16 October to 15 March) and 87 km in winter (16 March to 15 October). Dry Cargo vessels need to keep a minimum distance of 65 km off the site. However, when tankers or dry cargo vessels are calling for replenishment off the Port of Cape Town, they may come within 46 km of the site.
- L, the maximum ship travel length in this area is <100 km.
- T, the journey time per ship through this area is assumed to be at most 5 h (100 km at 20 km/h). Typical speeds are nearer to 15 knots (roughly 28 km/h)
- N, the number of ships transiting this area is equal to the number of ships rounding the Cape in east and west directions. This number is 127 747, the maximum reported during 2015 to 2020 in *Section 5.7*. The maximum number of oil tankers in 2019 was 31 857.
- F, the max accident frequency is 4.9×10^{-6} per ship hour (***Table 6B-3***).

The annual oil tanker accident frequency (P) is:

P (oil tankers) $\leq T\times N\times F$

$\leq 5\times31\,857\times4.9\times10^{-6}$

$= 0.78/y$

The result appears to be overly conservative and it can be ascribed to the fact that the frequency value F also reflects ship traffic lanes that are much busier per sea surface area, such as near Singapore, than around the Cape. Section 5.7 reports that three ships have sunk/grounded in the site vicinity and an additional eight accidents were recorded in the site region for the period 1994 to 2018. Five significant oil spills have occurred in the site region for the same period.

The probability value, P, only estimate ship accidents in the impact area. An accident will not necessarily challenge nuclear safety of NPS. Wind direction and emergency response actions, for example, will lower the annual occurrence frequency of an actual impact on the cooling water intake structures and the heat sink safety function. However, the conservative estimates for ship accident frequencies indicate that the event should be considered as a DBEE. An earlier and detailed oil spill risk assessment for the site concluded that a definite risk does exist from oil spillages in the area of the site (ALCADIA, 2006). The study concluded that the probability of an oil spill originating from either an accident occurring during the transit of a vessel in a sea lane or an accident occurring within the Port of Cape Town and entering the cooling water intake basin within 10 hours would be 1.05×10^{-4}/y.

Appendix 6-C: Additional Information on External Events and Screening

Table 6C-1 provides an extensive list of EEs to be considered for NPSs. It is based on a research project initiated by EURATOM (Decker, 2017).

Table 6C-1: External Events

Code	External Hazard	Hazard definition and impact	Comment
N1	Vibratory ground motion	The hazard is defined by the contemporaneous impact of vibratory ground motion on all civil structures and SSCs of the plant and its surrounding.	Effects of long period ground motion and aftershocks need to be considered.
N2	Vibratory ground motion induced or triggered by human activity (oil, gas or groundwater extraction, quarrying, mine collapse)	The hazard is defined by the contemporaneous impact of vibratory ground motion on all civil structures and SSCs of the plant and its surrounding.	See note: N2
N3	Surface faulting (fault capability)	The hazard is defined in terms of impact on the plant of co-seismic fault rupture and surface displacement. It includes surface rupture at secondary faults.	See note: N3
N4	Liquefaction, lateral spreading	The hazard is defined by the loss of shear strength of foundation soil and its effects on civil structures and underground installations such as pipes or cable trays.	See note: N4.
N5	Dynamic compaction (seismically induced soil settlement)	The hazard is defined by the effects of soil settlement on civil structures and underground installations such as pipes or cable trays. It includes effects of seismically induced surface cracks.	

Code	External Hazard	Hazard definition and impact	Comment
N6	Permanent ground displacement subsequent to earthquake	The hazard is defined in terms of impact on the plant of permanent ground subsidence or ground heave due to strain release after an earthquake.	See note: N6. Ground settlement (N63) and ground heave (N64) due to other geological processes is treated separately.
N7	Tsunami (seismic, volcanic, submarine land-sliding, meteorite impact)	The hazard is defined by flooding by a series of water waves and the drawdown during the wave troughs.	See note: N7. Earthquake (N1), landslide (N60, N61), and volcanic hazards (N68, N69) are treated separately.
N8	Flash flood: flooding due to local extreme rainfall	The hazard is defined in terms of damage to the plant due to flooding by extreme rain.	See note: N8. Damage due to rain load on structures is treated separately (N25). Note links to other meteorological phenomena.
N9	Floods resulting from snow melt	The hazard is defined by flooding caused by seasonal or rapid snow melt.	Rapid snow melt due to volcanic phenomena is treated separately (N68).
N10	Flooding due to off-site precipitation with waters routed to the site (including river floods)	The hazard is defined in terms of damage to the plant due to flooding by waters routed to the site.	
N11	High groundwater	The hazard is defined in terms of damage to the plant due to flooding by high ground water.	
N12	Flooding or low water level due to obstruction of a river channel (downstream or upstream) by landslide, ice, jams caused by logs	The hazard is defined by flooding due to downstream river impoundment or by the breach of upstream river damming, and low water level due to upstream damming.	

Code	External Hazard	Hazard definition and impact	Comment
	or debris, or volcanic activity		
N13	Floods or low water level resulting from changes in a river channel due to erosion or sedimentation, river diversion	The hazard is defined by flooding due to changes of a river channel or low water level caused by such phenomena.	Instability of the coastal area due to erosion is treated separately (N23).
N14	Flood resulting from large waves in inland waters induced by volcanoes, landslides, avalanches or aircraft crash in water basins	The hazard is defined by flooding due to large waves in inland waters.	Flooding by wind induced waves is treated separately (N19).
N15	Flood and waves caused by failure of water control structures and watercourse containment failure (dam, dike, or levee failure)	The hazard is defined by flooding due to the failure of dams, dikes, or other water containments, e.g., due to hydrological or seismic effects.	
N16	Seiche	The hazard is defined by flooding due to fluctuations of water level due to standing waves in enclosed or partly enclosed bodies of water.	See note: N16. The effect of seiches may aggravate other hazard phenomena such as tsunami or tides.
N17	Bore	The hazard is defined by flooding due to high tide or spring tide.	
N18	Seawater level: high tide, spring tide	The hazard is defined by flooding due to high tide or spring tide.	
N19	Seawater level, lake level or river: wind generated waves	The hazard is defined by flooding due to wind generated waves including	See note: N19 for rogue waves. Such waves are not

Code	External Hazard	Hazard definition and impact	Comment
		long-period, short-period, and rogue waves (freak waves).	predictable and progress rapidly.
N20	Seawater level: storm surge	The hazard is defined by flooding due to storm surge.	See note; N20
N21	Seawater level, lake level or river: impact of man-made structures such as wave/tide breaks and jetties	The hazard is defined by flooding caused or amplified by the hydrological effects of manmade structures.	
N22	Corrosion from salt water	The hazard is defined in terms of impact on the plant of corrosion by salt water.	
N23	Instability of the coastal area due to erosion by strong water currents or sedimentation (sea and river)	The hazard is defined in terms of damage to plant structures due to erosion or sedimentation by strong water currents.	
N24	Underwater debris	The hazard is defined in terms of the damage or clogging of cooling water intake or outlet affecting the availability of the Ultimate Heat Sink (UHS). It may result from sediment load swept in by water.	The effects of ice on water intake structures is treated separately (N48).
N25	Precipitation (rain or snow), snow pack	The hazard is defined in terms of damage to the plant due to extreme rain or snow. It includes damage due to rain or snow load on structures.	Flooding by extreme rain (N8) or snow melt (N9) is treated separately.
N26	Extremes of air temperature (high and low)	The hazard is defined in terms of impact on the plant of extremely high temperatures (e.g., the stop of	Impact of high or low water temperature (N28) or ice is treated separately.

Code	External Hazard	Hazard definition and impact	Comment
		ventilation function) and low temperatures (e.g., freezing of pipes).	
N27	Extremes of ground temperature (high and low)	The hazard is defined in terms of impact on the plant of high or low ground temperature, e.g., leading to freezing of pipes.	The impact of extreme soil frost is treated separately (N38).
N28	Extremes of cooling water (sea, lake or river) temperature (high and low)	The hazard is defined in terms of impact on the plant of high or low cooling water temperature.	Freezing (surface ice; N48) and frazil ice (N49) are treated separately.
N29	Humidity (high and low), extreme atmospheric moisture	The hazard is defined by the impact of moisture on the functionality of safety related equipment and electronic devices (I&C equipment), e.g., by condensation of droplets in electrical and electronic devices.	See note: N29
N30	Extremes of air pressure	The hazard is defined by the impact of moisture on the functionality of safety related equipment and electronic devices (I&C equipment), e.g., by condensation of droplets in electrical and electronic devices.	See note: N29
N31	Extreme drought: low river or lake water level	The hazard is defined as an extended drought period that lowers the water level of lakes, rivers and open water basins challenging the availability of cooling or service water.	High air temperature (N26) and high water temperature (N28) are treated separately. Extremes of ground water level are treated separately (N32)
N32	Low ground water	The hazard is defined by low ground water levels challenging the availability of cooling or service water.	

Code	External Hazard	Hazard definition and impact	Comment
N33	Low seawater level	The hazard is defined in terms of impact of white frost including switchyards and power lines, and blocking of air intakes by rime.	See note: N35
N34	Icing, freezing fog	The hazard is defined in terms of the impact of ice cover caused by freezing rain or fog. It includes the loading of structures (electric power lines and switchyard) and blocking of air intakes by ice.	See note: N34
N35	White frost, hard rime, soft rime	The hazard is defined in terms of impact of white frost including switchyards and power lines, and blocking of air intakes by rime.	See note: N35
N36	Hail	The hazard is defined in terms of damage to the plant due to extreme hail. It includes damage by the impact of hailstones and hail load.	Flooding due to melting of hail are bounded by flooding due to rain and snow melt (N8, N9). Possible effects on the UHS are judged to be bounded by surface ice hazards (N48).
N37	Permafrost	The hazard is defined in terms of impact of thawing and refreezing of permafrost.	
N38	Recurring soil frost	The hazard is defined in terms of impact of soil frost, e.g., on shallow underground installations such as water pipes.	
N39	Lightning (including electromagnetic	The hazard is defined in terms of damage to the plant due to lightning. The impact may be direct, causing	Fire started by lightning is bounded by external fires

Code	External Hazard	Hazard definition and impact	Comment
	interference)	structural damage or loss of off-site power, or indirect through an electromagnetic feeder fire started by lightning.	(N73, M 24) and internal fire analysis.
N40	High wind, storm (including hurricane, tropical cyclone, typhoon)	The hazard is defined in terms of damage to the plant by the direct impact of strong winds and wind pressure.	The hazard does not include tornado (N41) due to the unique characteristics of such storms. The hazard does not include the differentiating effects of blizzard, salt spray or sandstorm. However, the wind effects of these hazards are included. Flooding by storm surge is treated separately (N20). Hazards by wind-blown missiles are treated separately (N46).
N41	Tornado	The hazard is defined in terms of damage to the plant due to tornado. It includes the effects of pressure differences and rotating wind.	The hazard is separated from other strong winds (N40) due to the special characteristics of tornados with respect to duration, wind speed, and occurrence frequency. Damage due to windblown missiles is treated separately (N46).
N42	Waterspout (tornadic waterspout)	The hazard is defined in terms of the rotational energy. Waterspouts contain water vapour, not solid water.	See note: N42
N43	Blizzard, snowstorm	The hazard is defined by the impact on the plant by wind-blown snow. It includes contamination of external high-voltage insulation in switch gear	The effects of wind pressure from snowstorms are covered by the hazard high wind (N40). Snow load is treated separately (N25).

Code	External Hazard	Hazard definition and impact	Comment
		and power lines, and blocking of air intakes.	
N44	Sandstorm, dust storm	The hazard is defined in terms of impact on the plant of storm-borne sand or dust and its abrasive effects. It includes contamination of external high-voltage insulation in switch gear and power lines and blocking of air intake.	The effects of wind pressure from sandstorms are covered by the hazard high wind (N40).
N45	Salt spray, salt storm	The hazard is defined as a storm involving salt covering of plant structures and the corrosive attack by a salty atmosphere. It includes contamination of external high-voltage insulation in switch gear and power lines, and dielectric breakdown caused by salt particles.	The effects of wind pressure from salt storms are covered by the hazard high wind (N40).
N46	Wind-blown debris (external missiles)	The hazard is defined by the damage of the impacts of wind-blown debris resulting from high winds and tornado.	Typical missiles to include are cladding panels, both insulated and uninsulated aluminium, scaffolding planks, scaffolding poles, trees, and cars.
N47	Snow avalanche	The hazard is defined in terms of impact on the plant of avalanches.	Avalanches may be triggered by heavy snow fall or snowmelt.
N48	Surface ice on river, lake or sea	The hazard is defined in terms of the damage or clogging of cooling water intake or outlet by drift ice or thick surface ice affecting the availability of the UHS.	Frazil ice (N49) and ice barriers (N50) are treated separately.

Code	External Hazard	Hazard definition and impact	Comment
N49	Frazil ice	The hazard is defined in terms of the impact of frazil ice on the cooling water intake or river damming.	See note: N49
N50	Ice barriers	The hazard is defined in terms of impact on the plant of ice barriers, e.g., by clogging the water intake.	Flooding due to down-stream ice barriers is treated separately (N12).
N51	Mist, fog	The hazard is defined in terms of impact on the plant, electric power lines, and switchyard of mist. It includes reduced visibility on site.	
N52	Solar flares, solar storms (space weather); geomagnetic storms	The hazard is defined in terms of malfunction and damage to electrical and electronic equipment by electromagnetic interference and the breakdown of the terrestrial power grid.	See note: N52
N53	Marine/river/lake growth (seaweed, algae), biological fouling	The hazard is defined by excessive growth of algae, seaweed, bacteria or else affecting the availability of cooling water from the UHS.	
N54	Crustacean or mollusk growth (shrimps, clams, mussels, shells)	The hazard is defined in terms of clogging of water intake or outlet by encrusting organisms effecting on the availability of cooling water from the UHS.	
N55	Fish, jellyfish	The hazard is defined by the unavailability of the UHS due to clogging of water intake by exceptional quantities of fish/jellyfish or abnormal fish population in the cooling pond.	Clogging by seaweed (N53) and biological flotsam (N58) is treated separately.

Code	External Hazard	Hazard definition and impact	Comment
N56	Airborne swarms (insects, birds) or leaves	The hazard is defined in terms of damage to the plant due to blockage of air intake by birds or blockage of ventilation systems by leaves or insects in the filters. It includes blocking of the air intake of emergency diesels.	
N57	Infestation by rodents and other animals	The hazard is defined by damage of cables or wires attacked by rodents (rats, mice), and by undermining of structures by burrowing mammals.	
N58	Biological flotsam (wood, foliage, grass etc.)	The hazard is defined in terms of the damage or clogging of cooling water intake or outlet affecting the availability of the UHS by the accumulation of large quantities of flotsam.	
N59	Microbiological corrosion	The hazard is defined in terms of damage to the plant by microbiological corrosion.	
N60	Subaerial slope instability (landslide, rock fall; including meteorologically and seismically triggered events)	The hazard is defined in terms of impact on the plant of landslide or rock fall including possible clogging of cooling water intake or outlet affecting the availability of the UHS.	The effects of mass movements causing flooding due to the blockage of streams (N12) or by inducing tsunamis in the sea or lakes (N7) are treated separately.
N61	Underwater landslide, gravity flow (including seismically triggered events)	The hazard is defined in terms of impact on the plant of underwater landslide.	Underwater landslides may be due to above water causes, such as prolonged and intense precipitation.

Code	External Hazard	Hazard definition and impact	Comment
			Underwater erosion (N23) and tsunami triggered by landslide (N7) is treated separately.
N62	Debris flow, mud flow (including seismically triggered events)	The hazard is defined in terms of impact on the plant of debris flows or mud flows. Effects may include clogging of cooling water intake or outlet structures.	Lahar hazard is treated in volcanic hazards (N68).
N63	Ground settlement (natural or man-made by mining, ground water extraction, oil/gas production)	The hazard is defined in terms of impact on the plant of ground settlement.	
N64	Ground heave	The hazard is defined in terms of impact on the plant of ground heave.	
N65	Karst, leeching of soluble rocks (limestone, gypsum, anhydrite, halite)	The hazard is defined in terms of impact to the plant of fissures, sinkholes, underground streams, and caverns caused by chemical erosion.	
N66	Sinkholes (collapse of natural caverns and manmade cavities)	The hazard is defined in terms of impact on the plant of sinkholes resulting from underground collapse.	
N67	Unstable soils (quick clays etc.)	The hazard is defined in terms of impact on the plant of unstable soils.	
N68	Volcanic hazards: phenomena occurring near the volcanic centre	The hazard is defined in terms of impact on the plant of: volcanic vent opening; launching of ballistic projectiles; fallout of pyroclastic material such as ash, tephra, lapilli or pumice; pyroclastic flows; lava flows; debris avalanches, landslides and	The large variety of volcanic phenomena necessitates separate treatment of these phenomena. Earthquakes (N1) and tsunamis triggered

Code	External Hazard	Hazard definition and impact	Comment
		slope failures; lahars, maars and floods induced by snow melt; air shocks and lightning; release of gases (including 'glowing avalanches'); ground deformation; geothermal and groundwater anomalies; forest fire ignited by volcanic activity.	by volcanic activity (N7) are treated separately.
N69	Volcanic hazards: effects extending to areas remote from the volcanic centre	The hazard is defined in terms of impact on the plant of volcanic phenomena such as fallout of ash.	Earthquakes (N1) and tsunamis (N7) triggered by volcanic activity are treated separately.
N70	Methane seep	The hazard is defined in terms of impact on the plant of methane seeping from soils or rocks.	
N71	Natural radiation	The hazard is defined in terms of impact on the plant of natural radiation.	
N72	Meteorite fall	The hazard is defined in terms of damage to the plant due to meteorite impact (direct impact, shock waves, impact-induced vibration, and fire).	See note: N72. Flooding by tsunami triggered by meteorite fall is treated separately (N7).
N73	Forest/veld fires	The hazard is defined in terms of damage to plant or the loss of off-site power due to fire or threatened operator action owing to the release of smoke and toxic gases. It includes hazard due to sparks igniting other fires and combustion gas of fire.	The hazard is a possible effect of extreme meteorological conditions (high temperatures, drought or storms). Fire caused by human activity is treated separately (M24).

Code	External Hazard	Hazard definition and impact	Comment
M1	Industry accident: explosion	The hazard is defined in terms of damage to the plant resulting from explosions (deflagration or detonation) of solid substances, liquids or gases that leads to damage to the plant, loss of off-site power or threatened operator action. The damage may be due to pressure impact or impact of missiles.	This hazard is most relevant for chemical or fuel storage facilities (oil refinery, chemical plant, storage depot, other nuclear facilities). Explosions in connection with transportation (M11) and pipeline accidents (M13) are treated separately. Fire due to industrial accident is treated separately (M24).
M2	Industry accident: chemical release (explosive, flammable, asphyxiating, toxic, corrosive or radioactive substances)	The hazard is defined by the impact of releases from industrial plants that lead to damage to the plant or threatened operator action owing to the release of explosive, flammable, asphyxiating, toxic, corrosive or radioactive substances.	This hazard is most relevant for chemical or fuel storage facilities (oil refinery, chemical plant, storage depot, other nuclear facilities). Hazards resulting from transportation accidents (/M12) or pipeline accidents (M14) are treated separately.
M3	Missiles from high energy rotating equipment	The hazard is defined in terms of the impact of missiles from high energy rotating equipment.	
M4	Military facilities (permanent and temporary): explosion, projectiles, missiles and fire	The hazard is defined by the impact accidents in military facilities such as explosion, projectile generation (shrapnel), or missiles.	Chemical releases from military facilities are treated separately (M5). Fire from military facilities is treated with the fire hazard due to human/technological activity (M24).
M5	Military facilities (permanent and temporary): chemical release (explosive,	The hazard is defined by the impact of releases from military facilities that lead to damage to the plant or threatened operator action owing to	

Code	External Hazard	Hazard definition and impact	Comment
	flammable, asphyxiating, toxic, corrosive or radioactive substances)	the release of explosive, flammable, asphyxiating, toxic, corrosive or radioactive substances.	
M6	Military activities	The hazard is defined in terms of damage to plant resulting from military activity.	Explosion and fire induced by military action should be considered as a minimum.
M7	Ship accident: direct impact	The hazard is defined in terms of the direct impact of a ship.	Collisions with water intake structures and components of the UHS are treated separately (M8). The hazard does not cover consequences of releases in connection with a ship accident (explosion, pollution, intake clogging or release of toxic gases). These hazards are treated separately (M9, M11).
M8	Collisions with water intake and ultimate heat sink components (ship, pontoon, fishing net)	The hazard is defined in terms of damage or clogging of water intakes and UHS structures by collision with ships, pontoons, fishing nets, etc.	The hazard does not cover consequences of releases in connection with a ship accident (explosion, pollution, intake clogging or release of toxic gases). These hazards are treated separately (M9, M11).
M9	Ship accident: solid or fluid (non-gaseous) releases	The hazard is defined in terms of damage or clogging of water intakes and UHS structures by impurities released into the water from a ship, such as oil spills or corrosive fluids, which could affect the availability or quality of cooling water, and its heat exchange capacity.	

Code	External Hazard	Hazard definition and impact	Comment
M10	Ground transportation accident: direct impact	The hazard is defined in terms of the direct impact of railway trains and wagons, road vehicles outside the site.	The hazard does not cover consequences of releases in connection with transport accidents (explosion, pollution, intake clogging or release of toxic gases). These hazards are treated separately (M11, M12).
M11	Transportation accident: explosion, fire	The hazard is defined in terms of damage to the plant resulting from explosion after ground transportation accidents or due to sea, lake or river transportation accidents. Damage may be due to pressure impact or impact from missiles.	Consequence of other hazards (different prime cause). Hazards due to aircraft crash (M15, M16) or pipeline accident (M13) are treated separately. Toxic effects from a chemical release are treated separately (M12).
M12	Transportation accident: chemical release (explosive, flammable, asphyxiating, toxic, corrosive or radioactive substances)	The hazard is defined by the effects of chemical releases after ground transportation accidents or due to sea, lake or river transportation accidents that affect the plant both externally and internally, damaging or impairing safety related systems and operator action. Releases may originate from transportation accidents, spills or leakages of transported substances.	
M13	Off-site pipeline accident: explosion, fire	The hazard is defined in terms of damage to the plant resulting from explosions (deflagration or detonation) after a pipeline accident (including pumping stations) outside the site. The damage may be due to pressure impact or impact of missiles.	Effects from chemical release are treated separately (M14).

Code	External Hazard	Hazard definition and impact	Comment
M14	Off-site pipeline accident: chemical release	The hazard is defined by the effects of chemical releases after pipeline accidents (including pumping stations) that affect the plant both externally and internally, damaging or impairing safety related systems and operator action.	Explosion effects from pipeline accidents are treated separately (M13).
M15	Aircraft crash: airport zone	The hazard is defined in terms of damage to the plant by abnormal flights leading to crashes. Damage can by caused by direct impact, explosion, missiles, fire (kerosene), smoke (toxic), and inducted vibration.	The hazard depends on flight frequencies, runway characteristics, and types and characteristics of aircrafts. The aircraft may be commercial, private or military.
M16	Aircraft crash: air traffic corridors and flight zones (military/civil/agricultural)	The hazard is defined in terms of damage to the plant by abnormal flights leading to crashes. Damage can by caused by direct impact, explosion, missiles, fire (kerosene), smoke (toxic), and inducted vibration.	The hazard depends on flight frequencies, characteristics of air traffic corridors, and types and characteristics of aircrafts. The aircraft may be commercial, private or military.
M17	Satellite crash	The hazard is defined in terms of damage to the plant resulting from satellite impact. Damage can be caused by direct impact, induced vibration, or shock wave.	
M18	Excavation and construction work	The hazard is defined in terms of impact on the plant of excavation construction work outside the site area including destructive work on cabling and piping buried underground which may lead to the breach of underground supplies or the release of	

Code	External Hazard	Hazard definition and impact	Comment
		explosive, flammable, asphyxiating, toxic or corrosive substances.	
M19	Instability of the off-site power grid	The hazard is defined by the impact of disturbances coming from manipulation on the grid and switchyards from outside the site. It includes external grid disturbance leading to voltage surges.	
M20	Industrial contamination of insulation of high voltage in outdoor switchgear and power lines	The hazard is defined by the impact on the insulation of high voltage in outdoor switchgear by industrial contaminants such as dust or chemical releases.	
M21	Electromagnetic interference, radiofrequency interference or disturbance from off-site sources	The hazard is defined in terms of impact of human-induced magnetic or electrical fields, and radio magnetic disturbance that could cause malfunction in or damage to safety related equipment or instrumentation.	The main examples of such fields are those attributable to radar, radio, and mobile telephone systems, or to the activation of high voltage electric switchgears.
M22	High-voltage eddy current into ground (off-site sources)	The hazard is defined by corrosion of underground metal ground components and grounding problems.	
M23	Flooding: malfunction or miss-management of water-gate or dam	The hazard is defined in terms of damage to the plant by high level water and water waves caused by human-induced damage, malfunction or miss-management of water control structures.	The hazard may be enveloped by flood hazard caused by failure of water control structures (dam failure) caused by natural events (N15).
M24	Fire as result to human/technological activity	The hazard is defined in terms of damage to the plant or loss of off-site power resulting from human-induced forest, wildland or grassland fire, or	Fire may result from industrial accident or free time activities.

Code	External Hazard	Hazard definition and impact	Comment
		fire in urban area. It includes hazard due to sparks igniting other fires, smoke, combustion gas of fire, and heat (thermal flux).	

Additional notes on Natural Occurring External Events:

- N2: Vibratory ground motion induced or triggered by human activity

Seismic ground motion caused by human activity is treated together with natural seismicity due to the identical effects of both phenomena and the difficulties which may arise to discriminate between man-made and natural events. The hazard type includes induced seismicity, which is entirely controlled by human intervention, and triggered seismicity. In the latter case human intervention causes the initiation of the seismic rupture process of a fault while the subsequent rupture propagation is controlled by natural stress. A triggered earthquake is advanced by human intervention and natural stress aggravates the ground shaking. Seismic ground motion may be triggered or induced by oil, gas or deep groundwater extraction (including both producing and empty reservoirs), geothermal heat production, liquid waste dumping in deep boreholes, quarrying and mining.

- N3: Fault capability

The displacement of the Earth's surface at a fault during an earthquake is referred to as fault capability. Co-seismic displacement may occur at the master fault or splay faults which fractured during the earthquake, or by induced slip at secondary faults which are not directly related to the earthquake fault.

- N4: Liquefaction, lateral spreading

Liquefaction of soil and unconsolidated fine-grained sediment is caused by ground shaking during an earthquake. The process results from the expulsion of pore water and leads to an extreme reduction of shear strength of the soil. In such cases, soil behaves more like a liquid than a solid and is unable to carry loads. Lateral spreading refers to the down-slope flow of liquefied soil. Both phenomena may lead to base failure at the foundation of buildings and the destruction of underground infrastructure (e.g., cables, pipes and pillars).

- N6: Permanent ground displacement subsequent to earthquake

Strain release after strong earthquakes may lead to permanent ground displacement of a large area that is caused by the release of elastic deformation (strain) during the earthquake. Elastic strain accumulates in the inter-seismic time period between earthquakes. Well-known examples of permanent ground displacement include cases of regional costal uplift above subduction zones and thrust faults. The type of ground displacement is distinct from the displacement caused by fault capability which is restricted to the earthquake fault or secondary faults.

- N7: Tsunami

A tsunami is a series of waves (wave train) in an ocean or lake that is caused by the displacement of a large volume of a body of water by earthquake, underwater landsliding, landsliding into water, volcanic eruption, or meteorite impact. Tsunamis travel very large distances. The phenomenon that triggered the wave train may therefore have occurred far from the site where the waves arrive.

- N8: Flash flood

Extreme flood events induced by severe stationary storms have been considered as flash floods. Most generally, the storms inducing flash floods lead to local rainfall accumulations exceeding 100 mm over a few hours and affect limited areas: some tens to some hundreds of square kilometres. Larger scale and longer lasting stationary storm events may, however, occur in some meteorological contexts.

- N16: Seiche

Seiches are standing waves that form in enclosed or semi-enclosed water basins due to the reflection of waves at the basin edges. Repeated wave reflections and interference of waves lead to the formation of standing waves. The superposition of waves with frequencies equal to the eigen-frequency of the basin (or multiples of this frequency) lead to resonances in the body of water and amplitude amplification. Wave initiation may be due to meteorological effects (wind, atmospheric pressure variations), seismic activity, or tsunamis.

- N17: Bore

A tidal bore is a series of waves propagating upstream as the tidal flow turns to rising. It forms during spring tide conditions when the tidal range exceeds 4 to 6 m and the flood tide is confined to a narrow funneled estuary. Its existence is based upon a fragile hydrodynamic balance between the tidal amplitude, the freshwater river flow conditions and the river channel bathymetry. Tidal bores are characterized by strong turbulence that may lead to sediment erosion beneath the bore wave and on banks. Turbulence may further lead to scouring and sediment entrainment, and impact on obstacles.

- N19: Rogue waves (freak wave)

Freak waves are extraordinarily large water waves whose heights exceed by a factor of 2.2 the significant wave height of a measured wave train. The significant wave height is defined as the mean of the largest third of waves in a wave record. Rough waves often occur as single and steep wave crests that may cause severe damage to offshore/onshore structures and ships. The formation of such waves results, among other factors, from the presence of strong currents or from a simple chance superposition of different waves with coherent phases.

- N20: Storm surge

Storm surge is a coastal flood phenomenon that can result from several different types of storms such as tropical cyclones, extra-tropical cyclones, squall lines (a line of thunderstorms ahead of a cold front), and hybrid storms in low-pressure weather systems. Flood levels are a function of the depth of the water body, the orientation of the shoreline, the wind direction, the storm path, and tides. Two main meteorological factors contribute to storm surge: the long fetch (i.e., the length of water over which wind has blown) of winds spiraling towards the centre of the storm, and the elevated water dome drawn up by low the air pressure in the storm's centre. The second effect is responsible for destructive meteo-tsunamis (a tsunami-like wave of meteorological origin.

- N29a/b: Humidity (high and low)

Extremes of humidity have an impact on the cooling capacity of nuclear power plants that utilize evaporation based designs for the ultimate heat sink (e.g. mechanical draught cooling towers). Together with other parameters such as wind, precipitation, temperature, and air pressure extremes of humidity may combine to meteorological conditions representing (a) maximum evaporation potential (leading to maximum cooling water consumption) and (b) minimum water cooling (e.g. cooling capacity of the cooling tower).

- N34: Icing

The term refers to clear ice that precipitates from rain or fog and covers cold objects in a sheet-like mass of layered ice. Such ice covers have a higher density than ice crystals formed by frost or rime (refer to N35) and therefore a higher potential to damage objects by loading. Examples of vulnerable structures include power lines and (high voltage) outdoor switchgears of NPSs.

- N35: White frost, hoar frost, hard rime, soft rime

The hazard type summarizes the effects of several types of ice coatings that form in humid and cold air and produce ice crystals in a greater variety of forms. Crystals freeze to the upwind side of solid objects. Rime refers to ice deposits forming from water droplets in freezing fog or mist at calm or light wind. Super-cooled water drops are involved in the formation of rime. Meteorological literature distinguishes hard rime, which has a comb-like appearance and firmly adheres to objects, from soft rime, which consists of fragile and delicate ice needles. In contrast to rime, where vapor first condensates to droplets before freezing, white frost and hoar frost forms by desublimation of ice directly from water vapor. Both types of frost do not form from fog but from air of different degrees of relative humidity at low temperatures. Frost and rime is less dense than solid ice and adheres to objects less tenaciously. Their damage potential is therefore less than that of clear ice covering objects (refer to N34, Icing).

- N42: Waterspout

A waterspout (tornado occurring over water) is a small and weak rotating column of air over water. It consists of a columnar vortex which is upwards connected to a funnel-shaped cloud. The phenomenon is mostly weaker than tornadoes on land. Most of the water contained in the funnel of a waterspout is formed by the condensation of droplets, not by sucking up water from the underlying water body. Stronger waterspouts may originate in meso-cyclone thunderstorms.

- N49: Frazil ice

Frazil ice is generally defined as the mass of ice crystals formed in a turbulent flow which is in a super-cooled condition. Super-cooling results in a suspension of loose, randomly oriented needle-shaped ice crystals in water resembling slush. Frazil ice forms in turbulent, supercooled water (rivers, lakes and oceans) when air temperature reaches –6°C or lower. At high speeds of water currents the small ice crystals are not buoyant and may be carried into deeper water instead of floating at the surface. Continuing crystal growth may result in underwater ice adhering to objects in the water such as trash racks protecting water intake structures. This process may proceed very fast and lead to total blockage of trash bars.

- N52: Solar flares, solar storms (space weather); electromagnetic interference

A solar flare is a sudden release of extremely large energy of the Sun caused by electromagnetic phenomena within the Sun. Flares may lead to the ejection of plasma (coronal mass ejection) and particle storms (solar storms) with clouds of electrons, ions, and atoms moving through the corona of the sun into space. Such clouds may reach the Earth within hours or few days after the solar event. Massive solar flares with coronal mass ejections have a strong impact on the space weather near the Earth. They cause temporary disturbances of the Earth’s magnetosphere and magnetic field causing geomagnetic storms. The latter may lead to severe disturbances of electrical systems including the disruption of communication by absorption or reflection of radio signals, and the damage of terrestrial electric power grids by moving magnetic fields that induce currents in conductors of the power grid. These currents may particularly damage transformers. Geomagnetic storms may therefore cause long-lasting breakdowns of the electrical power grid. Other effects include the heating of long conductors such as pipelines. Since solar flares affect the whole Earth the assessment of the likeliness of hazardous events is fully not site specific. Occurrence probabilities and hazard severities depend on the geographical latitude. Direct and indirect observations of solar flares show downward-cumulative frequency distributions of fluences of solar energetic particle events.

- N72: Meteorite fall

Observations and modelling of asteroid impacts support the assumption of uniform impact distribution for all parts of the Earth independent from geographical latitude and longitude. Hazard assessments for meteorite fall therefore are not site specific. Hazard estimates may be derived from globally established correlations between the size of the impacting object (or its impact energy) and the yearly probability to hit the Earth, and the correlation between the size of the area affected by destructive phenomena and the impact energy.

IAEA Site Exclusion Criteria (IAEA, 2003)

- The following exclusion criteria have been used to eliminate postulated hazards from being included as a design basis:
  - A phenomenon which occurs slowly or with adequate warning with respect to the time required to take appropriate protective action.
  - A phenomenon which in itself has no significant impact on the operation of a nuclear power plant and its design basis.
  - A phenomenon which by itself has a probability of occurrence less than the 10^{-7} per year upper limit of acceptable undefined failure probability and consequences.
  - Locate the nuclear power plant sufficiently distant from the postulated phenomenon to mitigate its effects.
  - A phenomenon which is included or enveloped by design for another phenomenon. For example, storm surge and seiche are included in lake flooding; toxic gas is included in pipeline accident or industrial or military facility accident.

Table 6C.1: Application of IAEA EE Elimination Criteria

Hazards Natural	Elimination Criteria no.	Remarks
High summer temperature	A phenomenon which occurs slowly or with adequate warning with respect to the time required to take appropriate protective action.	Ultimate heat sink conservatively designed for 30 days evaporation
Waterspout	Locate the nuclear power plant sufficiently distant from the postulated phenomenon to mitigate its effects	Considered in conjunction with tornado. Tornado governs. Loading due to water in spout not governing
Sandstorm	Locate the nuclear power plant sufficiently distant from the postulated phenomenon to mitigate its effects	Extreme wind should include this phenomenon. Blockage of air intakes with particulate matter should be considered separately
Volcanic activity	A phenomenon which by itself has a probability of occurrence less than the 10^{-7} per year upper limit of acceptable undefined failure probability and consequences. Locate the nuclear power plant sufficiently distant from the postulated phenomenon to mitigate its effects	Currently there is no criteria for anti-volcanic design
Fog	A phenomenon which in itself has no significant impact on the operation of a nuclear power plant and its design basis.	Could however increase probability of human made hazard involving surface vehicles or aircraft
Forest fire	A phenomenon which in itself has no significant impact on the	Site cleared for such fire. Control room habitability

Hazards Natural	Elimination Criteria no.	Remarks
	operation of a nuclear power plant and its design basis.	required for smoke.
Drought	A phenomenon which occurs slowly or with adequate warning with respect to the time required to take appropriate protective action.	Assumes multiple sources of ultimate heat sink or ultimate heat sink not affected by drought: e.g. cooling tower with adequately sized basin
Lightning	A phenomenon which in itself has no significant impact on the operation of a nuclear power plant and its design basis.	Plant lightning protected by use of a grounding network
Frost	A phenomenon which in itself has no significant impact on the operation of a nuclear power plant and its design basis. A phenomenon which is included or enveloped by design for another phenomenon. For example, storm surge and seiche are included in lake flooding; toxic gas is included in pipeline accident or industrial or military facility accident.	Snow and ice govern
Meteorite	A phenomenon which by itself has a probability of occurrence less than the 10^{-7} per year upper limit of acceptable undefined failure probability and consequences.	Less than 10^{-7} per year depending on latitude
Hail	A phenomenon which in itself has no significant impact on the operation of a nuclear power plant and its design basis.	Other missiles govern

Hazards Natural	Elimination Criteria no.	Remarks
	A phenomenon which is included or enveloped by design for another phenomenon. For example, storm surge and seiche are included in lake flooding; toxic gas is included in pipeline accident or industrial or military facility accident.	
Coastal erosion	A phenomenon which occurs slowly or with adequate warning with respect to the time required to take appropriate protective action.	See note 1
Flood	Locate the nuclear power plant sufficiently distant from the postulated phenomenon to mitigate its effects	
Tsunami	Locate the nuclear power plant sufficiently distant from the postulated phenomenon to mitigate its effects	
Retaining structure failure	Locate the nuclear power plant sufficiently distant from the postulated phenomenon to mitigate its effects	
Soil shrink-swell consolidation	A phenomenon which occurs slowly or with adequate warning with respect to the time required to take appropriate protective action.	See note 1

Hazards Natural	Elimination Criteria no.	Remarks
Low lade or river water level	A phenomenon which occurs slowly or with adequate warning with respect to the time required to take appropriate protective action.	Ultimate heat sink should be conservatively designed for 30 days of evaporation
Avalanche	Locate the nuclear power plant sufficiently distant from the postulated phenomenon to mitigate its effects	
Landslide	Locate the nuclear power plant sufficiently distant from the postulated phenomenon to mitigate its effects	
Wave Action	Locate the nuclear power plant sufficiently distant from the postulated phenomenon to mitigate its effects A phenomenon which is included or enveloped by design for another phenomenon. For example, storm surge and seiche are included in lake flooding; toxic gas is included in pipeline accident or industrial or military facility accident.	Included under flood
Seiche	Locate the nuclear power plant sufficiently distant from the postulated phenomenon to mitigate its effects A phenomenon which is included or enveloped by design for	Included under flood

Hazards Natural	Elimination Criteria no.	Remarks
	another phenomenon. For example, storm surge and seiche are included in lake flooding; toxic gas is included in pipeline accident or industrial or military facility accident.	
Precipitation	Locate the nuclear power plant sufficiently distant from the postulated phenomenon to mitigate its effects A phenomenon which is included or enveloped by design for another phenomenon. For example, storm surge and seiche are included in lake flooding; toxic gas is included in pipeline accident or industrial or military facility accident.	Included under flood
Storm Surge	Locate the nuclear power plant sufficiently distant from the postulated phenomenon to mitigate its effects A phenomenon which is included or enveloped by design for another phenomenon. For example, storm surge and seiche are included in lake flooding; toxic gas is included in pipeline accident or industrial or military facility accident.	Included under flood
Ice cover	A phenomenon which in itself has no significant impact on the	See remark under snow for roof loading. Ice effects on

Hazards Natural	Elimination Criteria no.	Remarks
	operation of a nuclear power plant and its design basis. A phenomenon which is included or enveloped by design for another phenomenon. For example, storm surge and seiche are included in lake flooding; toxic gas is included in pipeline accident or industrial or military facility accident.	intake structures may require design consideration. Ice blockage of rivers causing flooding is included under river flooding
Snow	A phenomenon which in itself has no significant impact on the operation of a nuclear power plant and its design basis.	When snow (or ice) load in excess of design live loads is considered in the design of power plant structures, the resulting load combination should be treated as an extreme environmental condition with unit load factors
Aircraft crash. Large Aircraft crash. Small	A phenomenon which by itself has a probability of occurrence less than the 10^{-7} per year upper limit of acceptable undefined failure probability and consequences. A phenomenon which is included or enveloped by design for another phenomenon. For example, storm surge and seiche are included in lake flooding; toxic gas is included in pipeline accident or industrial or military facility accident.	If more than 10km from commercial airport flyway Included in tornado design 100 m sec

Hazards Natural	Elimination Criteria no.	Remarks
Surface Vehicle, Pipeline and Military or Industrial facility accident (Explosion)	Locate the nuclear power plant sufficiently distant from the postulated phenomenon to mitigate its effects	
Toxic and Flammable Gas	A phenomenon which is included or enveloped by design for another phenomenon. For example, storm surge and seiche are included in lake flooding; toxic gas is included in pipeline accident or industrial or military facility accident.	Control room habitability required for toxic gas accident. This assumes no operator action outside the control room is required to render the consequences of the event acceptable

Note 1: Site related characteristics, such as subsidence due to subsurface pumping mining sink holes or alteration of groundwater regions active surface faulting liquefaction potential chemically active soils and rocks or volcanic activity which have expansive heave shrinkage characteristics flood plane level are natural phenomena which should be considered and evaluated during the site suitability evaluation process. Such characteristics either result in (1) the site being considered unsuitable or (2) necessary design consideration and construction techniques are employed to mitigate or present the hazard.

Appendix 6-D: Eskom Plant Parameter Envelope Values and Criteria

PPE Section	Definition	Enveloping limit (s)	Characteristic of Limiting Parameter Value	Parameter Value to be Prorated Based on the Number of Units on Site	References
0.Plant thermal/ electrical characteristic					
0.1 Electric Output per unit	The electrical output of the plant per unit	1 708 MW (gross) 1 580 MW (net)	maximum	yes	EPR SAR [24] EUR Vol. 2 [11]
0.2 Megawatts Thermal per unit	The thermal output of the plant per unit, including electrical output and rejected heat load	4 616 MW	maximum	yes	EUR Vol. 2 [11] EPR SAR [24]
0.3 Station Capacity Factor	The percentage of time the plant is expected to deliver its stated electrical output over the lifetime of the plant, considering all expected outages	94%	maximum	no	EUR Vol.2 [11] EPR SAR [24] N-REP-1200-10000 [21]
0.4 Plant Design Life	The designed lifetime of the plant, including planned midlife refurbishments	60 yrs + 20 years life extension	maximum	no	EUR Vol. 2 [11] EPR SAR [24] UKP-GW-GL-793NP [34]
0.5 Plant Operating Life Cycle (Time of operation between refuelling)	The normal plant operating cycle length	18 - 24 months	maximum	no	EUR Vol. 2 [11]
0.6 Plant efficiency	The ratio of useful electricity energy output from the plant, over a time period T, to the energy source supplied to the unit	37%	maximum	no	EPR SAR [24]
1.Structure					
1.1 Building Characteristics					

PPE Section	Definition	Enveloping limit (s)	Characteristic of Limiting Parameter Value	Parameter Value to be Prorated Based on the Number of Units on Site	References
1.1.1 Height (without stack and cooling towers)	The height from finished grade to the top of the tallest block structure, excluding cooling towers (excludes stairway towers, elevator, etc.)	76.4 m Dependent on the chosen reactor technology	maximum	no	APR 1400 DCD [16]
1.1.2 Foundation Embedment	The depth from finished grade to the bottom of the base-mat or the most deeply embedded power block structure	Approx. 16.4 m from finished grade (11.9 – 25.7 m) Dependent on site specific information	maximum	no	EUR Vol. 2 [11]
1.2 Precipitation (for roof design)					
1.2.1 Maximum rainfall rate	The probable maximum precipitation (PMP) value that can be accommodated by a plant design. Expressed as maximum precipitation for 1 hour in 1 square km and as maximum precipitation for 5 minutes in 1 square km.	100 mm/hr 400 mm in 24 hours 157 mm/5 mins	maximum	no	EUR Vol. 2 [11]
1.2.2 Normal and Extreme Winter Precipitation Events (Snow and ice load) Depth of 48-hour probable maximum winter precipitation (PMWP)	The loads on structure roofs due to the accumulation of snow and ice that can be accommodated by a plant design (i.e. the weight of the 100 year period ground level snowpack and the weight of the 48 hour probable maximum winter precipitation (PMWP)	Design-basis level snow Loading: 0.4 kPa. Upper design limit: 1.5 kPa Addition for man access: 0.75 kPa	minimum	no	EUR Vol. 2 [11]
1.2.3 Hail	The maximum 100-year return interval snow load on structure roofs that can be accommodated by a plant design.	Covered by the standard vendor design for 1:100 year recurrence interval. Minimum value of 0.4 kPa (quantities of derived liquid subject to ice density).		no	EUR Vol. 2 [11]

PPE Section	Definition	Enveloping limit (s)	Characteristic of Limiting Parameter Value	Parameter Value to be Prorated Based on the Number of Units on Site	References
1.3 Geology and Seismology (Safe Shutdown Earthquake (SSE)					
1.3.1 Design Response Spectra (n/a)	The assumed design response spectra used to establish a plant's seismic design	To be determined based on site specific information	n/a	no	Reg Guide 1.60 [25]
1.3.2 Peak Ground Acceleration	The maximum earthquake ground acceleration for which a plant is designed; this is defined as the acceleration, which corresponds to the zero period in the response spectra taken in the free field at base mat elevation. The PGA is associated with the response spectrum shape as defined in the relevant standard and should not be used in isolation.	The horizontal free field Peak Ground Acceleration (PGA) for all site conditions shall be 0,3 g. The higher PGA value of 0.3 g is used instead of 0.25 g in the EUR. This PGA has been selected for design purposes only and does not relate to the level of seismic hazard at any specific site	minimum	no	EUR Vol. 2 [11] NEI-ESP-PPE Worksheet [17] N-REP-01200-1000 [21] US NRC Reg Guide 1.208 [28] UKP-GW-GL-793NP [34]
1.3.3 Time History	The plot of earthquake ground motion as a function of time used to establish the plant's seismic design	The floor time history responses shall be converted into response spectra and combined with the response spectra obtained from the other directions of input if applicable.	minimum	no	EUR Vol. 2 [11] NEI-ESP-PPE Worksheet [17]
1.3.4 Capable Tectonic Structures or Sources	Assumption made in a plant design about the presence of capable faults or earth quake sources in the vicinity of site (e.g. no fault displacement potential within the investigative area	No displacement permitted within the site area.	minimum	no	EUR Vol. 2 [11] NEI-ESP-PPE Worksheet [17] UKP-GW-GL-793NP [34]
1.3.5 Volcanism	Volcanism is a process whereby liquid	History and/or evidence of volcanic		no	IAEA SSG-21 [14]

PPE Section	Definition	Enveloping limit (s)	Characteristic of Limiting Parameter Value	Parameter Value to be Prorated Based on the Number of Units on Site	References
	lava/ash/gases from the mantle/deep interior of the earth erupts into the atmosphere and/or flows onto the surface. Apart from the destructive power of a volcanic eruption, volcanoes can also precipitate various consequential events including: lahars, earthquakes, floods, missiles, lightning, tsunamis and pyroclastic flows.	activity in recent geologic times (< 10 000 000 years) in the site region (R ≤ 50 km) are unacceptable. A generic screening distance value of 100 km for basaltic lava is required.			
1.4 Site Water Level (Allowable)					
1.4.1 Maximum Flood or Tsunami (Terrace height) (i.e. lowest elevation))	Design assumption regarding the difference in elevation between finished plant grade and the water level due to the probable maximum flood (or tsunami).	The terrace height must be such that the NNI terrace is elevated above design basis flooding hazards.	minimum	no	IAEA SSG-18 [13] EUR Vol.2 [11]
1.4.2 Maximum Groundwater Level (i.e. lowest elevation))	Design assumption regarding the difference in elevation between finished plant grade and the maximum site ground water level used in plant design	The extreme groundwater levels at the site and the associated pressures on structures should be characterized. If groundwater levels are expected to reach the ground surface or the levels of groundwater drains, the expected discharge rate should be characterized, together with the ways in which the water would be discharged. The potential need for dewatering should be identified where appropriate.	minimum	no	IAEA SSG-18 [13]
1.5 Soil Properties Design Bases					

PPE Section	Definition	Enveloping limit (s)	Characteristic of Limiting Parameter Value	Parameter Value to be Prorated Based on the Number of Units on Site	References
1.5.1 Liquefaction (minimum)	Design assumption regarding the presence of potentially liquefying soils at a site (e.g., none at Site-Specific SSE).	No liquefaction is permitted for site specific SSE. If evaluations of the site investigations indicate the presence of potentially liquefiable soils, the resistance of these soils to liquefaction must be evaluated. It should also be determined whether the potentially liquefiable soils should be removed, whether remedial action should be undertaken, whether further field and laboratory investigations are needed or whether detailed stability and deformation analysis could demonstrate that an acceptable margin of safety is maintained for the design structures even if liquefaction is assumed to occur. Where no acceptable margin of safety can be maintained (where liquefaction is assumed to occur) then no liquefaction shall be permitted on the site, unless practicable engineering solutions are demonstrated to be available.	minimum	no	IAEA SSR-1 [15]
1.5.2 Minimum Bearing Capacity (Static)	Design assumption regarding the capacity of the competent load-bearing layer required to support the loads exerted by plant structures used in the plant design.	718.2 kPa over the footprint of the nuclear island at its excavation depth The potential for failure of the bearing capacity of the subsurface materials for a NPP under static loading should be low so that there are high margins of safety under static loading. These margins should be sufficient to meet SL-2 seismic loading conditions with	maximum	no	EUR Vol. 2 [11] IAEA NS-G-3.6 [12] NEI-ESP-PPE Worksheet [17] N-REP-01200-1000 [21]

PPE Section	Definition	Enveloping limit (s)	Characteristic of Limiting Parameter Value	Parameter Value to be Prorated Based on the Number of Units on Site	References
		reasonable safety margins. (In some states SL-2 corresponds to a level with a probability of being exceeded in the range of 1x10-3 to 1x10-4 (mean values) or 1x10-4 to 1x10-5 (median) per reactor per year.)			
1.5.3 Minimum Shear Wave Velocity	The assumed limiting propagation velocity of shear waves through the foundation materials used in the plant design.	304.8 m/s Generally, the soil/rocks on which the nuclear and conventional islands are founded will be engineered so that Vs > 300m/s Competent material is defined as in-situ material having a minimum shear wave velocity of ≥ 300 m/s. If the minimum shear wave velocity of the supporting foundation material is less than 300 m/s, additional studies need to be performed which consider the average shear wave velocity and its degree of variability addressing potential impact on soil-structure interaction, potential settlements and design of foundation elements.	maximum	no	N-REP-01200-1000 [21] EPR SAR [24] AP1000 DCD [33] UKP-GW-GL-793NP [34]
1.5.4 Dynamic Bearing Capacity	Design assumption regarding the capacity of the founding soil/rock to resist loads imposed by the structures in the event of an earthquake.	≥2 872.8 kPa at the edge of the nuclear island at its excavation depth. OR Site-specific analyses should demonstrate a factor of safety appropriate for normal plus safe shutdown earthquake loads.	maximum	no	EPR SAR [24] APR1400 DCD [16]

PPE Section	Definition	Enveloping limit (s)	Characteristic of Limiting Parameter Value	Parameter Value to be Prorated Based on the Number of Units on Site	References
1.5.5 Minimum Soil Angle of Internal Friction	Design assumption for the minimum value of the internal friction angle of foundation soils, fill soil, or excavation slopes that would provide a safe design of plant through soil structure interaction analyses including sliding along the base	≥35° below footprint of nuclear island at its excavation depth. If a minimum soil angle of internal friction is below 35 degrees, a site-specific analysis shall be performed using the site-specific soil properties to demonstrate stability	maximum	no	EUR Vol. 2 [11] UKP-GW-GL-793NP [34] APR1400 DCD [16]
1.5.6 Slope Instability	Slope instability is a phenomenon resulting from steep slopes, high ground water, and/or vibratory ground motion but not related to surface faulting. The movements encompass avalanches, landslides and general earth movements.	Slope instability which could affect the safe operation of the NPP or which could hinder emergency response is not permitted. If there is found to be a potential for slope instability that could affect the safety of the nuclear installation, the hazard shall be evaluated by using parameters and values for the site specific ground motion.		no	IAEA SSR-1 [15] APR1400 DCD [16] EPR SAR [24] UKP-GW-GL-793NP [34]
1.6 Tornado (Design Bases)					
1.6.1 Maximum Pressure Drop	The design assumption for the decrease in ambient pressure from normal atmospheric pressure due to the passage of the tornado.	4 kPa	minimum	no	US NRC 1.76 [27]
1.6.2 Maximum Rotational Speed	The design assumption for the component of tornado wind speed due to the rotation within the tornado.	57 m/s	minimum	no	US NRC 1.76 [27]
1.6.3 Maximum Translational Speed	The design assumption for the component of tornado wind speed due to the movement of the tornado over the ground.	14 m/s	minimum	no	US NRC 1.76 [27]

PPE Section	Definition	Enveloping limit (s)	Characteristic of Limiting Parameter Value	Parameter Value to be Prorated Based on the Number of Units on Site	References
1.6.4 Maximum Wind Speed	The design assumption for the sum of maximum rotational and maximum translational wind speed components.	72 m/s	minimum	no	US NRC 1.76 [27]
1.6.5 Missile Spectra	The design assumptions regarding missiles that could be ejected either horizontally or vertically from a tornado. The spectra identify mass, dimensions and velocity of credible missiles.	130 kg (0.168 m dia x 4.58 m long) steel pipe having a velocity of 24 m/s 1 178 - 1814.4 kg automobile at a velocity of 24 horizontal and 33.1 m/s vertical 0.0669 kg solid steel sphere, 2.54 cm dia, having a velocity of 6 m/s horizontal and 5.2 m/s vertical.	range provided	no	US NRC 1.76 [27] NEI-ESP-PPE Worksheet [17]
1.6.6 Radius of Maximum Rotational Speed	The design assumption for distance from the centre of the tornado at which the maximum rotational wind speed occurs.	45.7 m	maximum	no	US NRC 1.76 [27]
1.6.7 Rate of Pressure Drop	The assumed design rate at which the pressure drops due to the passage of the tornado.	13 mbar/s	minimum	no	US NRC 1.76 [27]
1.7 Wind (Non Tornado)					
1.7.1 Wind Speed (3 second gust)	The design wind for which the facility is designed – basic wind speed 3 second gust velocity associated with a 100-year return period (straight line) at 10 m above ground level in the site area	43 m/s 70 m/s The revised SANS 10160 code of practice gives a maximum basic wind speed of 52 m/s for the whole country.	minimum	no	EUR Vol. 2 [11] EIA Consistency Data Set [5]
1.7.2 Importance Factors	Multiplication factors applied to basic wind speed to develop the plant design.	1.15 safety related 1.0 non safety related	minimum	no	EUR Vol. 2 [11] N-REP-01200-10000 [21]

PPE Section	Definition	Enveloping limit (s)	Characteristic of Limiting Parameter Value	Parameter Value to be Prorated Based on the Number of Units on Site	References
1.8 Lightning	An atmospheric electrostatic discharge accompanied by thunder, which typically occurs during thunderstorms, and sometimes during volcanic eruptions or dust storms.	First stroke: 200 kA, 10/350 µs Second stroke: 50 kA, 0,25/100 µs		no	EUR Vol. 2 [11]
2. Plant Heat Sink					
2.1 Ambient Air Requirements and Humidity Conditions					
2.1.1 Normal Shutdown Max Ambient Temperature (1% exceedance)	Assumption used for the maximum ambient temperature that will be exceeded no more than 1% of the time, to design plant systems capable of effecting normal shutdown under the assumed temperature condition	37.8°C DB / 25°C WB coincident	minimum	no	AP1000 DCD [33]
2.1.2 Normal Shutdown Max Wet Bulb Temperature (1% exceedance)	Assumption used for the maximum wet bulb temperature that will be exceeded no more than 1% of the time – used in design of plant systems that must be capable of effecting normal shutdown under the assumed temperature condition.	26.7°C WB on-coincident	minimum	no	AP1000 DCD [33]
2.1.3 Normal Shutdown Min Ambient Temperature (1% exceedance)	Assumption used for the minimum ambient temperature that will be exceeded no more than 1% of the time to design of plant systems that must be capable of effecting normal shutdown under the assumed temperature condition.	-23.3°C	maximum	no	AP1000 DCD [33]
2.1.4Maximum Air Design Temperature (0% exceedance)	Assumption used for the maximum ambient temperature that will never be exceeded – used in design of plant	Long term base (> 7 days) = 42°C, Short term daily (6hours to 7 days) =	minimum	no	NSIP0321 [8]

PPE Section	Definition	Enveloping limit (s)	Characteristic of Limiting Parameter Value	Parameter Value to be Prorated Based on the Number of Units on Site	References
	systems that must be capable of supporting full power operation under the assumed temperature condition.	46°C, Instantaneous (6 hours) = 50°C			
2.1.5 Maximum Wet Bulb Temperature (0% exceedance)	Assumption used for the maximum wet bulb temperature that will never be exceeded – used in design of plant systems that must be capable of supporting full power operation under the assumed temperature condition.	30.1°C WB non-coincident	minimum	no	AP1000 DCD [33]
2.1.2 Minimum Air Design Temperature (0% exceedance	Assumption used for the minimum ambient temperature that will never be exceeded – used in the design of plant systems that must be capable of supporting full power operation under the assumed temperature condition.	Long term base (> 7 days) = 2.8°C, Short term daily (6 hours to 7 days) = 0 °C, Instantaneous (6 hours) = -1.3°C	maximum	no	NSIP0321 [8][7]
2.1.3 Design Basis Maximum External Humidity	Assumption used for the maximum external humidity that the standard design shall be able to deal with (Relative humidity)	Winter: ≥20% (reaching as high as 100% for the Western Cape) Summer: 100%	minimum	no	EIA Consistency Data Set [5] NSIP03251 [8]
2.2 Condenser					
2.2.1 Max Inlet Temp Condenser/Heat Exchanger	Design assumption for the maximum acceptable circulating water temperature at the inlet to the condenser or cooling water system heat exchangers	13°C	minimum	no	Koeberg Safety Analysis Report [9]

PPE Section	Definition	Enveloping limit (s)	Characteristic of Limiting Parameter Value	Parameter Value to be Prorated Based on the Number of Units on Site	References
2.2.2 Condenser/Heat Exchanger Duty	Design value for the waste heat rejected to the circulating water system across the condenser	3 400 MW	maximum	yes	N-REP-1200-10000 [21]
2.3 Once-Through Cooling					
2.3.1 Cooling Water Discharge Temperature	Expected temperature of the cooling water at the exit of the condenser/heat exchangers	45.6°C	maximum	no	N-REP-01200-10000 [21]
2.3.2 Cooling Water Flow Rate	Total cooling water flow rate through the condenser (also the rate of withdrawal from and return to the water source)	76 000 l/s	maximum	yes	EIA Consistency Data Set [5]
2.3.3 Cooling Water Temperature Rise	Temperature rise across the condenser (temperature of water out minus temperature of water in)	12°C	maximum	no	KNPS Coastal Water Discharge Permit Application [7]
2.3.4 Evaporation Rate	The expected (and maximum) rate at which water is lost by evaporation from the receiving water body as a result of heating in the condenser	915 l/s	maximum	yes	N-REP-01200-10000 [21]
2.3.5 Heat Rejection Rate	The expected heat rejection to a receiving water body	3 397 MW/hr	maximum	yes	N-REP-01200-10000 [21]
2.3.6 Cooling Water Temperature Range	The range of water temperatures at the intake	-0.5°C - 30°C	range	no	EIA Consistency Data Set [5]
2.3.7 Maximum increase in the cooling water source	Design value for the maximum temperature increase in the cooling water source	The intake and the outfall configuration should not result in a net rise in CW. The maximum increase in the temperature of the recirculated water should be < 1.5°C.	minimum	yes	EIA Consistency Data Set [5]

PPE Section	Definition	Enveloping limit (s)	Characteristic of Limiting Parameter Value	Parameter Value to be Prorated Based on the Number of Units on Site	References
		Increases in the water temperature will most likely be limited by environmental issues for each specific site.			
3 Potable Water/ Waste System					
3.1 Discharge					
3.1.1 Flow Rate (Effluent Normal)	Expected (normal) effluent flow rate from the potable/ water system to the Waste Water Treatment System (WWTW). 80% of sewerage directed to municipal WWTW. The rest (20% <100m3/day) to be treated on site before discharge into the sea.	0.0384 m^3/s Dependent upon chosen reactor technology		yes	331-301 [6] 240-129930970 [10] KNPS Coastal Water Discharge Permit Application [7]
3.1.2 Flow Rate (Effluent Maximum)	Expected (maximum) effluent discharge rate from on-site WWTW	7.8 l/s (Koeberg) 16.7 l/s (nuclear new build) Dependent upon chosen reactor technology	maximum	yes	KNPS Coastal Waters Discharge Permit Application [7]
3.2 Water Requirements					
3.2.1 Potable Water Requirements	Potable water is water of sufficiently high quality that can be consumed or used with low risk of immediate or long term harm. It is free from pollution, harmful organisms and impurities. Desalination plants may be	27.2 l/s (site establishment) 35.3 l/s(early site activities) 36.5 l/s (early construction activities)	maximum	yes	EIA Consistency Data Set [5] 331-301 [6]

PPE Section	Definition	Enveloping limit (s)	Characteristic of Limiting Parameter Value	Parameter Value to be Prorated Based on the Number of Units on Site	References
	used to produce potable water in the NPP. The potable water system is designed to furnish water for human consumption in compliance with National Primary Drinking water standards bacteriological and chemical quality requirements.	31.6 l/s (construction) 15 l/s (operation)			240-129930970 [10]
3.2.2Maximum Use	The maximum short-term rate of withdrawal from the water source for potable water systems.	52 l/s	maximum	yes	331-301 [6]
3.2.3 Monthly Average Use	The average rate of withdrawal from the water source for the potable water systems.	15 l/s	maximum	yes	331-301 [6] 240-129930970 [10]
3.2.4 Stored Water Volume (potable water supply requirements)	Total capacity of on-site water storage tanks/reservoirs (operational phase)	Site water (SEP) – 37 492 m^3 Feed water (SER) – 6 210 m^3 Demineralised (SED) – 1 035 m^3 Condensate feed water (ASG) – 3 312 m^3 Demineralised primary make-up water (REA) – 35 190 m^3 Borated Refuelling Water (PTR) – 6 624 m^3	maximum	yes	240-129930970 [10]
4. Demineralised Water System					
4.1 Discharge to Site Water Bodies					

PPE Section	Definition	Enveloping limit (s)	Characteristic of Limiting Parameter Value	Parameter Value to be Prorated Based on the Number of Units on Site	References
4.1.1 Flow Rate	The expected (and maximum) effluent flow rate from the demineralised processing system to the receiving water body.	4.42 l/s	maximum	yes	N-REP-01200-10000 [21]
4.2 Raw Water Requirements					
4.2.1 Capacity per unit		2 450 m^3/day	maximum	yes	Koeberg Safety Analysis Report [9]
4.2.2 Conductivity		<170 mS/m	maximum	yes	EIA Consistency Data Set [5]
4.2.3 Silica (SiO2)		<20 x 10^{-3} mg/l	maximum	yes	EIA Consistency Data Set [5]
4.2.4 Free bases (CaCO3)		<15 mg/l	maximum	yes	EIA Consistency Data Set [5]
4.2.4 Sodium		<200 mg/l	maximum	yes	EIA Consistency Data Set [5]
4.2.5 Suspended solids		5 x 10^{-3} mg/l	maximum	yes	EIA Consistency Data Set [5]
4.2.6 Maximum Use	The maximum short-term rate of withdrawal from the water source for the demineralised water system	34.07 l/s Dependent upon chosen reactor technology	maximum	yes	N-REP-01200-10000 [21]
4.2.7 Monthly Average Use	The average rate of withdrawal from the water source for the demineralised water system	5.1 l/s Dependent upon chosen reactor technology	maximum	yes	N-REP-01200-10000 [21]

PPE Section	Definition	Enveloping limit (s)	Characteristic of Limiting Parameter Value	Parameter Value to be Prorated Based on the Number of Units on Site	References
4.2.8 Stored Water Volume	Capacity of demineralised water storage tanks/reservoirs.	1 035 m^3 {1 Demineralised water tank (SED) [500 m^3]} 35 190 m^3 {2 Demineralised primary make-up water tanks (REA) [8 500 m^3] 17 595 m^3}	maximum		331-301 [6] 240-129930970 [10]
5. Fire Protection System					
5.1 Raw Water Requirements					
5.1.1 Maximum Use	The maximum short term rate of withdrawal from the water source for the fire protection water system (does not include large area fire requirements).	39.4 l/s Dependent upon chosen reactor technology	maximum	yes	N-REP01200-10000 [21]
5.1.2 Monthly Average Use	The average rate of withdrawal from the water source for the fire protection system	0.315 l/s Dependent upon chosen reactor technology	maximum	yes	N-REP-01200-10000 [21]
5.1.3 Stored Water Volume	The capacity of fire water storage impoundments, basins, reservoirs or tanks.	1 water tank (SEP) = 1 730 m^3	maximum	yes	240-129930970[10]
6. Miscellaneous Drain					
6.1 Discharge to Site Water Bodies					
6.1.1 Flow Rate	The expected normal (and maximum) effluent flow rate from miscellaneous drains to the receiving water body.	3.2 l/s (Maximum) Dependent upon chosen reactor technology	maximum	yes	N-REP-01200-10000 [21]

PPE Section	Definition	Enveloping limit (s)	Characteristic of Limiting Parameter Value	Parameter Value to be Prorated Based on the Number of Units on Site	References
7. Fuel					
7.1 Fuel Design					
7.1.1 Fuel Enrichment	Concentration of U-235 in the fuel uranium	4.95%	maximum	no	EIA Consistency Data Set [5]
7.1.2 Mass of fuel in core	The total mass of uranium dioxide in the core	187.98 T	maximum	yes	EIA Consistency Data Set [5]
7.1.3 Mass of Zirconium alloys in core	The total mass of all zirconium alloys in the core	c.43 T	maximum	yes	N-REP-01200-10000 [21]
7.2 Spent Fuel					
7.2.1 Total Mass of used fuel during Licensed Operation	The total mass of used fuel (per unit) during the operating license life of the plant.	c.2712 T	maximum	yes	N-REP-01200-10000 [21]
7.3. Spent Fuel Storage Pool					
7.3.1 Pool Capacity	The number of years of reactor operation that spent fuel storage can accommodate all used fuel from the core	10 years + full core offload (nominal) 18 years + full core offload (high density) Vendor dependent	minimum	no	N-REP-01200-10000 [21]
7.3.2 Pool Volume	Volume of spent fuel storage pool	1 481 m^3 total volume inside fuel pool below normal water level (without fuel assemblies or racks) 1 185 m^3 available for fuel storage Vendor dependent	maximum	yes	N-REP-1200-10000 [21]

PPE Section	Definition	Enveloping limit (s)	Characteristic of Limiting Parameter Value	Parameter Value to be Prorated Based on the Number of Units on Site	References
7.3.3 Annual dose	Annual dose at the EAB due to operation of the spent fuel storage pool	The annual dose at the EAB solely due to the spent fuel pool is not explicitly calculated. The contribution of operation of the spent fuel pool is expected to be a small percentage of the total dose (negligible)	maximum	yes	N-REP-01200-10000 [21]
7.4 Spent Fuel Dry Storage					
7.4.1 Acreage	The land usage required to provide onsite dry storage of spent fuel for the expected plant lifetime, including the fenced off area necessary to provide an acceptable radiation protection and security zone.	c.6 ha	maximum	yes	NEI-ESP-PPE Worksheet [17] N-REP-01200-10000 [21]
7.4.2 Storage Capacity	The years of plant operation for which spent fuel dry storage should be provided without taking credit for capacity in the spent fuel pool,	60 years	maximum	no	NEI-ESP-PPE Worksheet [17] N-REP-01200-10000 [21]
7.4.3 Annual dose	Annual dose at the EAB due to operation of the spent fuel dry storage area	<2E-5 Sv/a <2 mrem/a	maximum	no	N-REP-01200-10000 [21]
8. Plant Characteristics					
8.1 Access Routes					
8.1.1 Heavy Haul Routes	The land usage required for permanent heavy haul routes to support normal operations and refuelling	3.64 ha	maximum	no	N-REP-01200-10000 [21] EPR SAR [24]
8.1.2 Maximum Shipment Weight	The weight of the heaviest expected shipment during normal plant operations and refuelling	c.300 T Vendor specific.	maximum	no	N-REP-01200-10000 [21] UKP-GW-GL-793NP [34]

PPE Section	Definition	Enveloping limit (s)	Characteristic of Limiting Parameter Value	Parameter Value to be Prorated Based on the Number of Units on Site	References
8.2 Acreage (To Support Plant Operations)					
8.2.1 Office Facilities	The land area required to provide space for office facilities.	10ha	maximum	Note 1	UKP-GW-GL-793NP [34]
8.2.2 Parking Lots	The land area required to provides space or parking lots	c.2.5 ha	maximum	Note 1	N-REP-01200-10000 [21]
8.2.3 Permanent Support Facilities	The land area required to provide space for permanent support facilities.	6.5 ha	maximum	Note 1	N-REP-01200-10000 [21]
8.2.4 Power Block	The land area required to provide space for power block facilities. Power block is defined as all structures, systems and components which perform a direct function in the production of, transport of, or storage of heat energy, electrical energy or radioactive wastes. Also included are structures, systems and components that monitor, control or protect the public health and safety.	6.9 ha	maximum	yes	N-REP-01200-10000 [21]
8.2.5 Protected Areas (maximum)	The land area required to provide space for Protected Area facilities. Provide list of structures and associated acreage of each.	19.02 ha	maximum	Note 1	N-REP-01200-10000 [21]
8.2.6 Switchyard (maximum)	The land usage required for the high voltage switchyard used to connect the plant to the transmission grid	9.7 ha	maximum	no	N-REP-01200-10000 [21]
8.3. Plant Population					

PPE Section	Definition	Enveloping limit (s)	Characteristic of Limiting Parameter Value	Parameter Value to be Prorated Based on the Number of Units on Site	References
8.3.1 Construction	Maximum number of people on site during construction.	5 000 construction workers 2 200 vendor staff 180 Eskom Project Staff	maximum	no	EIA Consistency Data Set [5]
8.3.2 Operation	The estimated number of total permanent staff to support operations of the plant.	1 385 persons	maximum	Note 1	EIA Consistency Data Set [5]
8.3.3 Refuelling/Major Maintenance	The estimated number of total permanent staff required to conduct refuelling and major maintenance activities.	1 000 persons	maximum	no	N-REP-01200-10000 [21] UKP-GW-GL-793NP [34]
9. Construction					
9.1 Access Routes					
9.1.1 Construction Module Dimensions	The maximum expected length, width, and height of the largest construction modules or components and delivery vehicles to be transported to the site during construction	Reactor Vessel 6.71 D x 10.36 L Steam Generator 6.10 D x 24.38 L, Turbine Rotor 5.49 D x 8.84 L Generator Stator 5.49 D x 12.19 L Modules by barge: 27.43 (H) x 24.99 (W) x 28.35 (L) OR 39.62 (D) x 15.54 (H) (All dimensions in m)	maximum	no	N-REP-01200-10000 [21]
9.1.2 Heaviest Construction Shipment	The maximum expected weight of the heaviest construction shipment to the site.	861.8 T	maximum	no	N-REP-01200-10000 [21]
9.2 Acreage					

PPE Section	Definition	Enveloping limit (s)	Characteristic of Limiting Parameter Value	Parameter Value to be Prorated Based on the Number of Units on Site	References
9.2.1 Laydown Areas	The area required to provide space for construction support facilities.	5.1 ha (for laydown only)	maximum	no	N-REP-01200-10000 [21]
9.2.2 Temporary Construction Facilities	The land area required to provide space for temporary construction support facilities.	4.9 ha (concrete batch plant)	maximum	no	N-REP-01200-10000 [21]
9.2.3 Construction Parking Lot	The land area required to provide space for parking lots.	16.2 ha (Construction parking with separate construction site access road)	maximum	no	N-REP-01200-10000 [21]
9.3 Construction					
9.3.1 Construction Noise	The maximum expected sound level due to construction activities, measured ≥15 m from the noise source	101 dB(A) at 15 m from noise source	maximum	no	N-REP-01200-10000 [21]
10. Decommissioning					
10.1 Access Routes					
10.1.1 Decommissioning Dimensions	The maximum expected length, width, and height of the largest components and delivery vehicles to be transported on or off site during decommissioning	See 9.1.2	maximum	no	N-REP-01200-10000 [21]
10.1.2 Heaviest Decommissioning Shipment	The maximum expected weight of the heaviest shipment on or off the site during decommissioning	See 9.1.2	maximum	no	N-REP-01200-10000 [21]
10.2 Acreage					
10.2.1 Laydown Area	The land area required to provide space	Unknown at this stage	maximum	no	

PPE Section	Definition	Enveloping limit (s)	Characteristic of Limiting Parameter Value	Parameter Value to be Prorated Based on the Number of Units on Site	References
	for decommissioning support facilities				
10.2.2 Temporary Decommissioning Facilities	The land required to provide space for temporary decommissioning facilities	Unknown at this stage	maximum	no	
10.3 Decommissioning Noise	The maximum expected sound level due to decommissioning activities ≥15 m rom the noise source	80 -90 dB(A) at 15 m from noise source	maximum	no	N-REP-01200-10000 [21]
10.4 Plant Decommissioning Population	Peak employment during plant decommissioning.	100 – 200 persons	maximum	yes	N-REP-01200-10000 [21]
10.5 Site Preparation Duration	Length of time required to prepare the site for decommissioning.	Variable based on plant owner decommissioning strategy and plan. OR 1 to 2 years (Assuming preparation encompasses nuclear fuel (both new and spent) removal from site and removal of all radioactive wastes)	maximum	no	N-REP-01200-10000 [21]
10.6 Delay Time Prior to Decommissioning	Length of time required to allow radiation levels to decrease prior to commencing decommissioning.	If deferred dismantling is planned, then a wait time of 10 years is recommended to allow for short and intermediate lived nuclides to decay and Co-60 to reduce by a factor of four (half- life = 5.2 years)	maximum	no	N-REP-01200-10000 [21]
10.7 Mass of Plant Material and Components					
10.7.1 Mass of Highly Active Material	The total mass of plant components and materials that are highly active and require specially shielded handling techniques during, and/or significant time delays prior	800 T (steel and concrete)	maximum	yes	N-REP-01200-10000 [21]

PPE Section	Definition	Enveloping limit (s)	Characteristic of Limiting Parameter Value	Parameter Value to be Prorated Based on the Number of Units on Site	References
	to, decommissioning				
10.7.2 Mass of Moderately Active Material	Total mass of plant components and materials that are moderately active and require some shielded handling techniques during, and/or some time delays prior to, decommissioning	900 T (concrete)	maximum	yes	N-REP-01200-10000 [21]
10.7.3 Mass of Low Activity Material	Total mass of plant components and materials that are slightly active but require no shielded handling techniques during, and/or no time delays prior to, decommissioning	15 000 T	maximum	yes	N-REP-01200-10000 [21]
10.7.4 Mass of Non-Active Material	Total mass of plant components and materials that are not active but must be transported and/or handled during decommissioning	180 000 T	maximum	yes	N-REP-01200-10000 [21]
10.8 Decommissioning Materials					
10.8.1 Concrete	Total mass of concrete to be used in decommissioning	Not available	maximum	yes	N-REP-01200-10000 [21]
10.8.2 Land fill	Total mass of landfill to be used in decommissioning	Not available	maximum	yes	N-REP-01200-10000 [21]

Note 1: Prorated parameter value for multiple units on site will be greater than the single unit value but no greater by number of units on site.

Note 2: * Source Term Tables and Solid Activity Tables are not contained in this document.

	External Event	Plant Parameter Envelope Reference Values
1	External natural fire	SDV: 1 to 2 km depending on the land vegetation cover. Vegetation that can result in severe fires (e.g. dense forests) will require a larger distance.
	Human Induced Events	
2	Aircraft crash	Distance from commercial airports and runway orientation not to be controlling factors. Design basis to include aircraft in the general, military and commercial categories. Impact to be calculated separately for the mass of the aircraft engine and/or landing gear as well as the mass of the aircraft. Generally the engine impact will govern the minimum thickness of the structural element i.e. local effects and the aircraft impact, the global structural damage. Impact to be defined in terms of force time histories .Functional damage to SSC as a result of shock loads/vibratory effects to be checked. Fire damage to be checked in the crash zone. Aircraft crash analyses to be performed for general aircraft such as the Cessna 210 and the Lear Jet 23, military aircraft such as the Phantom RF-4E, and commercial aircraft such as the Boeing 777.The site specific aircraft crash hazard study will dictate whether other aircraft should be included.
3	Hazards from nearby land-based Installations	
3.1	External missiles in general (from tornadoes, high-energy rotating machinery, etc.)	Missile parameters for rotating machinery to be defined for each postulated missile.
3.2	External explosion (*pressure, fire, projectiles, smoke, vibrations, etc.*), solid, liquid or gaseous	$P_{wave} = 10^4$ Pa Duration = 300 ms Velocity = 4 500-7 000 m/s
3.3	Industrial facility incident	The effects of a rupture of pressure vessels, fluid pipelines and so forth that serve industrial facilities located near a nuclear power plant. Pressure and heat loads resulting from chemical energy dissipated Distance to pipelines to be limited such that they do not constitute controlling events for transient pressure waves. Pressure wave to be less than stated in item 18.2. Mitigating action to be taken to protect the safe operation of the nuclear installation(s) against the potential discharge of toxic liquids/gases.

	External Event	Plant Parameter Envelope Reference Values
3.4	Military facility incident	Distance to military facilities to be limited such that they do not constitute controlling events. Preventative actions to be taken such that missile and heat loads may not originate from such installations. Pressure wave to be less than stated in item 3.2.
3.5	Pipeline accident	Pressure and heat loads, toxic/flammable vapour clouds or liquids - distance to pipelines to be limited such that they do not constitute controlling events for transient pressure waves. Pressure wave to be less than stated in PPE item 3.2. Mitigating action to be taken to protect the safe operation of the nuclear installation(s) against the potential discharge of toxic liquids/gases.
3.6	Transportation accident	
3.7	Electromagnetic interference from off-site and/ or on-site activated sources. The process in which external signals are emitted and super-imposed on fundamental signals controlling critical plant instrumentation resulting in false, erroneous, inaccurate and/ or unwanted operation of equipment.	Hazard to be mitigated. Preventative action to be taken in the design phase to prevent an impact on the safe operation of the nuclear installation(s).
3.8	Release of asphyxiant and toxic gases	Distance to potential sources to be limited such that they do not constitute controlling events. Preventative action to be taken in the design phase to prevent an impact on the safe operation of the nuclear installation(s).
3.9	Release of corrosive gases and liquids, including atmospheric attack (salt) and aerosols.	
4	Extra-terrestrial objects: meteorites; satellite re-entry	Generally not considered in the design. Impact resistance of safety related structures designed for aircraft crash.

Appendix 6-E: Example of an External Event Interaction Matrix

There are various possible approaches to screen the potential combinations of EE's but the basis of any approach consists of an 'interaction' matrix. The matrixlists the set of EEs to be assessed in terms of their potential interaction in the first column and first row. It facilitates a systematic and iterative process to either screen out combinations or to identify combinations of events for further assessment. Each combination has to be interrogated in a systematic manner, using expert opinion, published literature and studies on EEs and prior assessments of individual EE. It is important that a team representing different engineering and scientific disciplines participate in the EE Matrix exercise to question the plausibility and credibility of combinations. Screening out combinations must be substantiated and documented. An EE screening matrix may require multiple reviews or passes.

Annotation of the Matrix cell of the EE combinations is carried as follows:

First pass:

(Note: Column/Row colour – Red; Green)

X = Event individually or in combination Screened Out; event cannot occur (e.g. dam failure since no dam in the region) or events combinations impossible (e.g. high sea water temperature and low sea water temperature).

0 = Combination not considered further based on the subjective concept of plausibility/expert opinion, e.g. tornado and extreme snow. Individually the events are plausible but in combination not.

1 = Further consideration of combination

E = Overlap of the EE sets of hazard parameters and the one event envelops the other

Second/subsequent pass(es):

1 in shaded block = More detailed consideration and assessment of combination

Comments on the combinations can be documented by using a unique identifier, by using a (row, column) number. For example (strong winds and surface ice) is comment

(1;8): Screened out because ……(site specific justification then follows).

Events initially screened out on assessment of single event considerations have to be considered in the EE screening matrix since they may be a consequence of another EE when combinations are considered. ***Table 6E.1*** illustrates sections, as an example, of a large EE interaction matrix.

Table 6E.1: Illustration of subsections of an EE interaction matrix

EE Combination Matrix				Flooding					Extra-terrestrial	
			35	36	37	38	39	40	41	42
			Site instability by erosion from the sea	Tsunami	Sea water level - tides, seiches, storm surge, waves, landslide into sea	Dams	Rivers	Groundwater related effects	Astroids and satellites	Solar flares (CME)
Human induced events	21	Chemcial release on-site	0	1	E	X	X	0	X	0
	22	Chemical release off-site	0	1	0	X	X	0	X	0
	23	Electromagnetic interference	0	0	0	X	X	0	X	E
	24	Aircraft crash	0	0	0	X	X	0	X	1
	25	Missiles	0	1	0	X	X	0	X	0
	26	Heavy transport on-site - direct impact	0	0	0	X	X	0	X	0
	27	Ship release- solid or fluid	0	1	1	X	X	0	X	0
	28	Ship collision - direct impact	0	1	1	X	X	0	X	0

EE Combination Matrix			Geological and seismotectonic events					Flooding			
			31	32	33	34	35	36	37	38	39
			Seismic (includes soil liquefaction)	Other geological phenomena - subsistence, uplift, mining, quarrying	Slope instability - avalanches, land slides	Volcanism and related phenomena - Lava, ash, gases, lahars, missiles, lightning,, flood	Site instability by erosion from the sea	Tsunami	Sea water level - tides, seiches, storm surge, waves, landslide into sea	Dams	Rivers
	34	Volcanism and related phenomena: Lava, ash, gases, lahars, missiles, lightning,, flood					X	1	X	X	X
	35	Site instability by erosion from the sea						1	1	X	X
Flooding (External)	36	Tsunami							E	X	X
	37	Sea water level - tides, seiches, storm surge, waves, landslide into sea								X	X
	38	Dams									X
	39	Rivers									
	40	Groundwater related effects									
	41	Astroids and satellites									

Appendix 6-F: Koeberg Design Parameters for External Hazards

Hazards	Defence		Plant Design Basis	Parameter	Methodology	Site Data Report	Comment	FSAR Reference
Geological								
Seismic	SSC Seismic Qualification	SSE	0.3g	PHGA	Newmark Hall Spectra	0.3g	Critical Damping Values: 5% Prestressed concrete, 7% for reinforced concrete (PSAR)	FSAR II-1.1.1.1.2
			0.2g	PVGA		0.2g		
		OBE	0.15g	PHGA		0.15g	Critical Damping Values: 3% Prestressed concrete, 5% for reinforced concrete (PSAR)	
			0.1g	PVGA		0.1g		
		DSE			PHGA	0.36g		
					PVGA	0.24g		
Hydrological								
Flooding (Sea)	Dry site (8m Terrace)		+8 m	GMSL	Dry Site		+6.97 m MSL originally based on return frequency 1E-6/y	FSAR II-1.4.1.1. FSAR II-7.3.6.2
Extreme Low Level			-2.5 m	MSL			-2.5 m MSL originally based on return frequency 1E-6/y	FSAR II-7.3.6.2
Sea Temperature	Safe Operation	Max	23°C	Seawater Temp,	For accident analysis	23°C		FSAR II-7.2.2.2

Hazards	Defence		Plant Design Basis	Parameter	Methodology	Site Data Report	Comment	FSAR Reference
	Normal Operation (Max)	Max	20°C		Max Normal full power operation	20°C		
	Normal Operation (Design)	Range	9°C to 13°C		Normal Operating Range	9°C to 13°C	Reference Site Data Report	
Meteorological								
Rainfall	Storm Drain Design Capacity	Max	80 mm/hr			80 mm/hr		FSAR II-1.9.2.4.3
	Safety of Plant (Category 1 Buildings)		200 mm/hr			200 mm/hr	Category 1 Buildings	FSAR II-1.3.2
Temperature (Ambient)	Containment Building	Max	34°C				SAR Reference: KBA001A1C01009 Rev AB = 34°C	
	Emergency Diesel Generators		38°C		Air Cooling Limit (DSE)		EDG Radiator Air Cooling Limit (DSE)	
	Ventilation Systems		34°C		Dry Bulb	34°C		FSAR II-1.3.2
			22°C		Wet Bulb	24°C		
	Containment Buildings	Min	-2°C					
	Ventilation Systems		5°C		Dry Bulb	5°C		

Hazards	Defence		Plant Design Basis	Parameter	Methodology	Site Data Report	Comment	FSAR Reference
	Ventilation Systems		4°C		Wet Bulb	4°C		
Wind	All Buildings	Max Mean	138 km/h	Hourly Mean	The building have been designed n accordance with NV 65-67	138 km/h	Basis appears to be based on a windspeed of 104 km/h having a 1E-6/y return frequency, based on note KBA00A1C01026	FSAR II-1.3.1
	Normal Dynamic Pressure		*900 Pa*					
	Nuclear Safety Related Buildings	Max Gust	225 km/h	3 s Gust		225 km/hr	Class 1 Buildings (Site Data Report terminology)	
	Extreme Dynamic Pressure		2396 Pa					
	Non Safety Related Buildings	Max Gust	184 km/h	3 s Gust			Other Buildings (Site Data Report terminology)	
	Extreme Dynamic Pressure		1575 Pa					
Tornadoes	Explicitly not included		-		Not taken into account in the design			FSAR II-1.3.3
Hurricanes	Explicitly not included		-					FSAR II-1.3.3

Hazards	Defence		Plant Design Basis	Parameter	Methodology	Site Data Report	Comment	FSAR Reference
Snow	Explicitly not included		-		Not taken into account in the design	Not taken into account		FSAR II-1.3.1
Lightning		Peak Current	150 kA					
Industrial and Transportation								
Turbine Missiles	Turbine Missile Wall	Missile Wall Thickness	N/A		900 mm			FSAR II-1.5.1
	Containment Dome Design	Containment Dome Wall Thickness	N/a		800 mm			
Other Missiles	Aircraft Crash		Unclear		Not taken into account in the design		Aircraft crashes are not taken into account in view of the restrictions applicable to the use of air space above the site and other considerations. Koeberg documentation of the connecting building does not make any reference to this issue. However, since the design of Koeberg is based on a standard French plant, it is assumed that the bunker	FSAR II-1.5.1 FSAR II-1.9.6.4

Hazards	Defence		Plant Design Basis	Parameter	Methodology	Site Data Report	Comment	FSAR Reference
							walls are designed to withstand the impact of aircraft (LEAR JET and CESSNA) as per the French safety report.	
	Tornadoes and Hurricanes		None		Not taken into account in the design		The FSAR still states that hurricane or tornado-borne missiles are not postulated as the weather bureau has indicated that, under the present climatic regime, hurricanes or tornadoes do not occur in the Cape Town area.	FSAR II-1.5.1.1
External Explosions	None		50 mbar		Not taken into account in the design		There does not appear to be original external explosion design base, so it is assumed conservatively that the plant can withstand 50 mbar, which equates to	FSAR II-1.7.1.4

Hazards	**Defence**		**Plant Design Basis**	**Parameter**	**Methodology**	**Site Data Report**	**Comment**	**FSAR Reference**
							100 kg TNT equivalent at 100m or 100 t of TNT equivalent at 1 000 m.	
External Fire	None		None				The Koeberg plant was not explicitly designed to withstand external fires. There are currently no credible fire risks originating from the industrial environment that could have a detrimental effect on nuclear safety.	FSAR II-1.7.2E
Extraterrestrial								
Solar Storms	None		None		Never mentioned			
Meteorites	None		None		Never mentioned			